Innovations in Dairy Value Chains - Evidence from Uganda

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Abstract

The dairy sector in Uganda has undergoing substantial changes over the last decade. A combination of policy changes, the injection of foreign direct investment in processing plants aimed at export, changing diets of an increasingly demanding urban and rural population and technological progress have substantially altered the entire value chain over time. Using a combination of primary and secondary data on different actors throughout the value chain, we highlight key drivers of value chain development. We exploit the fact that the sector seems to be evolving at two speeds, with one area highly focused on production for export processors and another area mainly catering for the local market. We find that commercialization is associated with increased technology adoption among farmers and a professionalization of intermediation. We also find that milk collection centers are important not only for quality assurance, but also provide a range of services to its suppliers. Processes still seem unsure the optimal level of vertical integration in such competitive and dynamic value chains.

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Introduction

The dairy value chain has undergone substantial changes in the last few years. These changes are driven by different factors, both on the demand side and on the supply side. First, local consumption of milk is increasing. Following yeas of poverty reduction, the high price elasticity of dairy products means people have started to consume more of it. Especially in cities, consumers become aware of the health benefits of dairy products and are persuaded by an ever increasing supply, both in informal milk shops and emerging supermarkets. Second, Uganda's strong liberalization record also means processing plants were built, often in the form of green field investment to exploit the low production price of milk in parts of the country that makes the sector very competitive in the international market. On the supply side, technological innovations have also resulted in increased production, better quality and smoother functioning markets.

In this study, we highlight some of the more important changes that happened within the value chain over the past decade. We do this by comparing data collected at key nodes in the chain between two so called milk shed that have evolved quite differently. In the southwestern milk shed, the value chain has transformed dramatically in the course of only a few years, with processors converting milk into complex products with a long shelf life, such as UHT and casein, often for export. At the same time, in a nearby milk shed with comparable production levels, most of the production and trade is still largely informal, and the milk that is processed is generally sold as pasteurized milk in Kampala.

We consider four main categories of actors in the value chain in this study. Upstream, there are cattle farmers that produce milk, most of it for the market. These farmers generally sell raw milk at the farm gate to traders, who in turn sell this unprocessed milk to milk collection centers. A significant number of farmers also sell directly to milk collection centers, often because they are members of the cooperative that runs the center. There is also an important informal market, with farmers selling directly to neighbours, especially in the central milk shed. Another important actor in the chain is the processor, who sources milk from milk collection centers, and in the southwestern region also directly from traders. We collected primary data on 1600 producers, 700 small traders, and 100 milk collection centers. We also conducted interviews at two processors.

We find that integration in a modern dairy value chain goes hand in hand

with the adoption of higher yielding animals. In the southwestern milk shed, more than 82 percent of the herd consists of crossbred cows. We see that the Central milk shed is catching up with the southwestern milk shed in terms of adoption of crossbred cows. While 10 years ago, only 8 percent of the herd consisted of improved animals, this has now become almost 50 percent. We find that especially farmers that are located close to milk collection centers are replacing local Ankole cows with fresian cross-breeds. We also find that producers that have better access to acaricides are more likely to adopt cross-breeds, as these animals are particularly susceptible to East Coast Fever.

We also find that often agreements exist between producer and buyer (either trader or milk collection center). However, mostly these are non-binding oral agreements. Indeed, as producers interact with buyers on an almost daily basis and payments are usually done weekly, more formal agreements may not add much to an already close relationship. While farmers generally sell to more than one neighbour, they tell to use on and the same traders. At the same time, we do find that technology adoption is generally higher among farmers that report more formal agreements with buyers.

The dairy value chains is also characterized by the existence of small traders and transporters who collect milk using bicycles or motorbikes in villages and take it to milk collection centers or processors. There seems to be a reasonable degree of competition among these middlemen. Our data suggests that traders and transporters tend to be more professional in the southwestern milk shed: they visit significantly more clients on the average day and transport quantities that are three times as big than traders and transporters in the central milk shed.

Over time, traders have also embraced technology to facilitate their work. For instance we see that almost all traders use mobile phones. Many also use motorbikes. We generally do not find differences between the two milk sheds. We do find that virtually all traders in the southwestern milk shed use stainless steel milk storage containers for transport, while this is often done using jerrycans in the central milk shed.

Arguable the most fascinating link in the chain are the milk collection centers. Located at strategic places in rural areas, these centers collect and chill the milk in large coolers, often powered by generators. However, our data suggests that these centers are much more than just collection points: they also offer a range of services to their clients, ranging from credit to veterinary services, particularly of they are cooperatives.

Finally, we also provide some insights on processing companies. The

largest processors are located in the southwestern milk shed, and process milk mostly for export. Their main challenges are procuring enough milk, especially in the dry season. Their operations are also greatly constrained by the poor industrial base in Uganda: most of the packaging material needs to be imported from Kenya.

The rest of this article is organized as follows. We start by describing the increase in demand. We then briefly tough on the policy context in which the dairy value chain has developed. Next, we describe how the milk put on the market by an average farmer flows through the value chain, separately for the southwestern and the central milk shed. We then zoom in on farmers and look at adoption of cross bred cows and milk production and market participation. We also devote some attention to contracting between farmers and buyers. Next, data on traders and transporters is presented, an a comparison of their profile between the central and southwestern shed is made. We then turn to milk collection centers, where ownership is an important qualifier. We briefly mention some stylized facts about how processors experiment with different degrees of vertical integration. A final section concludes.

The demand for milk

Consumption of dairy products has been increasing over time in Uganda. Figure 1 shows yearly per capita liquid milk consumption in liters as estimated using three different waves of the Uganda National Household Survey (UNHS). We see that as recent as 2005/06, the average Ugandan consumed only about 10 liter of milk per year. At that time, consumption in rural and urban areas was virtually the same, underlining the importance of the informal market and auto-consumption of milk. Over time and against a background of significant welfare improvements particularly in urban areas, milk consumption has soared: by 2009, milk consumption had tripled in urban areas. In rural areas, the increase in consumption came later and was less outspoken. The observed pattern is consistent with a high income elasticity of milk; indeed, analysis of the Uganda National Panel Survey suggests that from 2013/14 onward, milk consumption started to decrease in urban areas, in line with an increase in poverty as a result of the rising cost of living.

The consumption reported in Figure 1 captures only liquid milk. However, Ugandans also consume dairy products in other forms. For instance, in rural areas, *bongo*, a type of buttermilk that can be stored longer than

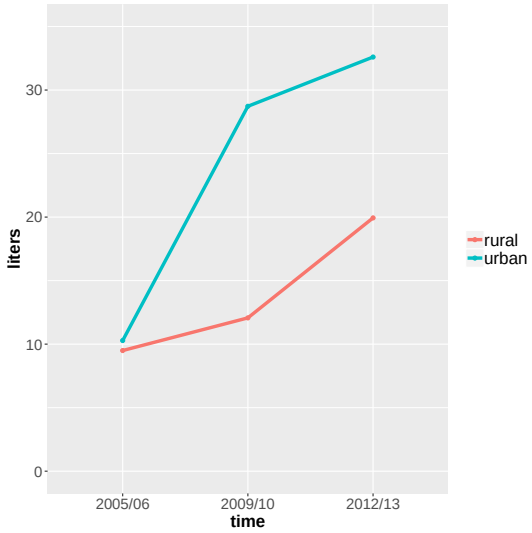


Figure 1: Consumption of liquid milk over time

liquid milk, is very popular. Furthermore, in rural areas, ghee is used in cooking, and in urban areas, butter and yogurt consumption is taking off quickly. Unfortunately, the UNHS does not explicitly differentiate between different dairy products. For instance, while ghee consumption is recorded separately, there is no mention of *bongo*, which is likely to be more important as a source of micro-nutrients. Primary data collected from about 1,600 milk farmers in the central and southwestern milk shed (which will be described in detail later) suggests that more than half of the farmers consume bongo on a regular basis and the volumes consumed are only slightly lower than liquid milk. As a result, the consumption of dairy products is likely to be substantially higher than what is reported in Figure 1.

