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Investing in agriculture when it is worth it. Evidence from rural Uganda.

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Investing in agriculture when it is worth it. Evidence from rural Uganda.*

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Abstract

One of the reasons for the persistent low agricultural productivity in Sub-Saharan Africa is the lack of adoption of profitable agricultural technologies. Yet, what is profitable in a controlled experimental setting may not be profitable in a real-world setting. Estimating the returns to a single input is, in fact, challenging as farmers may respond to adoption by re-optimizing the use of other inputs. This paper explores farmers behavioral response to a positive random shock on future productivity by disentangling inputs returns from farmers' response. Using a unique household panel dataset collected in rural Uganda, I proxy a future productivity shock with the birth of a female calf against that of a male calf. Calves have no technical returns, but female calves will become cows producing milk, providing a stable source of income, while bulls and oxen are of little use in this context. The main OLS and difference-in-differences results show the existence of a crowd-in effect. Farmers react to the birth of a female calf by increasing inputs' expenditures. They invest more on their cattle's health, increase hired labor and are more willing to pay for cattle-related investments but not for other activities. This increase in investments leads to an increase in milk production and revenues that lasts over time. Further results show that economies of scale associated with the number of female animals seem to explain this behavioral response.

Résumé

L'une des raisons de la faible productivité agricole persistante en Afrique Sub-saharienne est le manque d'adoption de technologies agricoles rentables. Cependant, ce qui est rentable dans un cadre expérimental contrôlé peut ne pas l'être une fois appliqué sur le terrain. En fait, il est difficile d'estimer les retours d'une seule technologie, car les agriculteurs peuvent réagir à l'adoption en re-optimisant l'utilisation d'autres facteurs de production. Cet article explore la réponse comportementale des agriculteurs à un choc aléatoire positif sur la productivité future en dissociant les retours des facteurs de production à la réponse des agriculteurs. En utilisant des données de panel de ménages uniques collectées dans des zones rurales ougandaises, je

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mesure un choc sur la productivité future par la naissance d'un veau femelle par rapport à celle d'un veau mâle. Les veaux n'ont pas de rendements techniques, mais les veaux femelles deviendront des vaches productrices de lait, offrant une source de revenu stable, tandis que les taureaux et les bœufs sont très peu rentables dans ce contexte. Les principaux résultats obtenus par des estimateurs MCO et de Double Différences montrent l'existence d'un effet de *crowd-in*. Les agriculteurs réagissent à la naissance d'un veau femelle en augmentant les investissements productifs. Ils investissent davantage dans la santé de leurs animaux, augmentent la main-d'œuvre embauchée et ont une disposition à payer plus élevée pour des dépenses liées au bétail, mais pas pour d'autres activités. Cette augmentation des investissements entraîne une augmentation de la production de lait et des revenus qui dure dans le temps. D'autres résultats montrent que les économies d'échelle associées au nombre d'animaux femelles semblent expliquer cette réaction comportementale.

Keywords: cattle, investments, Sub-Saharan Africa.
Mots clés: bétail, investissements, Afrique Sub-Saharienne.
JEL codes: C26, C33, D24, O12, 013, 055, Q12

Introduction

Despite the sustained economic growth rates experienced by Sub-Saharan African countries in the past 60 years, averaging at least 5%, more than half of the overall population still lives in rural areas and is employed in agriculture. The African landscape is still today characterized by family farms, mainly small and poor, heavily relying on household labor for their own production and food consumption. Agricultural productivity is, in fact, the lowest in the world, in contrast to that of emerging economies in East and South Asia, where agricultural yields per hectare in the last 60 years have substantially increased (FAO, 2015).

One of the explanations for this low agricultural productivity in Sub-Saharan countries is that the yield potential has not yet been reached, leaving room for further improvements through the adoption of best suited agricultural technologies and the use of most efficient practices (Duflo et al. (2008), Fischer and Shah (2010)). According to this hypothesis, African farmers are not investing enough in their agricultural activity, ending up in low production and low income. Indeed, the adoption of agricultural technologies is still today much lower in Sub-Saharan Africa than in other developing countries. For instance, cultivation of modern varieties of maize represent only 17% of the total harvested area in Sub-Saharan Africa compared to 90% in East and South East Asia and the Pacific (Jack, 2013).

In addition to a variety of constraints and market failures that may hamper technology adoption,[1] it may be hard for farmers to obtain a clear signal about the profitability of the technology

1. Recent economic literature investigated a variety of causes behind those low rates of adoption. The main constraints appear to be the lack of access to information about new technologies (Bandiera and Rasul (2006), Conley and Udry (2010)), the lack of infrastructures and utilities (e.g., roads, electricity, irrigation) (see e.g., Binswanger et al., 1993; Jack et al., 2015), incomplete insurance, savings and credit markets (see e.g., Brune et al., 2016; Karlan et al., 2014; Rosenzweig and Wolpin, 1993) and insecure property rights (see e.g., Ali et al., 2014; Fafchamps and Pender, 1997). See the literature review by Jack (2013) about market inefficiencies linked to agriculture and how technology adoption may tackle them.

itself.[2] Technologies that have proven to be profitable in a laboratory setting may not show any positive returns in a real world setting. This is partly because farmers react to the adoption of a new technology by changing other complementary inputs. Their behavioural response to a discrete change in the price or availability of one input may crowd-out or in the technical returns associated with that same input. Beaman et al. (2013), for example, find that the increase in output's value, yielded by the adoption of fertilizers, is more than compensated by an increase in inputs' expenditures, nullifying any positive effects on profits. In turn, Emerick et al. (2016) find that farmers make profitable investments in response to the adoption of a flood-resistant rice variety, even though the net effect on profits is not assessed.

While farmers are likely to adopt what is profitable to them (Schultz et al., 1964), empirically separating the net effect of a technology from the behavioral response is challenging (Bulte et al., 2014). This paper manages to disentangle assets returns from the behavioral response by exploiting a positive random shock on future productivity. Using a unique household panel dataset collected in Uganda in 2015, 2016 and 2017, I proxy a positive shock on future productivity by the birth of a female calf against the birth of a male calf between 2015 and 2016. Female calves are not more productive than male calves, but in about two-year time they will become cows producing milk, providing a major and fairly constant source of income. In turn, male calves will become either future bulls, providing income only if used for breeding, or future oxen, useful for agricultural work but not providing any direct revenues (and in fact rarely employed in this context).[3]

There are two main advantages in focusing on calves. First, they have no technical returns. They are not productive animals and their market value resides in being a future cow or a future bull. Hence, if the birth of a female calf has any positive effect on production and revenues in the short term, this will be completely due to farmers behavioral response. Exploiting the random variation in the sex of a calf allows me to isolate a potential crowd-in effect. Second, farmers have expectations about the future profitability of a female calf, which translates in bulls having a much lower market values than cows. This limits noise in the signal about the returns to the technology itself.

The main identification assumption is the exogeneity of a recently born calf's sex to observable and unobservable farmers' characteristics. Under this condition, the OLS estimate of the effect of a newborn female calf on dairy activities will have a causal interpretation. To further explore the change in farmers' dairy behavior and take into account temporal variation and across households heterogeneity, I apply a double difference strategy by comparing households with a recently born female calf to those with a recently born male calf, before and after the birth of the animal. This strategy allows me to explore farmers' reaction over time and across households, while controlling for unobservable household fixed effects. The identification assumption of parallel trends means that in the absence of the birth of a female calf all farmers' investment decisions would have been the same. I test this by checking that the birth of a female calf between 2016 and 2017 is not

2. The noise of the signal is even greater when the quality of the technology is hard to observe (Bold et al., 2017).

3. Either cases are rare and the revenues gained do not represent a large share of household income in the data. Moreover, in this context animals are not slaughtered for consumption and beef is not part of the common diet. For all these reasons, the market value of bulls is half that of cows.

significantly correlated with outcomes variation between 2015 and 2016. Reassuringly, results show the absence of any significant correlation.

