Domestic versus export-led agricultural transformation: Evidence from Uganda's dairy value chain

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Abstract

Driven by increased demand from both local and export markets and facilitated by far-reaching liberalization and privatization policies, the dairy sub-sector in Uganda has undergone significant changes in the last decade. With a comparative advantage in milk production, the southwest of Uganda has started to attract considerable Foreign Direct Investment (FDI) in processing capacity, mainly targeting the export market. As a result, processing capacity increased five-fold and dairy became Uganda's third most important export product, coming from negligible amounts a decade earlier. In this study, we use observational data collected at different nodes within the value chain to compare the structure of the chain and the roles and economic activities of different actors between export-led value chains and value chains that cater for the local market. Doing so allows us to identify the technological and institutional innovations that both result from the emergence of export-led dairy value chains and at the same time drive further upgrading. Our analysis underscores the importance of milk collection centers, which often take the form of farmer cooperatives, in providing many of the support services that enable other actors in the value chain to produce sufficient milk, and maintain milk sanitation levels necessary for an export sector to emerge.

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1 Introduction

Agricultural value chains are rapidly changing in developing countries, also in Africa (eg. Reardon et al., 2012, 2015; Jayne, Chamberlin, and Benfica, 2019), but the nature and causes of these changes – and especially the role of Foreign Direct Investment (FDI) – are not well understood. FDI has been shown to have been a major diver of the upgrading of value chains in a number of developing countries, in particular through relaxing of capital constraints and the transfer of technology and know-how (e.g. Reardon and Barrett, 2000; Blalock and Gertler, 2008; Blomström and Kokko, 1998; Stokke, 2009). In the case of the dairy sector, investments by multinational companies can lead to important and quick upgrading of value chains (e.g. Farina, 2002), sometimes through the set-up of vertical integration mechanisms (e.g. Dries et al., 2009; Dries and Swinnen, 2004). Vandeplas, Minten, and Swinnen (2013) have further shown in India how farmers supplying dairy multinationals are more efficient than farmers in the cooperative and traditional value chains.

However, evidence on this phenomenon is still limited in developing countries, especially so in Africa. In this paper, we will look at FDI, modernization, and innovation in the case of dairy value chain transformation driven by local and export incentives in Uganda. Uganda is an interesting case as the dairy value chain has undergone substantial and rapid changes as seen by a number of indicators. First, national production has increased by more than 50 percent in the last decade, from 1.4 to 2.2 billion liters annually. Second, there has been quick modernization in dairy value chains through large investments in processing plants – for the large majority through FDI – leading to a five-fold increase in processing capacity (to about 2.5 million liters per day) over the last decade. Third, while a decade ago, Uganda imported more dairy products than it exported and there was little hope that this would change (Shepherd, 2016), in 2018 dairy had become Uganda's third most important export product. Fourth, while good recent data are lacking, available household surveys suggests that dairy consumption has increased substantially: As regional poverty has decreased dramatically, higher incomes resulted in rapidly increasing consumption of dairy products, which are known to be highly income elastic (Colen et al., 2018; Delgado, 2003). Especially in cities, consumers are confronted with an increasing availability of various dairy products such as milk, yogurt and ice cream in both informal shops and emerging supermarkets, and consumers become increasingly aware of the health benefits of dairy products (Ruel et al., 2017; Francesconi, Heerink, and D'Haese, 2010).

Interestingly, due to a combination of agglomeration effects and a compara-

tive advantage in milk production, the transformation was more outspoken in the so-called southwestern milk shed. Most of the FDI was concentrated here, and as a result, this area has become tightly integrated in a global export-led value chain, with large processors sourcing raw milk from farmers and converting raw milk into complex products with a long shelf life, such as Ultra High Temperature (UHT) treated milk and powder milk. At the same time, a nearby area similar in agro-ecological conditions and with similar aggregate production levels and referred to as the central milk shed, has become the main supplier for dairy products for the local market.

The co-existence of both export-led and domestic market-led value chains for the same commodity in a single country provides an interesting case. Generally, studies on value chain transformation in developing countries analyze either export-led chains for commodities with little or no local market (Maertens and Swinnen, 2009; Maertens, 2009; Minten, Randrianarison, and Swinnen, 2009) or domestic chains (Minten et al., 2016; Janssen and Swinnen, 2019). This makes it difficult to identify which innovations are most important in both driving and enabling value chain upgrading, as the context may be too dissimilar. In this study, we will compare value chains from the southwestern milk shed to value chains from the central milk shed and document differences in key technological and institutional dynamics. However, we acknowledge that defining inclusion in export-led value chains solely on the basis of location may not be completely accurate. Indeed, there may be dairy farmers located in the southwestern milk shed that supply only to the local market, just as well as there are likely to be traders operating in the central milk shed that ship to processors that export. We therefor also define an alternative indicator that captures inclusion in modern value chains.