Not only national consumption has increased. Over time, and especially since 2014 after the establishment of various processing plants in the south-western milk shed and a declining local currency, dairy exports have increased exponentially (Figure 2). The latest available data suggests that US$ 130 million worth of dairy products have been exported in 2018. While a substantial part of this export is to neighboring markets, Kenya in particular, Uganda also exports to the United States (in the form of the protein casein with applications in both food and non-food industries), the Middle East and even Japan.

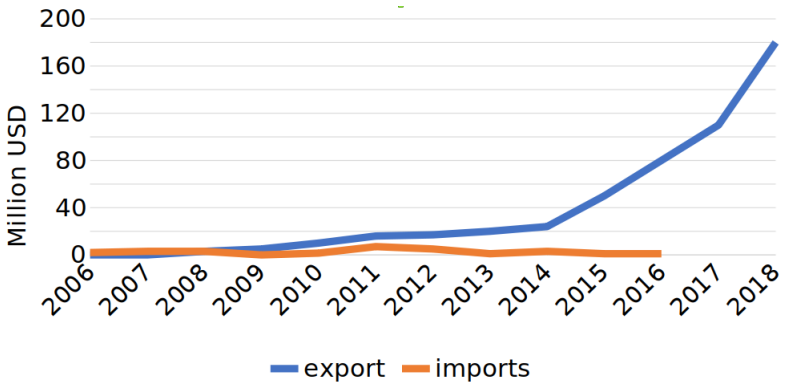


Figure 2: Import and export of dairy products (in millions USD)

In a sense, the success in the dairy sector also came as a surprise. For instance Shepherd (2016) is hesitant about the future of the dairy sector in Uganda as a strong export oriented sector, pointing out informality of relationships constrained the development of contractual interactions resulting in supply uncertainties at the level of the processors. While dairy is not considered a priority sector from an export point of view, it has become the third most important export commodity, after coffee (US$ 555 million) and fish (Nile Perch, US$ 140 million), and leaves other traditional export sectors such as tea (US$ 80 million) and flowers (US$ 60 million) trailing behind. Uganda's dairy exports are now similar to South Africa and Uganda is poised to become the largest dairy exporter on the continent in the near future.

Policy context

To better understand the evolution of the dairy sector in Uganda, it is important to be aware of some key policy changes. In the past, the (formal) dairy sector was heavily centralized, and all milk needed to pass through the National Dairy Corporation, a parastratal dairy processing organization. The privatization push of the new government of Museveni that came to power in 1986 also impacted the dairy sector. One of the first milestones was the passing of the Dairy Industry Act in parliament in 1998, which established the Dairy Development Authority (DDA). This entity under Uganda's Ministry of Agriculture, Animal Industries, and Fisheries (MAAIF) was established to create an enabling environment for the sector. As such, it assumes the

dual role of both promoting diary production and regulating the industry. However, it was only in 2006 that the National Dairy Corporation was privatized, and even then, the state monopoly was simply replaced by another monopoly: the National Dairy Corporation was bought by Sameer Agriculture and Livestock Ltd. As part of the deal, Sameer also acquired all the milk collection centers, coolers and bulking centers that were part of the cold chain. This left smallholder milk producers with few options other than selling to Sameer at very low prices.

Due to this, and the realization that much money was left on the table, both individual inverters as well as cooperatives began to install their own coolers and organize milk collection and bulking. One noteworthy initiative was taken by the Uganda Crane Creameries Cooperative Union (UCCCU), an umbrella organization that brings together dairy cooperatives in Uganda. The UCCCU approached the Agricultural Business Initiative (aBi) Trust, a multi-donor entity devoted to private sector agribusiness development, to assist in the procurement of 100 milk coolers, 92 generators, 92 sets of milk testing equipment, 1,500 metallic milk cans, and 10 insulated milk tankers.

Some observers say that the sector only really took off with the advent of processing companies that, attracted by low prices, focus on dairy export. For instance, Amos Dairies Limited, a diary processing company, based in Ludhiana, Punjab State, India, set up a processing plant in Kirihura that focuses on the extraction of casein in 2014. Pearl Dairy Farms Limited opened in 2013 and mostly processed milk into powder. The success of these processors also attracted a range of smaller processors to the area, often in the form of (Indian) foreign direct investment.

Structure of the value chain and data collected

Uganda is divided into so-called milk sheds, each with different characteristics in terms of agro-ecological conditions, farm typologies and market dynamics. The southwestern milk shed around Mbarara, and in particular the district of Kiruhura, and the central milk shed are the most important ones. While the agro-ecological conditions and farmer types are pretty similar between the two sheds (both lie in the so-called cattle corridor), market dynamics are very different. In the southwestern milk shed, low prices have attracted processors that are able to compete in the international market. This has pushed the supply market for the local dairy value chain that supplies Kampala to the

central milk shed. This, as we will see later, resulted in substantial differences in the organization and functioning of the value chain and how these areas are integrated in the wider economy.

There are many actors involved in the dairy value chain. Upstream, there are the producers who produce for own consumption, but also sell significant amounts of milk. Often, these are small producers that reside in remote areas. Small traders and transporters collect milk in villages at the farm gate daily, and transport this to milk collection centers using bicycles or motorbikes. Collection centers bulk the milk in coolers and for further transport to processors or consumer markets. There are also a range of actors that provide services along the value chain, such as veterinary services, or sell inputs such as feeding supplements. Finally, milk is consumed in different forms and different consumers, ranging from neighbors in the village that consume raw milk to consumers in the US that use products based on the casein protein (glue, paint,...).

We collected data on three value chain actors: 1,600 milk producers, 700 traders and 100 milk collection centers. We used stratified sampling where strata were defined as a function of some of the hypotheses we wanted to test. Thus, our sampling strategy ensures sufficient variation in for instance distance to consumer center, distance to road, distance to processor, distance to Kampala, etc. 312 producers were located in the southwestern milk shed. Here, we interviewed 80 farmers that are relatively close to Mbarara, the second largest town in Uganda and the center of dairy processing for export, as well as 232 farmers in Kiruhura, a large district located northeast of Mbarara that mainly supplies the export oriented dairy industry. In Kiruhura, about 50 farmers were interviewed in two villages in Sanga sub-county, which is along the highway that connects Mbarara to Kampala in the south of the District. Adjacent to the north, we interviewed another 50 farmers that are further from the road. We further interviewed about 158 farmers that are located in the center of the district, in Kenshunga sub-county. Finally, we added another 35 farmers from Kazo sub-county in the remote northwestern tip of the district. We also collected information on 37 milk collection centers distributed over the two sub-counties and interviewed 153 traders that work in the two districts.

In the central milk shed we interviewed farmers in Kyankwanzi and Kiboga districts. Both districts are relatively well connected to the capital through the Hoima-Kampala highway. Kiboga is the district that is closer to Kampala and some areas have already high population density. We inter-

viewed 282 farmers in Nsambya, a very large sub-county in the north west of Kyankwanzi district, along the banks of the Nsuka-Kabi river. In the same district, we interviewed another 57 farmers in Wattuba in the souteast and closer to the highway. In Koboga, we interviewed farmers in 4 different sub-counties. Most of them were located close to the highway, but at varying distance to Kampala. Furthermore, in the central shed, we also interviewed farmers in Nakaseke district. As there is no highway that transects this district, it is relatively more inaccessible than Kyankwanzi and Kiboga. Often, it is more convenient for traders to transport milk to Kampala using the Masindi-Kampala highway located to the North East of the district. In this district, we interviewed a total of 267 farmers distributed over two sub-counties. In the central milk shed, we interviewed about 500 traders and also surveyed 50 milk collection centers.

We also included Masindi district in our sample. Technically, this district does not belong to the Central milk shed, but to the western shed. We focus on sub-counties that are just north of the Nsuka-Kabi river (Bwijanga and Kimengo; about 300 farmers interviewed), and hence similar in agro-ecology to Kyankwanzi and Nakaseke. Over time, the western milk shed is gaining in importance. The discovery of oil in the area has attracted a lot of foreign direct investment, and the dairy industry is anticipating a surge in demand. We thus also included one subounty more into the interior of the district, Miirya, where we interviewed 178 farmers. We also included about 30 farmers from the peri-urban area around Masindi town. In Masindi district, we also interviewed 36 traders and surveyed 5 milk collection centers.