The main results speak in favour of a positive behavioural response, in line with Emerick et al. (2016). I find that farmers increase inputs' expenditures, willingness to pay for dairy activities and invest 15% more in the health status of their herds, and in particular of their cows. These investments appear to be profitable, as milk production increases by 12% and milk revenues by 8%. The cross-section and longitudinal analysis yield very similar results.

What is the mechanism behind these results? Why would farmers invest further in their dairy activity after the birth of a female calf? There are at least three channels that we could think of. First, female calves have a higher market value than male calves, which makes their birth a positive wealth shock. Wealthier households may, hence, increase borrowing and investments. Second, this shock may not just increase temporary wealth but possibly permanent income. One more (future) cow may guarantee a more stable future source of income, reducing risk exposure and allowing households to smooth consumption and investments over time. Third, a large part of dairy investments are usually done at the herd level. Given the higher expected returns associated with female calves, a larger number of female animals may trigger economies of scale of dairy investments, pushing farmers to invest further in their dairy activities.

I test for these mechanisms and find evidence in support of the existence of economies of scale. To address the endogeneity of the number of female cattle, I instrument it with the number of newborn female calves while controlling for the initial number of female cattle. Results show that a larger number of female animals increases investments in cattle health, milk production, milk revenues and profits. In turn, the birth of a female calf does not affect the likelihood of farmers to obtain credit or access saving services, excluding the wealth mechanism and the permanent income hypothesis. The capacity of farmers to mobilise resources for inputs' expenditures without recurring to credit is in line with Karlan et al. (2014) and Brune et al. (2016), who find that relaxing the credit or saving constraints is not the main factor driving investments decisions, whereas reducing risk exposure plays a key role.

To the best of my knowledge, this is the first paper to explicitly address farmers' behavioural response to a future positive productivity shock. The main results show that the birth of a female calf pushes farmers to invest further in their productive activities, leading to higher production and revenues, by creating a virtuous cycle. This is an innovative contribution to the literature on agricultural investment decisions as it shows that providing farmers with productive assets that have a clear signal about their future profitability produces a crowd-in effect. This effect takes place most likely because farmers are already aware of the types of investments needed to boost their dairy productivity. Further results show, indeed, that farmers are more willing to pay only for expenditures related to cattle (animal drugs, hiring external workers and fencing), but not for other businesses, activities, school fees or for buying new animals. This is in line with the work by Argent et al. (2014) and Banerjee et al. (2015), who show that programs distributing free cows to poor households are effective only if accompanied with a specific training about cattle management.

In conclusion, this paper suggests that farmers adopt the appropriate investment decisions if provided with productive assets that have a clear positive future productivity. The investment response triggered by agricultural technologies is then a key aspect for boosting agricultural growth. Policies aiming at boosting agricultural growth through the adoption of improved agricultural practices should incorporate adequate incentives for promoting the right behavioral responses.

The rest of the paper is organized as follows. Section 1 describes the data in detail and reports descriptive statistics about farmers' dairy activity. Section 2 illustrates the empirical strategies employed. Section 3 provides the main results, investigates potential mechanisms and performs some robustness checks. In the last section I draw the main conclusions.

1 Data and descriptive statistics

The data source is a unique household panel data collected in three rounds in 2015, 2016 and 2017 in rural Uganda, in 632 villages in the districts of Kamuli and Buyende in the Near-East region. 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 all data rounds. The final sample consists of 2988 farmers.

The context under analysis 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 characterized 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, being mostly female animals. One third is made of cows, the rest is mostly calves and heifers (Table 1). Farmers own also male animals, but their use for economic activities is very limited. In the first data round, about 40% of farmers own a bull, while oxen are more rare (17%). Yet, controlled mating using bulls is very limited in the first data round (8.8%) and totally absent in the second data round. Only 14% of farmers declare having used the best breeding animals of a neighbor. [4] Renting out oxen is also rare, as only 16.7% of farmers declare earning revenues from such activity in the second data round.

Cows are, in turn, an important source of milk consumption and revenues. Consumption of home-produced milk is, indeed, the norm (on average farmers keep 2.5 litres per day for home consumption) and market-oriented production is fairly widespread. Among the farmers interviewed

4. Roughly 20% of farmers have used controlled breeding methods for their cows in the previous 12 months, though, due to data limitation I cannot tell which type of breeding method farmers mostly use.

in the first round, 81.7% produced some milk in the previous 12 months and 64.6% of those sold it. Similarly, in the second data round 82.6% of farmers produced some milk and 60.3% of those sold it. Even though markets for milk exist, milk is still mainly sold to neighbours and friends (45%). 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 not as a matter of family tradition. 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%).[5] Animals are rarely sold, only one third of farmers report selling animals in the past 12 months, mostly indigenous cows and calves. 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. In the first round 73% were also crop-growers and 57% of sampled households had at least one member working off-farm, in 90% of cases being the household head.

1.1 Investments, revenues and profits

Given the available data, I focus the analysis on dairy investments, such as animals health costs, wage of hired workers, household labor, expenses for buying animals and feeds costs. The main outputs of dairy farmers are revenues obtained in the past 12 months from producing milk, selling animals, renting out animals and selling manure. I, then, measure annual profits as the difference between outputs and inputs invested in dairy farming. These inputs represent the main investment types in dairy farming that farmers can make. Table 1 shows the main distribution statistics for the various inputs and outputs in both data rounds, which are described in detail here below.[6]

Outputs. Outputs concern milk production, milk revenues and other revenues related to dairy activities:

— Milk production: it is measured as the median of daily milk production over the last three days

— Milk revenues: it is measured as the median amount earned by farmers on a usual day in each season

— Revenues earned from selling animals: the information concerns the previous 12 months. These revenues are higher than the value of home-produced milk (325$ in the first wave

5. Only 30 farmers declared having used artificial insemination techniques for impregnating their cows in the first data round. Out of those, 18 declared the cow got pregnant, nine of which had a male calf and nine got a female calf.

6. All monetary measures are expressed in US dollars. For the first round the exchange rate is 1$=3400 Ugandan Shillings, as in August 2015, for the second round it is 1$=3337 Ugandan Shillings, as in September 2016 and for the third data round it is 1$=3609 Ugandan Shillings .

and 337$ in the second wave) and concern 31.2% of households in the first data round and 40.7% in the second data round.

— Revenues obtained from renting out animals and selling manure: the information concerns the previous 12 months and was collected only in the second and third round. These revenues amount at roughly 14$ in each round and only about 20% of the sampled farmers report positive values.

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

— Health costs: include detailed information about vaccination, artificial insemination, cross-breeding, health checks, curative treatments, deworming and preventive treatments against ticks. In 2015 the average farmer invested 21$ in cattle health treatments over the whole year. This expenditures more than doubled in the second round (47.6$) and kept increasing in 2017 (56.3$).

— Feeds costs. This information was collected only in the second and third round. It includes the cost of feeds bought in the previous 15 days and a farmers' self-assessment of the value of the home-grown feeds. To estimate the annual feeds costs I assume the same amount is spent during the rest of the year. These costs amount at 57$ in 2016 and 50$ in 2017 and are supported by the big majority of sampled households.

— Expenditures for buying animals. Few farmers bought new animals between 2015 and 2017, as it is a considerable investment. In 2015 only 12.4% of farmers bought heads of cattle in the previous 12 months, paying on average 22$, while in 2016 and 2017 roughly 18% of the sample declared to have bought animals in the past 12 months, spending on average 40$ and 35$, respectively.