Trade flows

Figure 3 shows how milk flows through the dairy value chain, differentiating between and the central milk shed that is catering mostly for local milk consumption (top) and the more export oriented southwestern milk shed (bottom)[1]. Starting from the quantity sold by the average farmers, it shows how the milk is distributed over the value chain. The average farmer in the central milk shed puts about 84 liter of milk on the market per week (measured in the week before the survey, which was during the dry season). Most of this milk, 40 liters, is sold to traders. Farmers also sell a lot of their

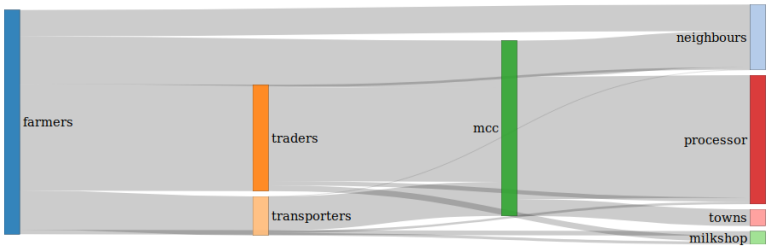
[1]An interactive version of this chart can be found at http://bjornvancampenhout.com/wp-content/uploads/2019/01/milk_flow.html

milk to milk collection centers, either directly (18 liters), or by contracting a transporter to take the milk from the farm-gate to the milk collection center (15 liters). Finally, about 10 liters is sold to neighbours. Farmers in the southwestern milk shed sell double of what farmers in the central milk shed bring to the markets (163 liters of milk per week). Also here, small traders that collect milk in the rural areas are very important, buying up more than half of all marketed milk (86 liters). One quarter of the milk is directly sold to milk collection centers (42 liters per week). The use of transport services is, relative to the central shed, somewhat less important in the southwest. Small quantities of milk are also directly sold to neighbours (6 liters) and to milk shops in the village of in nearby trading centers (4 liters).

We next estimate how much of the quantities that traders procure (40 liters in the central shed and 86 liters in the southwestern shed) is distributed over actors further downstream. In the central milk shed, traders almost exclusively ship to milk collection centers (35 liters). The remaining 5 liters is shared between processors (2 liters), milk shops (2 liters), and direct sales to villagers (1 liter). Trader behaviour is clearly different in the southwestern milk shed. Apart from supplying milk to milk collection centers (56 liters), substantial quantities of milk are also delivered to milk shops (18 liters) and directly to processors (8 liters). Traders selling to villages also seems not uncommon in the southwest (5 liters). Doing the same for transporters, we find that in both milk sheds, transporters deliver to milk collection centers.

In the next step, we estimate how the quantities collected by milk collecting centers (66 liter in the central shed and 122 liter in the southwestern shed) are disposed of. Interestingly, in the central milk shed, milk collection centers also seem to be important to sustain local milk consumption, as 21 percent of the milk is sold to villagers (14 liters). In the southwestern milk shed, sales by milk collection centers to villagers is marginal (3 liters). In the southwest, milk collection centers also often sell to large traders (21 liters, representing 17 percent of total sales by the milk collection center). Many of these traders take the raw milk to Kampala and other towns to supply urban consumers. While milk collection centers from the center also sell to traders, this is relatively less important (6 liters or about 10 percent of total milk sold by the milk collection center) Apparently, despite the fact that the southwestern shed sustains a large export sector, it is also still an important source of milk for Kampala and other towns. The main clients of milk collection centers are processors: In the southwest, milk collection centers sell 80 percent to processors that mainly export, while in the central shed,

Central Milk Shed



Southwestern Milk Shed

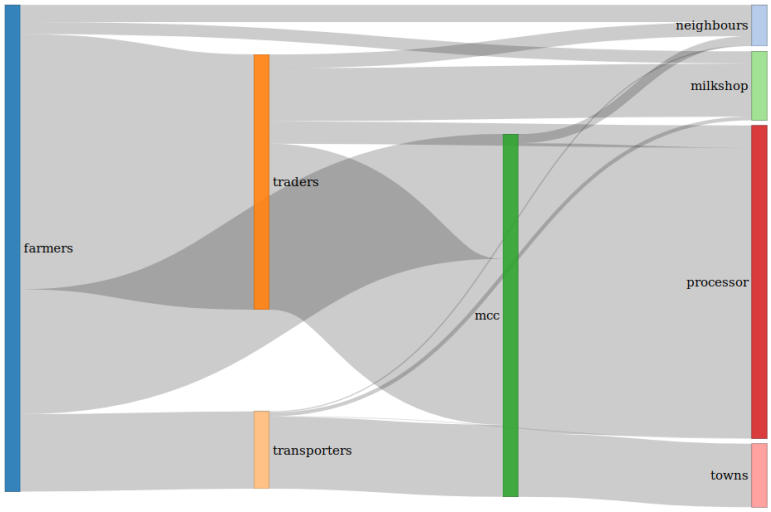


Figure 3: Milk Flows

milk collection centers sell 80 percent to processors for the local and regional market. In the central milk shed, these processors almost exclusively acquire milk from milk collection centers (46 liters). In the southwestern milk shed, processors also procure most of their milk directly from milk collection centers (98 liters), however, fierce competition for supplies means that processors will also buy non negligible amounts of milk directly from traders (8 liters).

Farmers

Herd size and production

At the micro level, the extent to which a farmer is integrated in modern commercial value chains and his level of technology adoption is determined simultaneously. Innovating farmers may be more likely to participate in modern value chains simply because they are more likely to produce a stable marketable surplus (Mather, Boughton, and Jayne, 2013). Processors in modern value chains may have stringent quality standards which only innovating farmers can guarantee (Reardon et al., 2009). At the same time, poorly functioning input and output markets erode the profitability of a technology, leading some farmers to opt-out. Increased vertical coordination may address many of the constraints to technology adoption that smallholder farmers face. For instance, contracts between processors or wholesalers and farmers may reduce the uncertainty related to finding a buyer for innovating farmers. Processors may provide credit and/or inputs to smallholder farmers.

An important technological innovation in dairy farming in Uganda is the introduction of improved breeds, in particular Fresian cows. Figure 4 compares herd size as reported by farmers in our sample now and 10 years ago, for the central milk shed in the left panel and for the southwestern milk shed in the right panel. We see that over time, herd size increased form on average 26 cows to 31 cows in the central milk shed and from 31 to 34 in the central milk shed. More importantly, we see that the Central milk shed is catching up with the southwestern milk shed in terms of adoption of crossbred cows. While 10 years ago, only 2 out of 26 cows were improved, this has now become almost 14 out of 31. In the southwestern milk shed, more than 82 percent of animals are of an improved breed.

Various reasons were reported by farmers as to why adoption of improved dairy animals was not even more widespread (EC fever and susceptibility,

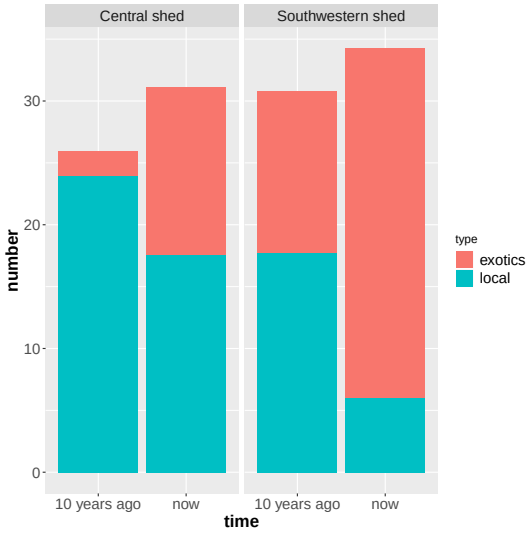


Figure 4: Adoption of crossbred cows

require lots of management, no feeding industry, lacking or poor quality artificial insemination services). The most important reason why farmers do not invest in improved animals is related to the higher susceptibility to pests and diseases. East Coast fever in particular, a tick-borne disease caused by the protozoan parasite, *Theileria Parva*, was reported to be killing many animals. Over time, the ticks have become resistant to acaricides. Local breeds are much more resistant to these ticks and also have shorter hair on the cowskin, making it easier to detect ticks early on. East coast fever is such as big problems that some farmers were of the opinion that extension should focus on animal survival first before trying to increase milk yields.

We thus also collected some information on the extent of the problem and what farmers do about it. First, we simply asked farmers if ticks are a problem on the farm. This was evaluated on a likert scale. The majority of farmers, over 60 percent, report that ticks is a huge problem, and there seems to be no different between the two regions. Next, we ask if East Coast Fever is a problem on the farm and use the same likert scale. We find that two thirds of farmers indicate East Coast Fever is a problem in the southwestern milk shed, while this is only 45 percent in the central milk shed. The difference in subjectively assessed severance of East Coast Fever between the two sheds is confirmed using a chi square test ($p<0.001$). We

also find that more than 95 percent of farmer report to be spraying the cows against ticks. In the southwest, only 3 out of the 352 farmers reported they did not use acaraicides. More than 90 percent of households have at least one knapsack sprayer used to apply the pesticide to the cowskin. Again, this proportion is highest in the southwest.

Figure 5 shows how adoption of improved animals varies with distance to infrastructure and services. In the top left panel, a non-parametric regression shows that there is a negative relationship between the proportion of improved animals and distance to a milk collection center. We show separate curves for the southwest and the central shed. The figure clearly shows that adoption is higher among farmers that live close to a milk collection center. In the central milk shed, farmers that are living virtually next to a milk collection center have on average 1 improved animal for every second one. For farmers that live 20 km away from the nearest milk collection center, the adoption rate is only about 35 percent. In the southwestern shed, adoption is generally higher, but the negative correlation with distance to milk collection center is even more outspoken: while farmers that live very close to a milk collection center have adoption rates that are statically indistinguishable from 100 percent, this is only 75 percent for farmers that live about 10 km away from the milk collection center. The top panel on the left in Figure 5 shows a similar non-parametric regression, but this time with distance to the nearest market on the x-axis. Markets, generally organized only at particular days during the week, seem less important for farmers that have invested in improved breeds. Furthermore, yield increasing investments in the form of improved animals also do not seem to vary with distance to road infrastructure (not shown). The above suggests that access to a cold chain, where milk can be deposited daily, is an important pull factor for yield increasing technology adoption among smallholder farmers.

As mentioned above, ticks, and the associated East Coast Fever, are an important threat to improved cows. The bottom part of Figure 5 shows non-parametric regressions showing the relation between adoption of improved animals and distance to the nearest veterinary drug store. The pattern suggests that households that live closer to a veterinary drug store have higher adoption rates than households further away. The pattern is less present if we look at correlation between adoption of exotic animals and distance to a vet. This suggests that it is particularly the ticks that are causing havoc, and that other veterinary services such as artificial insemination are of secondary importance. It seem that the ability to obtain acaricides is more important

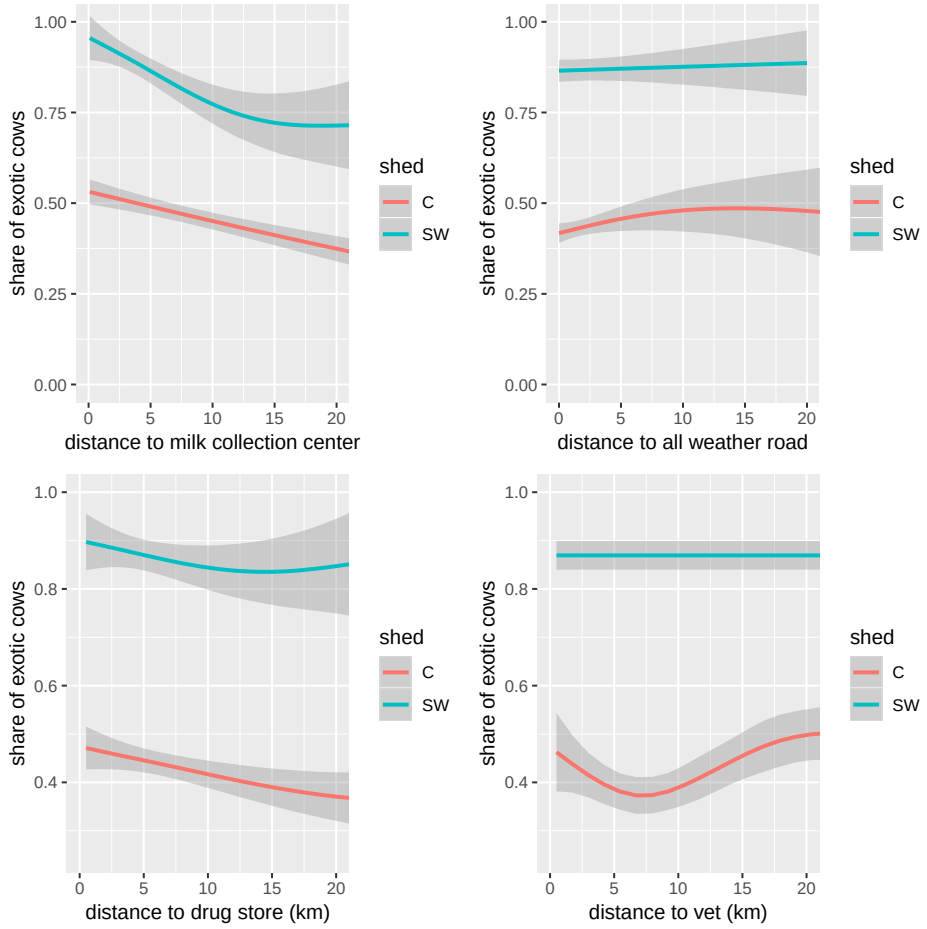


Figure 5: Adoption and distance

in the decision to invest in higher yielding livestock.

In some districts, such as Kiboga and Mbarara, increases at the extensive margin is constrained by high population density. In less densely populated areas, herd size is also constrained by availability of water. The dependence on water is also clearly reflected in production. During the rainy season, cows produce on average 5 liter. This is only 3.7 in the dry season. We also do not find that much difference between local cows and improved animals. An exotic animal produces on average 5.7 liters of milk per day, while a local cow only produces 3 liters. However, improved breeds do not only provide more milk per day, they also start producing milk sooner than local animals.

For a local heifer, it takes about 3 years before it carries the first calf. For an improved animal, this is only 2 to 2.5 years. Furthermore, exotic cows are also in milk for longer periods. An exotic cow keeps giving milk up to 7 months after conception. As a cow gives birth after 9 months, this means an exotic cow is dry for only 2 months. Local cows normally stop producing milk upon conception, or 2 months after conception max. Thus, a local cow will be dry about 7-9 months per cycle. All these factors need to be taken into account when evaluating the profitability.

We also asked to each farm household how many cows were in milk during the last rainy season (march to may 2018) as well as in the dry season (December 2017 to February 2018) Also here, we differentiate between local and exotic breeds. We find farmers have on average 4.3 crossbreeds in milk and 3.7 local cows in milk. The fact that farmer has more crossbreeds in milk while the share of crossbreeds is smaller confirms that exotic cows are longer in milk than local cows. We do not find that these numbers differ between rainy and dry season. Together with the average amounts of milk per cow produced, this enables us to get an idea of the total amount of milk produced per at the household level. We find that the average household produces about 40 liters of milk per day during the wet season and 30 liters per day during the dry season. However, the distribution is severely skewed; corresponding medians are 12 liters and 14 liters. Furthermore, there are large differences between the two milk sheds. Averaging over both rainy and dry seasons, average production per household per days is about 30 liters in the central shed, but almost 55 liter in the southwest. We also asked farmers to estimate how much milk they used to produce 10 years ago. This was only 35 liter in the southwestern milk shed, and less than 20 liters in the central milk shed. Our data suggests that a local cow is about 300 USD and an improved cow is 400 USD. For heifers it is 210 and 260, for calves it is 80 and 105.

Market Participation

During the rainy season, we find that farmer sell on average about 21 liters of milk daily. During the dry season, this is only 13 liter. As is the case for production, sales is also heavily skewed to the right, and median values are 10 liters and 7 liters respectively.