— Total labor costs: include expenditures for hiring external workers and an imputed value of household labor. 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)). We collected information about several workers (household members and hired workers) 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 workers spent herding, feeding, watering, milking the animals, selling the milk and cleaning the milking equipment. The same person may be in charge of multiple tasks and the same task can be performed by different persons. [7] In the first data round we collected detailed information on no more than three workers, whereas in the second and third data round we let the number of workers open. Household labor is, hence, underestimated in the first data round, while it

7. 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 labor intensity of cattle rearing we collected 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 labor tasks. To limit the risk of measurement error, I replace as missing the amount of labor exceeding 10 hours of work per day and 7 days per week. In addition, I exclude outliers at the bottom and top 1%.

is correctly measured in the second and third data round. Additional questions about hired labor were included in the questionnaires, allowing me to have a correct measure of the cost for hiring external workers in all three rounds.

— Hired labor cost: it pertains to workers hired for taking care of cattle, including paying veterinary and extension agents. This cost item slightly increased between the first and the second year from 12$ in 2015 and 16.7$ in 2016 and 15$ in 2017. Slightly more farmers report hiring external workers, from 17% in the first round to while it concerns 21.6% in the second round and 22.2% in the third round.

— Household labor: The amount of time household members dedicated to cattle management tasks drastically increased between the second and third data round. On average, in the previous week, a household member worked one day and half on dairy activities in 2016 and five days in 2017. Also the average number of household members involved in cattle keeping increased, from 8.5 to 10.8.

— Household labor cost: one of the main challenges in measuring profits in this context is the quantification of household labour costs, which is an important production factor. 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. (2016) and Attanasio and Augsburg (2016) use the daily wage reported in village surveys. In this study I consider the wage paid to hired dairy workers as reported by farmers in the sample, roughly 2.5$ in all three data rounds.[8] The large increase in household labor observed in 2017 translates in much higher labor costs, from 184$ in 2016 to 1207$ in 2017. Yet, considering household labor value only as part of the costs is reductive, as it partly constitutes also a wage earned from a working activity, meaning that part of it should be accounted among the outputs.

By subtracting inputs from outputs I estimate profits earned from farmers. Table 1 shows that profits are on average positive and increase over time from 120$ in 2015 to 225$ in 2017. Yet, if we include the imputed household labor costs, in 2017 profits are negative due to the huge rise in the amount of time household members dedicate to cattle keeping. Despite average positive profits, there is a wide heterogeneity across households. The share of farmers earning zero or negative profits ranges from 53.8% in 2015 to 36% in 2016 and 33% in 2017. If we include imputed household labor costs, this share increases to 60% in 2015, 48% in 2016 and 70% in 2017.

Two issues are worth mentioning here. First, cattle rearing is on average a profitable activity, showing fairly large profits, even though a considerable share of farmers earns negative profits, even when we ignore household labor costs. Given that I observe the sampled farmers only over a limited period of time, I cannot say whether those farmers permanently earn negative profits or not. For instance, there could have been some random productivity shocks affecting their dairy activity during those years. Nevertheless, median profits of those farmers reporting more than one negative 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

8. Assigning a positive value to household labor costs means assuming the existence of a labour market and of an opportunity-cost of labour. These assumptions seem reasonable in this context.

shocks, I still cannot fully rule out that those farmers are only temporarily earning negative profits. Indeed, as shown by Attanasio and Augsburg (2016), local climatic conditions affect animals health through fodder's price, decreasing production in dry years. Yet, the years of our data collection were good rainy ones, meaning that the computed profits may reflect an upper bound.

A second main issue concerns the risk of measurement error in inputs and outputs affecting the magnitudes of profits. De Mel et al. (2009) try to assess the role of measurement error in the measurement of profits by looking at the correlation between self-reported profits and a measure of profits calculated by the authors as revenues minus expenses. They find that those two measures correlate very poorly, around 0.2-0.3, suggesting large measurement error. In our data we asked farmers what was the income obtained from selling milk in a usual month during each single season over the past 12 months.[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. The correlation of self-reported income with the estimated measure of milk revenues is around 0.9 for all data rounds. Reassuringly, this suggests that measurement error is not a big matter for milk revenues. Still, I cannot fully rule out the existence of some measurement error in the data, which may downward bias the estimates.

2 Empirical strategy

The main aim of this paper is to investigate farmers dairy behavioral response to a positive shock on future productive assets. I adopt two empirical strategies. Given that the sex of a recently born calf is arguably exogenous to observable and unobservable farmers characteristics, I, first, estimate an OLS regression controlling for lagged outcomes. Second, I estimate a double difference regression controlling for household fixed effects, in order to to take into account temporal variation within and across households.

The sample is limited to households with a calf born between the first and second data round to avoid selection bias in the decision to make one's own cow calving. These households represent 70% of the overall sample. Clearly, households with a recently born calves are different from households without any recently born calves. Table 4 shows that the former are older, larger, richer, own larger herds and earn larger returns and profits.

Cross-section estimation. The first estimation strategy explores the linear effect of the random shock of having a female calf on a set of outcomes of interest. I consider the number of female calves born between 2015 and 2016 for all those households that had at least one newborn calf. The number of recently born female calves ranges from 0 to 2 as the information was collected for maximum two cows. To make sure that the number of recently born female calves does not simply capture the overall number of calves, I control for the number of calves in 2016. Conditioning on the overall

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

number of calves, the number of recently born female calves is arguably exogenous to the outcomes of interest.[10] 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_{it}). To correct for multiple hypothesis testing I provide Bonferroni-adjusted p-values for the variable of interest in all regression Tables. The OLS specification assesses the effect of the birth of a female calf (FC_i), conditioning on a vector containing the number of cows and of female calves at round 1 (C'_{it}), owned by household i on a set of outcomes measured at the household level:

$$Y_{it} = \beta_0 + \beta_1 Y_{it-1} + \beta_2 FC_{it} + C'_{it-1}\delta + \epsilon_{it} \tag{1}$$

Double difference estimation. By exploiting the longitudinal dimension of the data, I can use a double difference estimator to compare households with a recently born female calf versus those with a male calf, before and after the birth of the animal. This allows me to control for differences over time and across households. In addition, I control for households fixed-effects, in order to account for potential unobserved heterogeneity at the household level. Note that, as explained above, inputs and outputs of cattle rearing activity are all self-reported by farmers. Yet, as long as the sex of a recently born calf is not correlated with the measurement error, the results should not be biased. If the measurement error is serially correlated, which probably is in this case, controlling for household fixed effects should remove this downward bias present in the OLS estimator.

The main specification regresses various types of investment in cattle at time $t+1$ ($Y_{i,t+1}$) on a dummy equal to one if at least one female calf was born between t and $t+1$ interacted with the time trend t ($FC_i * t$). The dummy is equal to zero if the newborn calves are only male, thus excluding farmers without any newborn calf. I further control for the variation over time in the number of cows (K_{it}) and household fixed effects (μ_i). The parameter of interest of the double difference specification is β_2 :

$$Y_{i,t+1} = \beta_0 + \beta_1 FC_i * t + \beta_2 K_{it} + \mu_t + \mu_i + \epsilon_{it} \tag{2}$$

I assess the validity of the parallel trend assumption by testing whether the variation in outcomes is correlated to the sex of a newborn calf. I consider calves born between the second and third waves and outcomes measured in the first and second wave. In this way, I can test whether differences in outcomes between the first and second wave are correlated with the sex of calves born between the second and third wave. Table A.2 shows no significant results for all outcomes of interest, suggesting that past temporal variation of outcomes is not correlated with newborn calves' sex.

A female calf represents a positive shock on future productivity as the animal will become a milking cow in about two years' time, granting a constant source of revenue for several months of

10. Controlling in addition for time-varying household characteristics that might be correlated with dairy investments, such as the age of the household head, household size and number of household members working off-farm, does not affect the results (see Robustness Checks section).