Figure 6 compares the distribution of the share of milk sold in the total amount of milk produced int the rainy season and in the dry season, sepa-

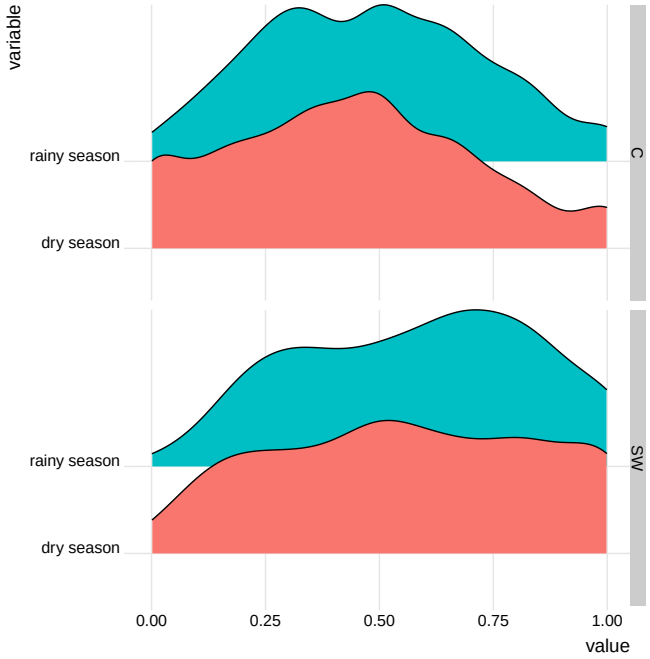


Figure 6: Share of milk sold

rately for the central milk shed (top panel) and the southwestern milk shed (bottom panel). Compared to other agricultural commodities commonly produced by these farmers, such as maize and beans, market participation rates are high (Barrett, 2008). We clearly see that the southwestern milk shed is much more commercialized than the central milk shed. In the rainy season, the modal farmer in the southwest sells three quarters of his milk. Also in the dry season, most of the farmers still sell more than half of the milk they produce. In the central milk shed, we find that in the rainy season most farmers sell between 30 and 50 percent of the milk they produce. During the dry season, the modal farmer sells half of what was produced.

The advent of small traders and transporters, specializing in collecting small amounts of milk using motorbikes or bicycles to deliver to milk cooling centers was also mentioned as an important characteristic of a modern dairy value chain. This change has affected marketing behavior of farmers. Table 1 provides information on market participation behaviour of dairy farmers in our sample, again separately for the central milk shed and the southern milk shed.

We see that milk is widely traded locally between neigbours. In the central milk shed, 31 percent of the farmer indicate that they have sold milk to a neighbour in the last week. Interestingly, in the milk shed that is dominated by a dairy export sector, sales between neigbours in the village is much less common. Here, only 11 percent of the farmers indicate that they sold milk to a neighbour in the last 7 days. In both milk sheds, selling milk at the farm-gate to a middleman is most common. In the central milk shed, 40 percent of households report that they sold to an itinerant trader, while this was one in two farmers in the southwestern milk shed. The majority of these are sales to traders that take the milk to milk collection centers (as opposed to traders that sell to consumers directly, to processors, or to milk shops). About 11 and 14 percent of farmers also report that they use transporters to take the milk to milk collection centers. We find that a significant share of farmers report the sold directly to milk collection centers at least once in the last week, especially in the southwestern milk shed. Direct sales to milk shops is negligible. These results indicate that production is much more for local consumption in the central milk shed than in the southwestern milk shed.

The table also shows, for each trader type, the average number of transactions that were reported in the previous week. In general, farmers transact each day of the week, and there does not seem to be much difference by trader type. In general, cows are milked only once in Uganda. This is done in the morning, and milk should arrive at the cooler within 3 hours, otherwise the milk will not pass the alcohol test. Few farmers also milk in the evening. Often, this milk is used for home consumption, as milk collection centers often cease to accept milk after 11 am.

We also asked with how many different agents of each trader type transactions were made. For instance, we find that in the central milk shed, the average farmer sold milk to about 3 different neighbours in the week previous to the survey. In the southwestern milk shed, this is almost four. In the southwestern milk shed, farmers seem to work with a designated trader. In the central shed, the number of traders used is almost two. In the southwest, farmers that directly supply milk collection centers also usually ship to one and the same. This is different in the central region, where to some extent, farmers seem to try different milk collection centers. Most likely, this is because, in the southwest, collection centers follow prices set by the processors. In the central region, milk collection centers deliver to varying outlets, which may lead to higher variance in prices. Farmers may attempt

to take advantage of this and ship milk to different milk collection centers depending on where highest prices are offered. Formal testing using an exact Wilcoxon Mann Whitney Rank Sum Test confirms that the number of milk collection centers used by the average farmer differs significantly between the two milk sheds (p-value=0.002).

The table also reports prices that were received by farmers conditional on marketing channel, again separately for the central milk shed and the southwestern milk shed. In the central milk shed, we find that highest prices are offered by milk collection centers. We also see that, generally, high prices are obtained when milk is sold to neighbours. This is different from what is generally found for other commodities such as maize or rice, where sales to neighbours usually happens at relatively low price because the farmer needs cash urgently. Prices reportedly received from traders and transporters are significantly lower. This suggests that transport and other transaction costs that the trader or transporter incurs are passed on to producers. In the southwestern milk shed, it seems that, by far, the lowest prices are offered by milk collection centers. We also note that even in the shed that is dominated by a well functioning export industry, sales of milk to neighbours remains a remunerative business.

Generally, commodity trade in rural villages are settled cash on delivery. Even though farmers will often sell to the same trader and trust relationships are important (Fafchamps and Minten, 2001), transactions are often too few and irregular for a more efficient payment arrangement. This is different for dairy value chains, where farmers deal with the same agents on an almost daily basis. Indeed, we see that in the majority of cases, where farmers sell to milk collection centers, either directly or through traders or transporters, payment is weekly or monthly. Recent research has shown that, in the absence of formal savings and credit markets, such infrequent payment also provides a commitment device, enabling farmers to save for bulky expenses (Casaburi and Macchiavello, 2019). For sales to neigbours, direct payment is still the most common arrangement.

Finally, we also report average quantities that were sold in the last transaction for each particular channel. As was to be expected, quantities sold to neighbours are lowest, on average on 5 to 7 liters depending on the milk shed. Amounts sold to traders and transporters are between 15 and 30 liters on average. The pattern also suggests that especially larger farmers engage directly with milk collection centers. For almost all categories, average amounts marketed are higher in the southwestern milk shed than in the central milk

Table 1: Market participation

	neighbour	trader	transporter	mcc	milk shop
			central milk shed		
proportion selling to...	0.31	0.40	0.11	0.10	0.02
average number of transactions per week with...	5.78	6.31	6.52	6.42	6.65
average number within trader type	3.07	1.71	1.50	2.84	3.22
average price (UGX)	906	784	814	928	938
average quantity in last transaction (liters)	5	16	20	27	13
			southwestern milk shed		
proportion selling to...	0.11	0.50	0.14	0.22	0.03
average number of transactions per week with...	7.38	7.18	6.71	6.92	6.50
average number within trader type	3.79	1.17	1.24	1.14	1.10
average price (UGX)	917	730	700	582	710
average quantity in last transaction (liters)	7	24	27	27	22

Note: Based on author's calculations

shed, which is again consistent with the hypothesis that the southwestern milk shed is more commercially oriented than the central milk shed.

Contract

Contracts are important in emerging value chains . Arrangements between seller and buyer are likely to be more common in the dairy sector, where interaction happen often on a daily basis and payments are usually at a lower frequency (eg weekly). In our data, we also find that contracts are, to some extent, important. For instance, we find that from the 1100 farmers that report the be selling either directly to a milk collection center, to a trader or to a transporter, only 40 percent of the producers say that they do not have any arrangement with an agent downstream. About 53 percent of the farmers report that they have an oral agreement. A minority, 7.5, have written contracts.