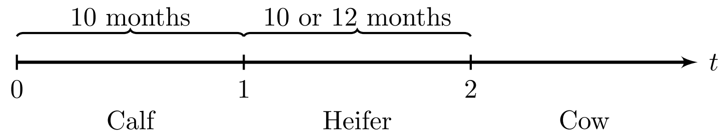
the year. A male calf, in turn, will become a bull, potentially exploitable for breeding other cows, though this is a rare case in our sample.

Information about the sex of recently born calves was collected with respect to the cows included in the cows roster. If a farmer had more than two cows, we randomly selected two cows and asked a series of questions about the two animals. For each cow we know, among other things, the last time she gave birth to a calf and the sex of the newborn calf. I limit the analysis only to calves born between the first and second data round to be able to look at outcomes few months after their birth and more than one year later.

In the selected sample, 20% of households did not report owning any cow, while 40% reported one cow and 40% reported more than one. Between the first and the second survey round, 70% of those owning at least one cow had a recently born calf. In particular, 49.5% had one calf, while 50.5% had two calves. This difference derives from the number of cows owned. Among those with a recently born calf, 65% had *at least* one female calf: 80% had one female calf and 20% had two female calves. Overall, the sex-ratio of recently born calves is in line with the biological one, reporting 52% of female calves.

It is important to note that the number of recently born calves depends on the number of cows owned, which is a very good proxy for herd size. Cows are so valuable in this context that owning one additional cow signals larger herds. This is why the balance test of observable characteristics measured in the first survey shows that households with *at least* one recently born female calf own 1.6 more cattle heads, 0.6 more cows and 0.4 more calves than those with a recently born male calf (Table 2). They also have slightly older spouses, are slightly larger (+0.4 members) and slightly richer households (+0.1 standard deviations). While controlling for these household characteristics does not affect the results, I address this imbalance in the OLS specification by controlling for the number of cows in 2016 and for the variation over time in the number of cows in the double difference model. It is worth saying that the imbalance disappears once limiting the sample to households with only one recently born calf (Table 3). While this sub-sample would be the preferred one, its small size prevents any empirical analysis from having enough statistical power.

The following diagram summarizes the three main life stages of a cow. A calf is usually weaned after 10 months. If it is a female calf, it becomes a heifer, i.e. an adult animal. After roughly 10 or 12 more months, which is to say when the animal is roughly 22 or 24 months old, it can become pregnant and becomes a cow. A cow usually lives for at least 20 years.



The data show that recently born calves are, on average, 5.7 months old. One fifth of recently born calves is older than 9 months, though they are still reported by the owner as calves instead of heifers, probably because farmers tend to wean their calves later in this context.[11] Female calves born *before* the first data round might have become heifers by the second data round, this is why I limit the analysis to calves born *after* the first data round. For heifers to become cows it takes roughly 22-24 months, which automatically excludes the risk that the observed calves are, in fact, milking cows.

A potential thread to the identification strategy is that farmers might tend to immediately get rid of their male calves, due to their low expected future productivity. Having a female versus a male calf could, then, increase herd size, directly affecting farmers dairy behavior. Anecdotal evidence suggests that farmers, indeed, prefer to sell male calves while maintaining constant herd size, whereas they keep their female calves for future milk production, raising herd size. Data show that among those having had a calf being born between the two data rounds, only 56 farmers have sold a male calf in the previous 12 months (2.7% of the sample), while 28 farmers have sold a female calf (1.35%). The difference is not statistically significant. More generally, animals sales are not correlated with calf's sex.

Finally, it is important to specify that the questionnaire does not distinguish between the amount of milk that is suckled by calves and the amount that farmers milk. It could be that farmers let female calves suckle more or less milk than male calves, ending up in a lower (higher) amount of milk to be consumed by the household or sold on the market. The measurement error in milk production would then be correlated with the calf's sex, biasing the results. Figure 2 shows that milk production for the average cow in the previous three days is not statistically significantly different according to the age of the last born calf. This is true for any age, except for calves between 6 and 8 months old, for which milk production is higher for those with a male calf. This Figure shows an interesting pattern in milk production: it decreases when calves are between 0 and 2 months, while it raises afterwards. This suggests that farmers let very young calves (both female and male) suckle more in their first months of life and answered our questionnaire by reporting the amount of milk obtained, excluding that given to calves. As long as this pattern is not significantly different between male and female calves, this source of measurement error in milk production should not bias our estimates.

3 Results

In this section I investigate the effect of the birth of female calves on farmers dairy behavior. I, first, present the estimates obtained with the cross-section analysis and, then, with the double difference estimator.

Cross-section results. Results reported in Table 5 show that the birth of female calves significantly affects farmers dairy behavior. On average, one additional female calf increases expenditures in cattle health by 9.4$, controlling for expenditures in the previous year. Compared to the sample

11. Results are robust to limiting the sample to calves under 10 months old.

average of 60.8$, this corresponds to a 15.6% increase. Costs associated with household labor, hired workers and buying new animals are not affected by the birth of female calves.

The increase in cattle health investments may affect dairy farming in the short-run if currently productive animals (cows) benefit from this type of investments. Indeed, milk production depends strongly on cows' health conditions. Basic interventions, such as deworming, curative treatments or spraying against ticks may considerably improve cows' health providing immediate effects on their productivity. Exploiting the information reported by farmers in the cows roster, I estimate the effect of newborn female calves on cows' health expenditures. [12] Results reported in column 5 indicate a 15.7% increase in cows' health expenditures, compared to the sample mean. This suggests that the increase in expenditures for cattle health is driven by investments in cows' health.

Using detailed information about the types of expenditures for cattle health, results reported in Table 6 show that one additional female calf increases expenditures for providing curative treatments by 2.3$, corresponding to a 12.6% increase compared to the sample mean. Expenditures for deworming and spraying increase by 12.5% and 18%, respectively. The point estimate of the effect on expenditures for vaccination is positive and in line with the other expenditures' items, though not statistically significant.

Overall, these results point in the direction of a positive complementary effect on farmers' dairy behavior, increasing investments in cattle health conditions. This result is echoed by the effect of recently born female calves on farmers' willingness to pay for a set of different investment alternatives. Figure 1 shows that a newborn female calf increases the likelihood that farmers are willing to invest in animal drugs and hiring labor for dairy activities. In turn, farmers are less willing to pay for animals' food seeds (in line with the negative point estimate in Table 5 column 6) to invest in other businesses or to buy other animals. Importantly, there is no effect on the willingness to pay for school fees or for increasing savings for animal emergencies, suggesting that a newborn female calf does not represent a wealth shock that affects any type of investment. It only affects investments strictly related to the cattle health conditions and milk production.

Are these investments effective in boosting dairy production? Is the increase in expenditures enough for stimulating milk production? Are these investments profitable? Results reported in Table 7 show that one additional female calf significantly increases the daily amount of milk produced by 0.352 liters, which corresponds to about 11% of the average daily amount produced in 2016. Given that on average milk production remained pretty constant from one year to the other, the magnitude of the effect is fairly large.

The increase in milk production translates in higher sales and higher milk consumption. Compared to the sample mean, the amount of money earned out of selling milk increases by 12.6% (column 2) and households milk consumption increases by 6.6% (column 3). In turn, revenues from selling animals do not increase, which suggests that, coupled with the non-significant result on expenditures for buying animals (Table 5, column 4), farmers do not react to newborn female calves

12. Given that we interviewed farmers about two randomly selected cows, these should be representative of the totality of a farmer's cows.

by buying or selling animals. Hence, herd size or composition are unlikely to be affected. Finally, other types of revenues related to cattle rearing (renting oxen and bulls or selling manure) are not affected by the birth of female calves (column 5). Is the increase in milk revenues large enough for compensating the increase in health expenditures? Results reported in column 6 indicate a positive and significant effect on profits, suggesting that the increase in milk revenues more than compensates the increase in inputs expenditures. One additional newborn female calf increases profits by 41$, corresponding to 19% of the sample mean.

The increase in health investments suggests that input markets for curative treatments are existent and accessible to farmers. The data indicate that farmers mostly perform those treatments by themselves (83%), while very few rely on private veterinaries (10%) and almost nobody turns to extension agents. Access to the National Agricultural Advisory Service, the main extension service system in Uganda, is, in fact, very limited among sampled households (17%) and farmers repetitively report lack of agents in the study area. The main source of information about dairy farming is still represented by fellow farmers (56%). This suggests that despite relevant constraints in access to extension services, farmers are aware of the importance to invest in cattle health and manage to overcome those constraints by applying the treatments themselves.

To formally test for the crowd-in effect on milk production, I follow Emerick et al. (2016) and regress milk production in the second round on the types of investments that are significantly affected by newborn female calves. If these investments matter for milk production, I expect the effect of female calves to be reduced by progressively conditioning on those variables. Table A.1 shows, indeed, that the estimated coefficient remains significant but considerably decreases compared to the unconditional estimates. In particular, investments in health and labor appear to considerably reduce the point estimate. These results are in line with a crowd-in effect, confirming the important role played by investments in cattle health on milk production.

Double difference results. By exploiting the longitudinal nature of the data, I apply a difference-in-differences estimator, comparing households with at least one recently born female calf versus those with at least one recently born male calf, before and after the birth of the animal. The interpretation of the results is different from the cross-section analysis, as here I estimate the effect of a temporal *change* in the number of female calves on the *change* in the outcomes of interest. I further control for household fixed effects, to account for unobservable household traits that may affect farmers behavioral response, and for survey fixed effects, to account for temporal trends common to all farmers.

Results reported in Table 8 are in line with the OLS results. On average, one additional newborn female calf between the two data rounds increases health investments by 7$, which corresponds to 20% of the sample average. The increase in milk production and revenues is confirmed as well, indicating a 8.3% and 11.4% increase compared to the sample mean. Again, revenues from selling animals and cost of hiring workers are not affected by newborn female calves. Contrary to the OLS results, I do not find any significant effect on milk consumption and overall profits. The point estimates reported in columns 4 and 6 are positive, but not significant. Interestingly enough, an increase in the number of cows is positively and significantly associated with an increase in milk consumption and profits, which might suggest that female calves may in the future increase profits once they will be producing milk.

The double difference estimates concerning each single item of cattle health expenditures are in line with the OLS results. Table 9 shows that expenditures for curative treatments increase by 22.7% and for spraying against ticks by 26.7%. Note that the results on health expenditures are driven by farmers with older calves on average (6 months or older) at the moment of the survey (results not shown), which is in line with the fact that it might take time for farmers to mobilise resources for increasing investments.

Overall, these results confirm the positive behavioural response of farmers in reaction to the birth of female calves. Yet, once we account for temporal variation and time-invariant unobserved farmers characteristics, the result on profits is not confirmed. This may suggest that the positive effect of newborn female calves only concerns the level of profits but not their variation. Also, it may be that some farmers have unobservable knowledge and capacities that make their behavioural response in terms of dairy investments more effective and profitable than that of other farmers. Unobservable fixed heterogeneity might affect the capacity of translating dairy investments into higher profits.

Does the farmers' investment response last over time or is it only temporary? To answer this question I compare the first data round with the last one collected in the summer of 2017, about one year and half after the calves' birth, and apply the double difference strategy as in Eq. 2. Results reported in Table 10 show a significant increase in expenditures for cattle health and also for hiring workers. The cost of health investments increase by 26% and for hired labor by more than 100%. Given the large increase in household labor occurred in 2017 (Table 1), I check whether newborn female calves affect household labor between 2016 and 2017 (I cannot test it between 2015 and 2017 due to how household labor was measured in the first data round). I do not find any significant effect (results not shown).

Importantly, the effect of newborn female calves on milk production and milk revenues lasts till 2017. Results in columns 3 and 4 show an increase of 17.2% and 9% with respect to the sample mean. The magnitude of the effect on milk production between 2015 and 2017 is more than twice the one previously found between 2015 and 2016 (8.3%, Table 8), suggesting that the effects of dairy investments do not fade away over time. Yet, farmers do not compensate the sustained raise of expenditures by selling their animals (column 5) and the increase in milk revenues does not appear to offset the increase in costs, leading to a non significant effect on overall profits (column 6).

3.1 Mechanisms

The birth of a female calf may affect farmers dairy behavior through several possible channels. The first mechanism may simply be a mechanical one. Farmers increase health expenditures just because they want to preserve their future productive asset (female calves). The increase in expenditures for cows' health may be a collateral effect: once the veterinary comes, she checks all animals' health and not just female calves'. Yet, as explained above, the great majority of farmers apply the curative treatments themselves, meaning that investing in their cows is not just a collateral effect but a clear decision.

Second, the birth of a female calf may increase future permanent income and reduce risk exposure, due to their future productivity potential as milking cows. Households may, then, increase future consumption, and one way to increase consumption tomorrow is to invest today. In this case, I would expect all types of savings to go up, and not just investments in cattle. Third, having a female calf may increase household's observable wealth, making it easier to access credit and relieving the credit constraint. In this case, I would expect access to credit services to increase.

Fourth, a female calf directly affects herd composition by changing the number of female animals. If returns associated with female cattle are higher than for male cattle, reaching a certain amount of female animals may trigger economies of scale making farmers invest more, as present costs will likely be compensated by future larger returns. Almost all types of investments in cattle are, indeed, usually made at the aggregate level. As such, it might be worth to invest further only if there is a certain number of female animals. A large part of dairy farming activities are characterized by an important initial fixed cost that farmers may not be eager to sustain until the number of animals is large enough for making the investment profitable. Building separate paddocks for calves and for pregnant cows, is, for instance, highly recommended for a more effective cattle management. This is typically one of those investments that farmers undergo only when there is a group of female calves to be isolated from the rest of the herd, but not for one single female animal. Similarly, calling a veterinary or buying new drugs for just one cow may be too expensive, but it may become worthwhile if there is also a female calf. Note that, on average, 70% of animals are female, including calves, cows and heifers, which suggests the importance that female animals represent in dairy farming.

To test for the wealth mechanism, I explore the effect of a newborn calf on the probability of using credit and saving systems, both formal and informal, and of getting a loan for cattle investments. Unfortunately the data do not report the amounts saved and borrowed by farmers, but only whether the farmers accessed banks, cooperatives, micro-finance institutions, informal savings/credit groups for saving or credit services or borrowed money from relatives, friends or moneylenders. Results (not shown) do not indicate any significant positive effect of newborn female calves on the probability of accessing this type of services.

The role played by the sex composition of cattle may matter for farmers investments decisions, given the higher returns associated with female cattle. To test for the existence of economies of scale, I estimate the following regression with a 2SLS estimator, by instrumenting the number of female cattle at round 2 (W_{it}) with the number of newborn female calves (FC_{it}), while controlling for the number of female cattle at round 1 (W_{it-1}):

$$\begin{aligned} Y_{it} =& \beta_0 + \gamma_1 W_{it} + \gamma_2 W_{i,t-1} + u_{it} \\ W_{it} =& \beta_0 + \delta_1 FC_{it} + \gamma_2 W_{i,t-1} + \epsilon_{it} \end{aligned} \tag{3}$$

The exclusion restriction will hold if, conditioning on the number of female animals at round 1, newborn female calves affect the main outcome variables only through the number of female animals at round 2. This hypothesis will be violated if farmers buy or sell some female animals due to simple fact of having a newborn female calf and not because the number of their female animals has increased. A more conservative specification is to replace W_i with the number of female calves. In this case the exclusion restriction requires that outcome variables are correlated with newborn female calves only through the increase in the number of female calves, which may be more reasonable. Reassuringly, the two specifications deliver very similar results (see Table A.3 for the more conservative specification).