Figure 7 shows differential rates of technology adoption by farmers conditional on the type of arrangement they have with traders, transporters or milk collection centers. The first technology we consider is again the adoption of cross-bred cows. We find that the average farmers that reports to have generally no arrangement with buyers, 58 percent of their herd consists of improved animals. We see that this share is slightly higher among farmers that report that they have an oral agreement with buyers (63 percent). Finally, among farmers that report to have a written contract with their main buyer, 71 percent of animals are improved.

The second technology we look at are stainless steel milk storage containers. Milk storage containers are very important for preserving the quality of the milk. The alternative that is mostly used, jerrycans, can not be cleaned properly, resulting in high post-harvest losses and health risks. Plastic cans are prone to microbial contamination because their surfaces are easily scratched when cleaning. They are also difficult to clean in unreachable parts in the handle or corners of the plastic containers. In the southwest, milk storage containers are the norm, due partly to the vigilance of the Dairy Development Authority. However, at the farm level, the use of stainless steel milk storage containers is still low. We find that, among farmers that have no arrangements with buyers, only 12 percent uses proper containers for storage. This proporiton increases to 21 percent if farmers have an oral arrangement with the buyer. The share further increases to 36 percent if farmers have a written contract with the client.

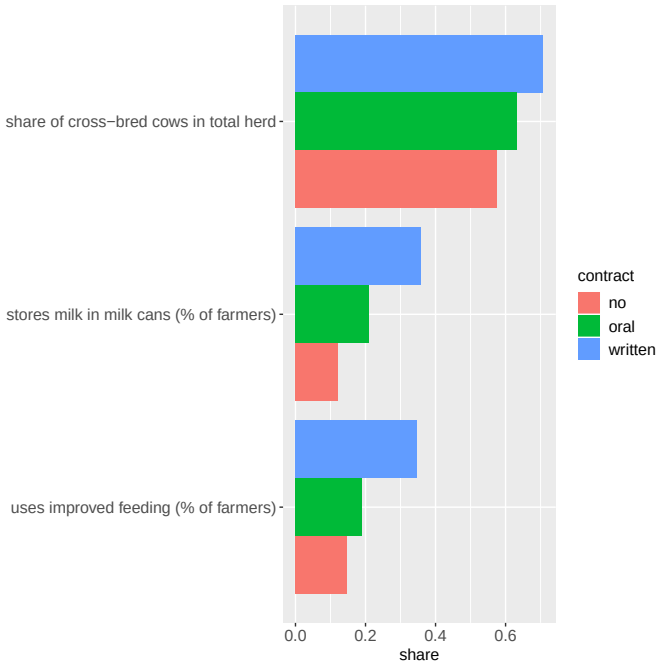


Figure 7: Contracts and technology adoption

Third, we look at innovations in the way which animals are fed. In general, cows just range freely, but more efficient feeding practices such as paddocking or zero grazing with (supplemental) feeding, are becoming more important. We see that among farmers that do not have agreements with buyers, only about 15 percent does not use free range. Among farmers with oral agreements, a slightly higher share is using more modern feeding methods. This share is substantially higher among farmers that report to be having a written agreement with buyers.

Traders and transporters

A second important group of actors in the dairy value chain link producers to other actors downstream, such as milk collection centers, milk shops or processors. Typically, this link consists of individuals that collect milk at the farm gate in the villages using a bicycle or a light Indian or Chinese made motorbike and transporting the milk to the next node in the value chain. We differentiate between two types of such middlemen. First, there are individuals who buy milk at the farm-gate, transport the milk and sell it to actors downstream. A key characteristic of these actors is that they assume ownership of the milk during transportation. This group will be denoted as traders. A second group acts as transport service providers. They receive a fee to transport the milk of the farmer to its destination, such as to the milk collection center. Here, ownership of the milk remains with the producer. These are called transporters. The data shows that almost half of all middlemen we interviewed report to be only transporting milk on account of their clients. About 30 percent report that they buy milk and sell it further downstream. The rest report to be doing both. The relatively high percentage of traders seems to suggest that, in the context of daily recurring transactions, sufficient levels of trust can be built between the farmer and the transporter. The relatively high level of transporters may also indicate credit constraints or an attempt of traders to transfer some of the risk associated with transporting milk to the farmer. For instance, if milk is rejected at the milk collection center, a transporter simply returns the milk to the farmer.

Competition between middlemen is important to prevent them from extracting excess rents form the value chain. We have asked each trader or transporter how many traders or transporters have similar trading activities in their trading area. We find that there are on average almost 14 other

middlemen to compete with. However, the distribution is skewed, with the median being 8 competitors. Still, there is only one person who reports no competition and only 9 that report that there is only one other trader or transporter. Interestingly, using an Exact Wilcoxon-Mann-Whitney Test, we conclude that competition is significantly lower in the southwestern area ($p<0.001$). We also asked each trader to estimate how many traders or transporters had similar trading activities as yours in your trading area at the time they started trading, which we use to calculate the average yearly increase in competition. We find that between the time the average middleman started his business, the number of competitors has increased yearly by about 18 percent. There is no difference in increase of competition over time between the two areas.

Traders and transporters are typically men. Also, compared to other actors in the dairy value chain, they are very young; on average 30 years old. Trading or transporting is indeed typically an activity for young men who are often forced to look for off-farm activities due to persistent record population growth rates in Uganda. Most traders and transporters are independent and work for their account, although in the southwestern milk shed there is also a sizable proportion of traders that work for a cooperative milk collection center (14 percent). Middlemen are generally recent to the business. Traders and transporters in the central shed have only 3 year of experience and those in the southwest have on average 4 and a half years of experience. However, it should be noted that these low figures might suffer from survivor-ship bias, as middlemen that go bankrupt disappear from the sample if they become farmer again. Most middlemen specialize in milk.

Table 2 gives some statistics on volumes and associated values that are handled by traders and transporters. The top panel gives details on the central milk shed, while the bottom panel provides corresponding statistics for the southwestern milk shed. We start by looking at how many farmers are visited on an average day by a trader and by a transporter. Traders seem to visit slightly more clients in a given day in the central region. In the southwest, the traders visit substantially more farmers, up to 12 on average in the rainy season. In terms of liters procured, average range from 100 liters during the dry season in the central milk shed to as much as 550 liters handled by traders during the rainy season in the southwestern milk shed. Given that the average transport capacity is about 164 liters in the central region and almost 200 liter in southwest, this means that in the dry season in the central milk shed, transporters make trips with milk cans that are only half full, while

Table 2: Volumes and value traded

central milk shed		
	traders	transporters
	dry season	
number of clients visted per day	6	5
liters procured per day	109	107
price received per liter	1,053	1,060
value of traded milk per day	115,229	113,643
	rainy season	
number of clients visted per day	8	6
liters procured per day	201	182
price received per liter	704	733
value of traded milk per day	141,108	133,119

southwestern milk shed		
	traders	transporters
	dry season	
number of clients visted per day	11	8
liters procured per day	303	348
price received per liter	994	1,017
value of traded milk per day	301,455	353,512
	rainly season	
number of clients visted per day	12	8
liters procured per day	507	489
price received per liter	551	514
value of traded milk per day	279,574	251,081

Note: Based on author's calculations

in the southern milk shed during the rainy season, traders make more than 2.5 trips to the milk collection center, milk shop, or processor.

The price paid for milk to traders and to transporters is similar. More interestingly, during the dry season the price per liter is about 1,000 UGX, and there seems to be no difference between the central and southwestern milk shed. During the rainy season, prices decrease dramatically. In the central region, prices are about 40 percent lower than in the dry season. In the southwestern milk shed, prices are only about half of what they are in the rainy season. This is surprising, as one would assume that processors that process milk into products with longer shelf life would reduce inter-temporal price volatility.

Traders and transporters have also experienced substantial technological change over the last decades. First, the advent of mobile telephones with coverage even deep in rural areas has had a profound impact on the agricultural sector, particularly on agricultural markets (Nakasone, Torero, and Minten, 2014). Second, Uganda experienced a rapid increase in the import of Indian motorcycles. While these so-called *boda boda's* were initially confined to the capital Kampala to transport individuals, they have now also penetrated rural areas, where they are also used to transport agricultural commodities. Third, the DDA has sensitized both farmers and traders on the importance of hygiene in the entire dairy value chain. In particular, it is obligatory to use the special aluminum milk cans when milk is stored and transported, as the alternative that is used, jerrycans, can not be cleaned thoroughly. Traders use sieves to keep cow hair and other foreign material out of the milk.