Results reported in Table 11 are in line with the hypothesis of economies to scale associated with a higher number of female animals. An increase in the number of female animals between the two time periods is positively associated with investments in cattle health, hired labor and profits. These results are very close to the ones presented in Tables 5 and 7.

Another potential mechanism, that I cannot test, is the almost complete absence of any doubts about future productivity. The certainty that female calves will produce milk in the next future might reassure farmers about the future profitability of increasing investments today in dairy farming. Note that future milk production is at risk only if calves are barren, which is something that the farmer cannot observe.

Overall, these results point in the direction of the existence of economies of scale associated with a higher number of female animals. In turn, newborn female calves do not seem to trigger a wealth or permanent income effect.

3.2 Robustness Check

As explained above, 20% of those having had at least one recently born female calf had two female calves. Is the effect robust to the exclusion of those with two newborn calves? To answer this question I run the OLS specification by limiting the analysis to farmers with only one newborn calf.

Table A.4 shows that having just one single newborn female calf confirms the increase in health investments (+13.8%) and milk production (+11.3%). The effect on milk revenues is still positive, though not statistically significant. Note that the sample gets reduced by half when limiting the analysis to farmers with only one newborn calf, decreasing statistical power.

Conclusions

The level of agricultural investments in Sub-Saharan Africa has grown very little in the past 60 years. Agricultural productivity still lags behind compared to other developing countries. Studying farmers investment decisions is, hence, key for understanding how to promote investments and boost agricultural growth.

This paper explores the effect of a future productivity positive random shock on farmers investment decisions. I proxy the future productivity shock with the birth of a female calf against a male calf. Female calves are not more productive than male calves, but in about two-year time they can become milking cows, providing a major and fairly constant source of income. This delayed effect on the productivity of the asset allows me to disentangle the behavioral response of farmers from the technical returns of the asset itself.

The main results show that farmers significantly increase investments in cattle health by about 20%. This translates into an increase in milk production of about 10% and in milk revenues of 12%. Interestingly, farmers' willingness to pay for animal drugs and cattle management practices increases as well, but not for other activities, suggesting that the shock on productive assets only affects investments decisions strictly related to dairy activity.

I investigate several possible mechanisms behind the main results. The analysis suggests the existence of economies of scale associated with the number of female animals. Due to the presence of important fixed costs, I find that farmers increase dairy investments only when they reach a higher number of female animals, which are, indeed, the most productive asset in dairy farming.

These results shed light on investment decisions of farmers living in a resource constrained environment and generally under-investing in a profitable activity, such as cattle rearing. This is the first paper to show that farmers positively respond to an increase in inputs future productivity, even in the absence of any current technical returns. Farmers appear to adopt complementary investments in a way that increases production and revenues for almost two years. This calls for promoting the adoption of technologies that allow for economies of scale and that push farmers to crowd-in the technical returns of the technology itself.

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Figures

Figure 1 – Effect of number of new female calves on Willingness to Pay

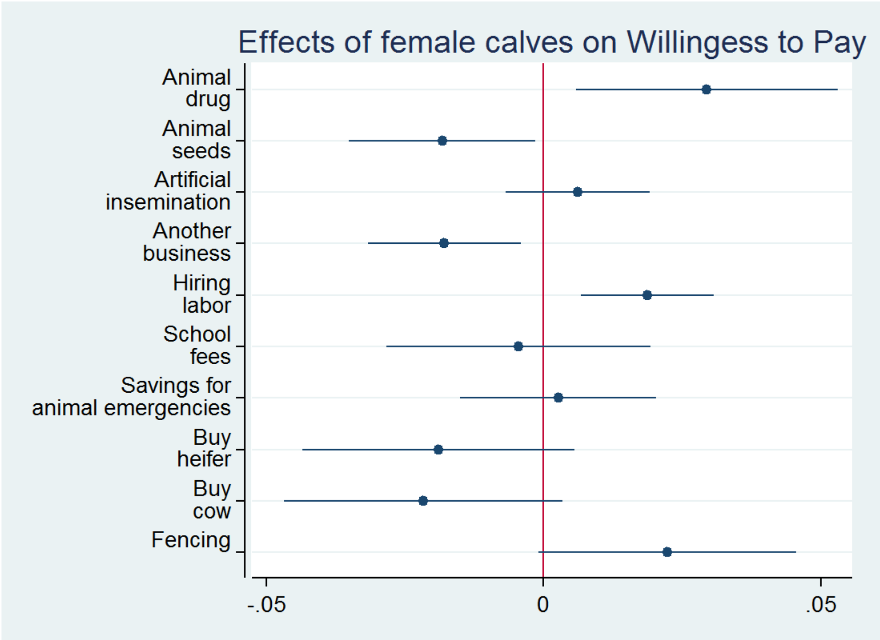
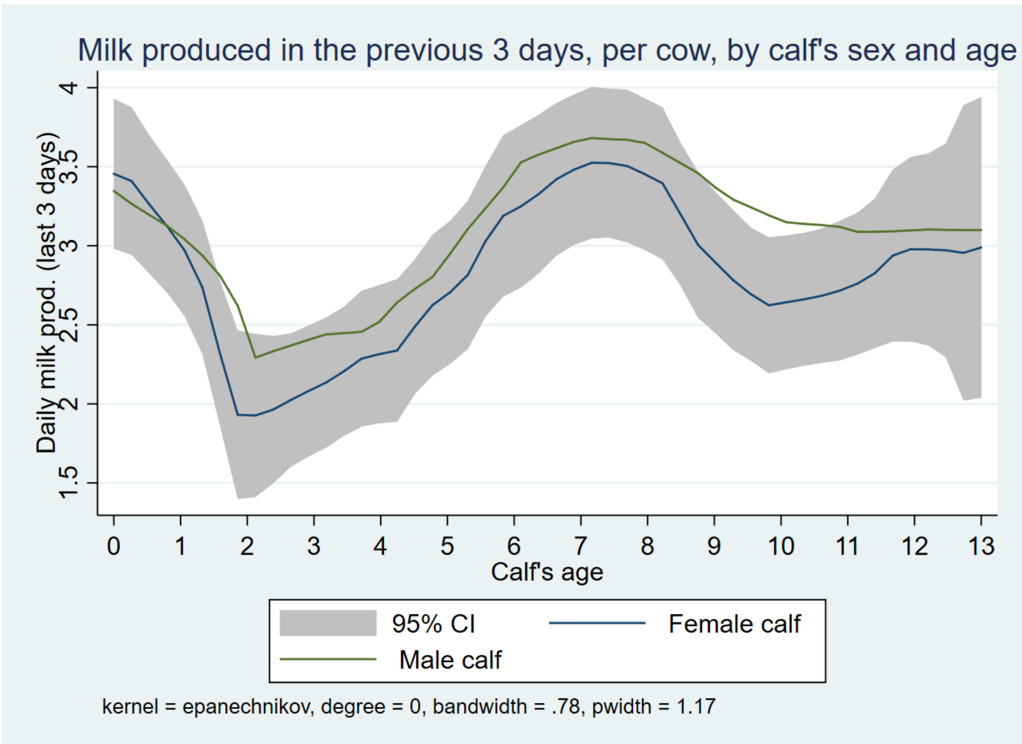


Figure 2 – Milk production per cow, by calf's sex



Tables

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

	(1) Round 1	(2) Round 2	(3) Round 3
N. cattle	5.871	5.770	6.971
	(6.354)	(6.514)	(6.965)
N. male cattle heads	1.784	1.916	2.470
	(2.091)	(2.246)	(2.595)
N. female cattle heads	4.079	3.849	4.515
	(4.652)	(4.710)	(4.835)
Daily milk prod. (last 3 days)	2.308	2.353	2.537
	(3.310)	(3.547)	(3.945)
Daily milk income	0.336	0.586	0.573
	(0.592)	(0.837)	(0.731)
Revenues from selling animals	104.4	145.0	187.9
	(213.5)	(236.5)	(271.7)
Other cattle-related revenues	NA	14.84	13.30
	NA	(44.44)	(38.67)
Health costs for cattle	20.91	47.59	56.33
	(33.53)	(47.62)	(56.58)
Cost buy animals	22.19	39.36	34.32
	(72.27)	(99.05)	(86.96)
Hired lab cost	12.54	16.74	15.10
	(39.17)	(48.67)	(44.34)
Total labor costs	59.14	184.2	1206.9
	(64.20)	(609.0)	(2764.3)
Days of work per hh worker		1.406	5.007
		(1.740)	(2.467)
N. HH workers		8.484	10.79
		(5.686)	(7.035)
Feeds costs		57.20	50.63
		(84.74)	(78.38)
Profits, tot.	119.5	197.5	225.4
	(287.5)	(365.3)	(368.8)
Profits, tot. (incl. HH labor)	69.57	75.28	-816.3
	(278.2)	(440.1)	(2198.3)
Observations	3109	2999	3122

mean coefficients; sd in parentheses

Table 2 – Balance check of household characteristics based on calf's sex.