Figure 8 compares traders in the central and southwestern milk sheds in terms of assets related to the above three technological innovations. We see that 90 percent of traders have at least one mobile phone, and there is no difference between the two milk sheds. In the central region, 71 percent of traders reports to be using a boda boda for transporting milk; in the southwestern milk shed, this is almost 80 percent. For farmers that reported to be using a boda boda, we further asked if they had adapted they motorbike for milk transportation. Generally, this means that iron bars are welded on the motorbike to easily fit the milk cans or jerrycans. About half of the traders adopted their motorbike, and this is only slightly higher in the more commercialized milk shed. The largest difference between the two milk sheds is found for the use of milk cans (generally cans of 50 liters). We find that in the central milk shed, only about 40 percent of traders uses aluminum milk cans, while this is 92 percent in the southwestern milk shed. At the same time, the use of sieves is slightly higher in the central region. Virtually all traders in the southwestern milk shed keep records.

Milk collection and bulking centers

Another key link in the dairy value chain in Uganda is the milk collection center. Milk collection centers are structures that have the infrastructure in place to bulk and cool the milk as it waits for further transport. Generally, this is the start of the cold chain. Often, these centers are located in rural

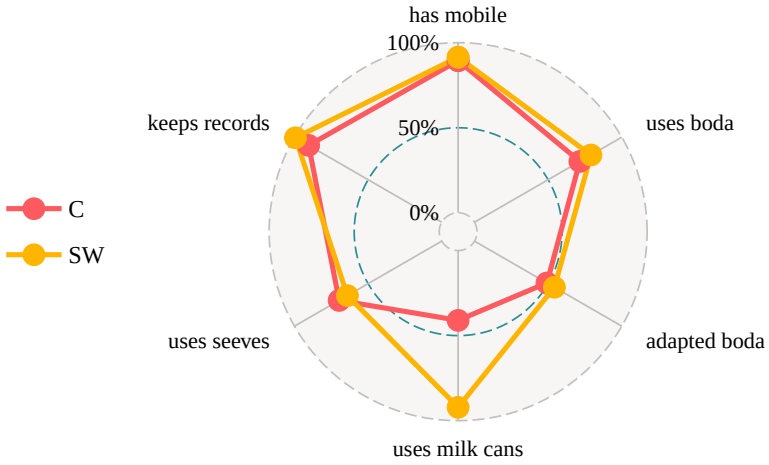


Figure 8: Trader assets

areas where production of milk is high. At the same time, it is also important that milk tankers can reach the center to further transport the milk down the value chain. Most centers have

In the last decade, many milk collections centers have been established. In the central milk shed, there are, according to data obtained from district officials, 18 milk collection centers in Kyankwanzi, 19 in Kiboga and about 20 in Nakaseke. In Masindi, there are only 5. In the southern milk shed, there seem to be many more milk collection centers: in Kiruhura district alone, there are more than 160 cooling centers, often with more than one cooler. The proliferation of milk collection centers in the southwestern shed is also reflect in the farm the farm level survey data. In the central milk shed, average distance to an milk collection center is 10 km, while this is only 5.4 km in the southwest. In the central milk shed, most of these are

Table 3: Prices and volumes handled by milk collection centers

	central shed	southwestern shed
	dry season	
liters collected per day	1693	2558
capacity used (%)	31	57
price offered (UGX)	1105	1027
	rainy season	
liters collected per day	3294	5342
capacity used (%)	62	94
price offered (UGX)	766	558

Note: Based on author's calculations

privately owned (about 60 percent). In the southwestern milk shed, most milk collection centers are cooperatives.

Table 2 shows statistics on volumes handled and price in both rainy and dry seasons and by milk shed. The average milk collection center has a capacity of about 5,600 liters, and there is no difference between the two sheds. The table shows that there is considerable under use of this capacity in the dry season, especially in the central milk shed, where tanks are on average only 30 percent full. Even during the rainy season, the average milk collection center in the central milk shed is only filled 60 percent. Only in the southwest, there is more milk than milk collection centers can handle. Here, 75 percent of all milk collection centers we surveyed reported they are operating at full capacity during the rainy season. This is also clearly reflected in the prices that milk collection centers pay for milk.

Another interesting difference between the central and southwestern milk shed is in terms of ownership of the milk collection centers. As mentioned above, a much larger share of the milk collection centers in the southwest are cooperatives. Cooperatives may emerge as an institutional innovation to address particular problems within the value chain. For instance, as many individual producers supply the milk collection center, traceability becomes difficult and milk collection centers have to rely on the collective reputation of the product they supply. Winfree and McCluskey (2005) point out similarities between collective reputation and a common property resource in which asymmetric information about the quality that is delivered leads to over extraction from the stock of reputation. A cooperative organization of the milk collection center may be an endogenous response to the challenges

related to collective reputation and quality[2].

We do indeed find that among cooperatives, the proportion of milk collection centers that responds that they were ever unable to sell their milk is lower than among milk collection centers that belong to individuals or processors, which may be a result of better quality control upstream. Furthermore, using data from the trader survey, we find that traders that report to supply to cooperative milk collection centers pay more attention to milk hygiene: they own significantly less jerrycans and are more likely to own sieves. They also are more likely to use aluminum milk cans that traders that supply privates collection centers, but the difference disappears after controlling for milk shed.

Figure 9 shows correlations between cooperative membership and various actives that may affect hygiene in dairy farming at the farm household level. The graphs show the estimated difference between farmers that are a member of a cooperative and farmers that are not a member of a cooperative. It also provides confidence intervals for the estimated coefficients. The coefficients are estimated using linear probability models and controls are included for milk shed, education level of the household head and whether dairy farming is considered the main business of the farm household. Results suggest that farmers that belong to a cooperative are 18 percentage points more likely to use aluminum milk cans to store their milk than farmers that are not a member of a cooperative. Furthermore, we see that farmers that are associated to dairy cooperatives are more likely to use aluminum buckets. A significantly higher share of members also report using udder cream. We do, however, not find that cooperative membership is correlated with the likelihood that farmers wash their hands with soap before milking, that udders are washed and dried before milking as recommended, or that cows are milked in a designated milking parlor.

In the event of a weak services sector, value chain actors may try to fill the gap by providing the services themselves. For example, in the absence of efficient public agricultural extension and advisory services, exporters may organize training to farmer to make sure that the products they deliver meet sanitary and phytosanitary standards. In the context of poorly functioning credit market, processors may provide credit to farmers such that they can

[2]It should be noted, however, that cooperatives often struggle with governance issues, which may affect its effectiveness. For instance, in Ethiopia, Francesconi and Ruben (2012) do not find a significant effect of cooperative membership on milk hygiene, and a negative impact on milk quality.