	At least one female calf	Male calf	Means-test	s.e.
HH head age	46.310	45.677	0.632	0.625
Spouse age	37.726	37.060	0.667	0.540
HH head gender	0.919	0.914	0.005	0.013
HH head born in village	0.775	0.803	-0.028	0.019
HH head able to read	0.782	0.806	-0.023	0.019
HH head member farmers group	0.167	0.175	-0.008	0.017
HH head grade completed	7.995	7.990	0.004	0.258
N. illness days	1.104	1.229	-0.125	0.224
HH head works off farm	0.519	0.512	0.007	0.023
Household size	8.840	8.429	0.411**	0.193
Saving inst.	0.653	0.658	-0.005	0.022
Wealth Index z-score	0.115	-0.006	0.122***	0.047
N. shocks	1.668	1.631	0.037	0.045
Food security	-7.185	-6.890	-0.295	0.360
N. cattle	7.445	5.770	1.674***	0.324
N. cows	2.698	2.088	0.610***	0.128
N. calves	1.863	1.442	0.420***	0.092
Observations	2072			

Table 3 – Balance check of household characteristics based on calf's sex. Farmers with only one recently born calf.

	One female calf	**One male calf**	**Means-test**	**s.e.**
HH head age	45.436	45.252	0.184	0.841
Spouse age	36.640	36.345	0.295	0.730
HH head gender	0.894	0.897	-0.003	0.019
HH head born in village	0.783	0.793	-0.011	0.026
HH head able to read	0.794	0.816	-0.022	0.025
HH head member farmers group	0.185	0.176	0.009	0.024
HH head grade completed	8.138	7.994	0.144	0.343
N. illness days	0.978	1.291	-0.314	0.305
HH head works off farm	0.534	0.503	0.031	0.031
Household size	8.354	8.016	0.337	0.242
Saving inst.	0.659	0.665	-0.005	0.030
Wealth Index z-score	-0.040	-0.091	0.050	0.063
N. shocks	1.676	1.619	0.057	0.061
Food security	-7.533	-6.693	-0.840*	0.471
N. cattle	4.019	3.761	0.257	0.237
N. cows	1.380	1.323	0.057	0.077
N. calves	0.959	0.996	-0.037	0.076
Observations	1026			

Table 4 – Characteristics of households with and without a recently born calf.

	At least one recently born calf	**No recently born calves**	**Means-test**	**s.e.**
HH head age	46.087	44.877	1.210**	0.543
Spouse age	37.494	36.578	0.916**	0.466
HH head gender	0.917	0.911	0.007	0.011
HH head born in village	0.784	0.763	0.021	0.017
HH head able to read	0.790	0.778	0.013	0.016
HH head member farmers group	0.169	0.130	0.039***	0.015
HH head grade completed	7.993	8.081	-0.087	0.220
N. illness days	1.148	0.990	0.158	0.189
HH head works off farm	0.516	0.527	-0.011	0.020
Household size	8.695	8.414	0.282*	0.167
Saving inst.	0.655	0.633	0.022	0.019
Wealth Index z-score	0.073	-0.158	0.230***	0.039
N. shocks	1.655	1.621	0.034	0.039
Food security	-7.082	-6.848	-0.233	0.307
N. cattle (W1)	6.849	3.752	3.098***	0.248
N. cows (W1)	2.481	1.250	1.230***	0.098
N. calves (W1)	1.714	0.838	0.876***	0.071
Profits (W1)	231.697	145.220	86.477***	14.503
Profits, p.a. (W1)	44.268	35.533	8.735**	3.439
Observations	2988			

Table 5 – OLS. Effect of newborn female calves on investments in cattle

	(1) Health cost	(2) HH lab (days)	(3) Hired lab cost	(4) Cost buy animals	(5) Health costs cows	(6) Feeds cost
N. newborn female calves	9.433***	12.121	1.924	-2.856	2.048***	-0.680
	(2.78)	(12.45)	(1.76)	(5.85)	(0.54)	(4.25)
N. female calves (W1)	2.151	16.753**	1.681	8.690**	0.203	4.832
	(2.26)	(6.86)	(1.29)	(3.84)	(0.29)	(3.31)
N. cows (W1)	2.700**	-2.512	1.732**	1.774	-0.045	0.507
	(1.26)	(2.55)	(0.68)	(1.79)	(0.12)	(1.13)
N	2072	1982	2020	2070	2072	2030
Dep. var. mean	60.8	278	20.8	54.8	13	70.6
Bonferroni p-value	.0007	.33	.28	.63	.00015	.87

Regressions in (1)-(4) include one-lag outcome. 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. Bonferroni p-values estimated for "N. newborn female calves".

Table 6 – OLS. Effect of newborn female calves on investments in cattle health

	(1) Treatment	(2) Vaccination	(3) Deworming	(4) Spraying
N. newborn female calves	2.293**	2.220	1.427**	4.436**
	(0.99)	(1.70)	(0.72)	(1.75)
N. female calves (W1)	-0.194	0.986	1.321**	-0.569
	(0.84)	(0.64)	(0.56)	(1.55)
N. cows (W1)	1.258**	0.480**	0.307	2.494*
	(0.53)	(0.24)	(0.21)	(1.30)
N	2049	2049	2047	942
Dep. var. mean	18.1	8.06	11.4	24.7
Bonferroni p-value	.02	.19	.046	.011

All regressions include one-lag outcome. See note of Table 5

Table 7 – OLS. Effect of newborn female calves on dairy activity.

	(1) Milk production	(2) Milk revenues	(3) Milk consumption	(4) Revenues selling animals	(5) Other cattle-related revenues	(6) Profits, tot.
N. newborn female calves	0.352***	0.092***	0.140**	12.412	4.764*	41.721***
	(0.11)	(0.03)	(0.06)	(13.31)	(2.88)	(12.36)
N. female calves (W1)	0.169*	0.035*	-0.006	9.705	-1.025	15.934*
	(0.09)	(0.02)	(0.04)	(9.74)	(2.24)	(9.35)
N. cows (W1)	0.123***	0.009	0.072***	13.098**	2.420*	7.277*
	(0.04)	(0.01)	(0.02)	(5.22)	(1.30)	(4.10)
N	2025	2030	1698	1903	2072	1984
Dep. var. mean	3.24	.726	2.1	162	24.7	218
Bonferroni p-value	.0021	.00041	.015	.35	.099	.00079

All regressions include one-lag outcome.See note of Table 5

Table 8 – Double difference. Effect of newborn female calf on dairy activity.