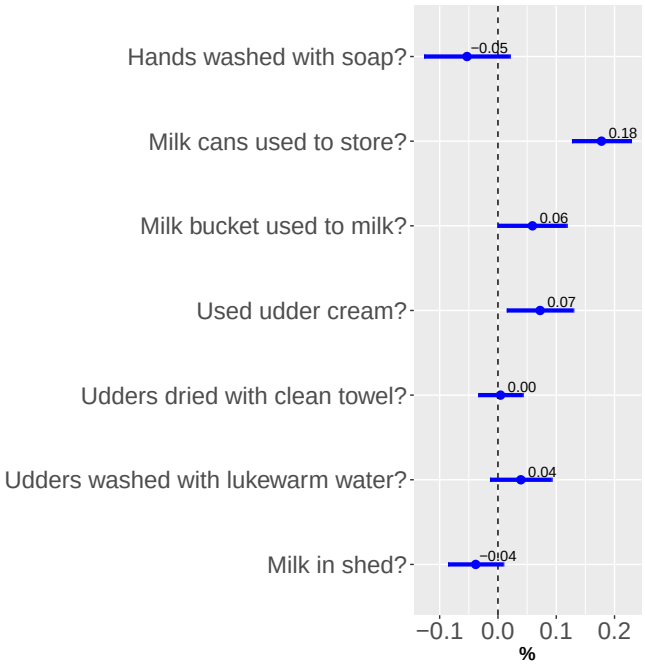


Figure 9: Cooperative membership and hygiene

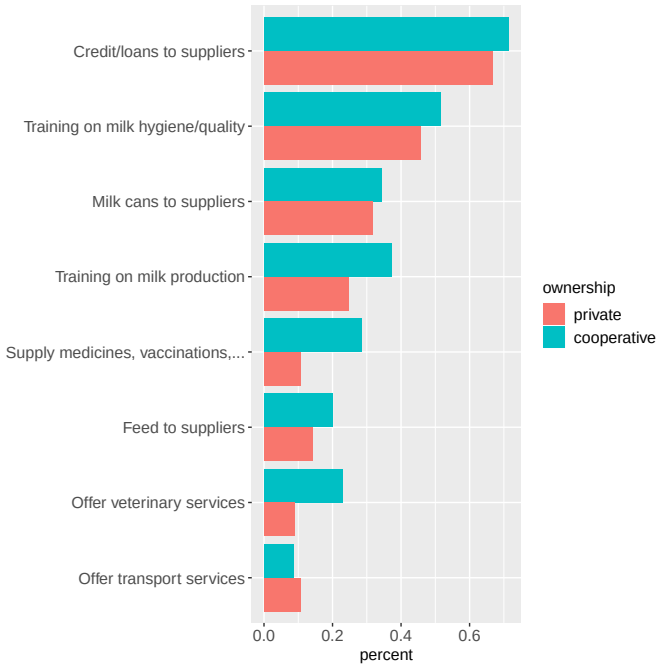


Figure 10: Services offered by milk collection centers

purchase inputs during planting. In the case that inputs are not available at the right time, processors may even go one step further and directly provide inputs.

In Figure 10, we check if milk collection centers provide a range of services to smallholders. We differentiate again between cooperative milk collection centers and centers that are privately owned. We see that milk collection centers in general do much more than just bulking and cooling the milk, especially if they are cooperatives. For instance, we find that more than 70 percent of milk collection centers also provide credit to their suppliers. About 50 percent of cooperatives also organize training on milk hygiene. More than 30 percent provide milk cans to suppliers. We also find a few big differences between cooperative and private milk collection centers. Especially for animal health related matters, many cooperatives report that they assist their members: almost 30 percent of cooperative milk collection centers report they are supplying medication and provide vaccination services and more than 20 percent have a vet on call. Private milk collection are slightly more likely to offer transport services than cooperatives.

Processors

These days, Uganda has quite a few dairy processing companies. According to data obtained from the Dairy Development Authority, there are six large scale processors in Uganda with a capacity to process more than 100,000 liters per day[3]. Most of these are located in the Southwestern milk shed. GBK Dairy Products Limited is the oldest in Mbarara, with a capacity of about 100,000 liters per day. Pearl Dairy Farms Limited is the largest. Founded in 2013, the plant can currently process up to 800,000 liters of milk per day. However, during the dry season the factory runs at less than 40 percent of its capacity, and even in the rainy season they only reach about 80 percent. The second largest processor in the southwest is Amos Dairies, with, according to the DDA information, a capacity of processing 400,000 liters per day. Lakeside, founded in 2014, currently only has a capacity of 50,000 liters per day but plans to expand to 100,000.

Brookside dairy is also still a large player, but the latest figures we could find still put it way behind Pearl in terms of processing capacity (560,000 liters per day). Located in Kampala, the processor sources milk from different areas. About 40 percent of the milk collection centers in the central region that supply processors take their milk to Brookside. Jesa is another large processor with processing facilities in Busujju in Wakiso district. It is currently processing 200,000 liters of milk per day. Jesa supplies most of the milk in Kampala in the form of pasteurized milk packaged in plastic bags.

Many of these processors produce for both the local market and the export market. This diversification is due to the fact that the local market is still very informal and milk from Uganda is competitively prices. At the same time, local milk consumption of processed milk in Uganda, particularly in Kampala, is increasing rapidly. Pearl Dairy is by far the largest exporter. About 90 percent of what they produce is exported. In 2017, the company exported worth 55 million USD, about 42 percent of total export. However, recently, the company has launched its local brand called LATO milk, which is becoming very popular in Kampala. Jesa also exports to Kenya. Even smaller players such as Lakeside sell UHT to South Sudan and Kenya.

In general, these large processors struggle to find sufficient milk. Processor use a variety of models to increase the milk procurement. For instance,

[3]However, we found substantial differences between capacities reported in the DDA data and capacity reported by the processors we interviewed. This may indicate that processors are rapidly increasing capacity.

Pearl Dairy Farms Limited mainly works with cooperatives or directly with farmers. They have recently started building their own milk collection centers, opening 6 more this month and then 10 more in the first quarter of 2019. They have also started declaring a 15 day price so it is transparent to all suppliers. Furthermore, a 2 certificate system was introduced: All deliveries receive a certificate for amount and for quality, then it is accepted and payment is calculated. This mode of working contrasts with what Lakeside reported. They mainly work with larger traders who collect milk with trucks from milk collection centers. They describe the sector as very unorganized with little contracting and characterized by fierce price competition. At some point in time, they experimented with collecting milk using their own trucks, but this proved to be too expensive. Jesa dairy limited still has a large number of animals themselves to assure sufficient quantity and quality. Brookside, because of its history as a state parastratal, owns many milk collection centers through which milk is procured.

One of the main challenges that processors face is the lack of a mature industry base in Uganda that supplies secondary inputs such as packing material. For instance, one processor told that the price of milk is about 1,300, but that the cost of packaging it is about 1,000 shilling, as UHT milk needs specialized packaging material. Milk in Kampala sells for about 2,400-2,500 UGX Furthermore, expertise on milk processing is scarce in the country. Often, experts have to be flown in from Kenya or India to fix processing machinery. Processors also see the large informal sector as a threat to the sector. They say that it prevents them from securing sufficient milk due to the fact that it undercuts the price and that it also provides a health hazard.

In addition to these large processors, there are also 5-10 medium scale processors. Finally there are many small scale processors that produce yogurt, cheese, ice-cream, butter or ghee.

Conclusion

In this paper, we provide a descriptive analysis of dairy value chains in Uganda. Comparing an area that is generally oriented towards dairy processing for export to an area that is more oriented towards to local market, we identify key differences in technologies used and institutional organization among the different value chain actors. We do so using primary data collected among 1,600 producers of various scale, 900 traders and 100 milk collection

centers. We supplement our analysis of primary data with secondary data from the DDA and with qualitative data obtained from two processors.

We describe a reasonably modern dairy value chain in the southwestern milk shed, with farmers supplying substantial amounts of milk to traders that specialize in collecting milk at the farm gate and bringing it to milk collection centers or directly to the processor. There is almost universal adoption of crossbreeds and producers have daily transactions with one and the same buyer. In the area that is more oriented toward the local market, the adoption of crossbreed cows is increasing, but still only one in two cows is improved. More is sold to neigbours, and producers seem less loyal to traders and milk collection centers.

Seasonality is an important feature of the sector in Uganda. This seasonality may also help explain the paradox that despite the fact that processors produce below capacity, prices collapse during the rainy season. The seasonality is expensive for milk collection centers, because they can only run at full capacity for a few weeks per year. This may result in under investment in capacity in areas where milk production is highest. During the rainy seasons, tanks fill up quickly, depressing prices. The same arguments likely hold for traders. During the rainy season, there is probably shortage of traders and farmers compete for space in the milk tanks of the traders. Seasonality is exacerbated by climate and a lack of a feeding industry. Zero grazing where cows are fed using silage and hay using the dry season and access to water from dams is likely to increase production also during the dry season, attracting more capacity to the area.

Processors also warn that the large informal sector is a threat to the industry. Often, people prefer the raw milk because they thing processed milk is diluted. Milk collection centers that are cooperatively owned appear to be an effective way to guarantee quality. At the same time, the fact that the DDA is also much more active in the southwestern milk shed may indicate that a repressive approach is needed for some actors in the value chain.

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