	(1) Health costs for cattle	(2) Hired workers cost	(3) Milk production	(4) Milk consumption	(5) Milk revenues	(6) Revenues from selling animals	(7) Profit, tot.
Female calf*t	6.974***	1.536	0.226*	0.075	0.057**	-14.321	4.663
	(1.61)	(1.70)	(0.12)	(0.08)	(0.03)	(9.39)	(13.48)
t	26.691***	4.522***	0.419***	-0.091	0.291***	30.947***	81.040***
	(1.24)	(1.29)	(0.10)	(0.06)	(0.02)	(7.10)	(9.54)
N	4044	4040	4050	3396	4060	3728	3968
Dep. var. mean	34.99	16.015	2.7227	1.99	.49907	118.9	163.57
Bonferroni p-value	.000015	.37	.065	.32	.026	.13	.73

Household fixed-effects included. Robust standard errors clustered at the household and year level. Bonferroni-adjusted p-values estimated for "Female calf*t".

Table 9 – Double difference. Effect of recently born female calves on cattle health investments.

	(1) Treatment	(2) Vaccination	(3) Deworming	(4) Spraying
Female calf*t	3.511***	-1.180	0.146	4.639**
	(0.95)	(1.27)	(0.76)	(1.89)
t	10.295***	1.727***	4.543***	5.171***
	(0.68)	(0.66)	(0.59)	(1.41)
N	4098	4098	4094	1884
Dep. var. mean	10.4	6.7	8.21	18.2
Bonferroni p-value	.00021	.35	.85	.014

See note of Table 8.

Table 10 – Double difference between 2015 and 2017. Effect of female calf on dairy activity.

	(1) Health costs for cattle	(2) Hired workers cost	(3) Milk produc- tion	(4) Milk revenues	(5) Revenues from selling animals	(6) Profit, tot.
Female calf*t	10.229***	8.180***	0.429***	0.042**	-7.793	-8.516
	(1.46)	(1.19)	(0.10)	(0.02)	(8.64)	(11.69)
t	32.584***	11.382***	0.038	0.229***	78.001***	94.275***
	(0.91)	(0.72)	(0.06)	(0.01)	(5.57)	(7.23)
N	5658	5638	5664	5662	5480	5536
Dep. var. mean	39.331	7.6598	2.492	.46693	144.47	184.19
Bonferroni p-value	2.7e-12	6.7e-12	.000034	.03	.37	.47

See note of Table 8.

Table 11 – 2SLS. Effect of the number of female animals on dairy activity.

	(1) Milk production	(2) Milk revenues	(3) Health cost	(4) Hired lab cost	(5) Profits, tot.
N. female cattle (W2)	0.267***	0.064***	6.535***	1.332	24.665**
	(0.09)	(0.02)	(1.80)	(1.23)	(12.34)
N. female cattle (W1)	-0.067	-0.025*	-1.962*	0.556	-12.475
	(0.06)	(0.01)	(1.16)	(0.71)	(9.31)
N	2025	2030	2072	2020	1986
Dep. var. mean	3.24	.726	60.8	20.8	86.3
F-test IV	67	57	45	57	75
F-test p-value	2.0e-15	1.6e-13	5.8e-11	1.8e-13	6.7e-17
Bonferroni p-value	.0025	.001	.00029	.28	.046

Robust standard errors clustered at the household level. Bonferroni-adjusted p-value estimated for "N. female cattle (W2)".

Appendix

Table A.1 – OLS. Testing the crowding-in effect

	Dep. var.: milk production W2							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
N. newborn female calves	.444***	.352***	.269**	.303**	.253**	.261**	.257**	.269**
	(.12)	(.12)	(.12)	(.12)	(.11)	(.12)	(.12)	(.12)
N. female calves (W1)		.169*	.161*	.184**	.16*	.176*	.178**	.166*
		(.095)	(.084)	(.094)	(.085)	(.09)	(.09)	(.089)
N. cows (W1)		.123***	.0821**	.132***	.0926**	.0866**	.0864**	.0848**
		(.044)	(.039)	(.044)	(.041)	(.041)	(.041)	(.041)
Milk production (W1)	.449***	.353***	.309***	.327***	.317***	.312***	.307***	.304***
	(.033)	(.037)	(.035)	(.038)	(.036)	(.037)	(.037)	(.037)
Health cost			.0138***					
			(.002)					
Health costs cows				.0274***	.0228***	.0225***	.0222***	.0218***
				(.0066)	(.0065)	(.0068)	(.0068)	(.0068)
Hired lab cost					.0083***	.00813***	.00816***	.00782***
					(.0022)	(.0023)	(.0023)	(.0023)
Feeds cost						.000528	.000537	.000552
						(.00047)	(.00047)	(.00047)
HH lab (days)							.00133	.00125
							(.00092)	(.00088)
Cost buy animals								.00183***
								(.00063)
Constant	1.7***	1.55***	1.06***	1.28***	1.31***	1.29***	1.25***	1.19***
	(.12)	(.12)	(.13)	(.13)	(.12)	(.13)	(.13)	(.13)
N	2025	2025	2025	2025	2024	1985	1985	1983
Dep. var. mean	3.24	3.24	3.24	3.24	3.24	3.23	3.23	3.24
r2_a	.185	.205	.251	.22	.257	.252	.253	.26

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 A.2 – OLS. Test for parallel trend assumption.

	(1) Diff. health costs	(2) Diff. hired labor	(3) Diff. milk prod.	(4) Diff. milk consumption	(5) Diff. milk revenues	(6) Diff. sold animals revenues	(7) Diff. profit
Female calf (W3)	-2.014	-0.264	0.192	0.019	-0.035	-9.099	-26.257
	(2.49)	(2.65)	(0.19)	(0.11)	(0.04)	(15.69)	(21.42)
N	1654	1658	1655	1361	1662	1509	1617
Dep. var. mean	-29.1	-5.35	.146	-.238	.281	21.5	77.6

All regressions control for the number of female calves in W2 and the number of cows in W2. Outcomes are measured as the difference between W2 and W1. Robust standard errors clustered at the village level.

Table A.3 – 2SLS. Effect of female calves on dairy production and profits.

	(1) Milk production	(2) Milk revenues	(3) Health cost	(4) Hired lab cost	(5) Profits, tot.
N. female calves (W2)	0.571***	0.143***	15.012***	2.910	57.593**
	(0.17)	(0.04)	(4.13)	(2.73)	(25.00)
N. female calves (W1)	0.108	0.032	0.579	1.606	-3.960
	(0.10)	(0.02)	(2.19)	(1.26)	(12.40)
N. cows (W1)	0.025	-0.016	0.166	1.186	-2.040
	(0.05)	(0.01)	(1.26)	(0.82)	(6.51)
N	1985	1990	2032	1980	1948
Dep. var. mean	3.3	.73	61.1	20.9	88.6
F-test IV	257	239	207	223	279
F-test p-value	1.5e-47	6.2e-45	6.2e-40	2.1e-42	8.0e-51
Bonferroni p-value	.0011	.00047	.00028	.29	.021

Robust standard errors clustered at the household level. Bonferroni-adjusted p-value estimated for "N. female calves (W2)".

Table A.4 – OLS. Effect of a newborn female calf for farmers with only one newborn calf

	(1) Health cost	(2) Hired lab cost	(3) Milk production	(4) Milk revenues	(5) Milk consumption	(6) Revenues selling animals	(7) Profits, tot.
N. newborn female calves	5.97***	1.13	.257*	.00371	.0467	.723	-1.21
	(2.2)	(1.9)	(.14)	(.033)	(.07)	(11)	(13)
N. female calves (W1)	4.68**	1.64	.117	.019	.0597	27.5*	15
	(2.3)	(1.9)	(.13)	(.023)	(.053)	(14)	(11)
N. cows (W1)	-.13	2**	.147**	-.00135	.0484***	6.13	8.51
	(1.6)	(1)	(.067)	(.0094)	(.015)	(6.5)	(5.9)
N	1265	1252	1255	1251	1014	1180	1237
Dep. var. mean	43.1	12.7	2.28	.529	1.86	115	149

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.