Our study mainly relies on primary data, supplemented with data from secondary sources. The primary data was collected at different nodes in the value chain. Upstream, we interviewed farmers that produce milk, most of it for the market. These farmers generally sell raw milk at the farm gate to traders, the second category of actors we collected data from. Traders and transporters in turn, ship this unprocessed milk mostly to milk collection centers, the third category of actors we interviewed. Another important actor in the dairy value chain is the processor, who sources milk mostly from milk collection centers. We collected qualitative data from two processors.

We find that milk collection centers are central to value chain upgrading. They are key in guaranteeing processors the quantities and quality of milk they need to compete on the international and modern local market. At the same time, they provide a stable market for producers (either directly or indirectly through mid-

dlemen). But these centers appear to do much more then just bulking and chilling milk for further transport. They also provide a range of services to farmers that enable and sustain additional innovations upstream. For example, milk collection centers also assist farmers with medicines and vacations, enabling farmers to adopt improved cross-bred cows that produce more milk but are also much more susceptible to pests and diseases. They are also important for quality assurance. Often they provide milk cans to their suppliers. Many milk collection centers are cooperatives, which may be an effective organizational form to safeguard collective reputation in cases where traceability is hard and provide loyalty when side-selling is an attractive option. We further observe a shift from informal to formal value chain financing and the adoption of rotational grazing practices.

In addition to the fact that this study allows for the direct comparison of two different types of value chains for a single commodity and in the same context, this study is also important for the following reasons. First, with almost 700 small traders interviewed, our study provides evidence on the behavior of a group of value chain actors that are hard to capture and often misunderstood (Sitko and Jayne, 2014). Second, we collected data on almost 100 milk collection centers, an institution that is specific to the sub-sector and key to its development. In most other value chain studies, the sample size for similar value chain actors is generally much lower[1]. Finally, while there is a substantial gray literature on dairy value chains in Uganda, most of these rely on qualitative data and are limited in terms of representativeness. Our study thus provides an important contribution to understanding the dairy sub-sector in Uganda.

The rest of this article is organized as follows. The next section uses secondary data to highlight the drivers behind the transformation of the dairy sub-sector. We point out potential demand side drivers and explain how policy reforms created an enabling environment that attracted considerable foreign direct investment. We then describe the structure of the value chain and visualize how raw milk flows through the value chain. We then turn to important innovations that we observe within the value chain. We first describe differences between the export oriented milk shed and the area that is supplying the local market. We identify milk collection centers as an important innovation, and also look at technology adoption among farmer, dynamics in value chain financing, feeding practices, and quality assurance. We then construct an indicator of integration into modern dairy value chains and compare a range of innovations within this chain to traditional con-

[1]For example, Minten et al. (2014) surveys cold storage facilities in the potato value chain in Bihar, India. However, they only interviewed 27 storage owners.

figurations using more formal models in an econometric analysis. A final section concludes.

2 Drivers of dairy value chain transformation

The dairy sub-sector in Uganda has grown substantially. According to the Uganda Dairy Development Authority, annual milk production has increased from 1.4 billion liters of milk in 2006 to 2.2 billion liters in 2017/2018. The expansion of the sub-sector is driven by an increase in demand, both from within Uganda as well as from abroad. At the same time, pro-market policy reforms encouraged investment in the sub-sector.

2.1 Demand factors

2.1.1 Local consumption

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 four different waves of the Uganda National Household Survey (UNHS). We see that according to this data, as recent as 2001/02, the average Ugandan consumed only about 12 liter of milk per person per year. At that time, consumption in rural and urban areas was virtually the same. By 2012/13, average consumption per capita had doubled. The figure shows that most of the increase in milk consumption is due to an increase in demand in urban areas, reaching 33 liters per capita per year in 2012/13. In rural areas, milk consumption seems to fluctuate between 10 and 20 liters per capita per year.

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 liquid milk, is very popular[2]. Furthermore, in rural areas, butter (or ghee) and yogurt consumption is taking off. Unfortunately, the UNHS only records milk and ghee consumption; there is no separate category for *bongo*. 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 amounts consumed are only slightly lower than those of

[2]Often, milk that can not be sold is processed into bongo.

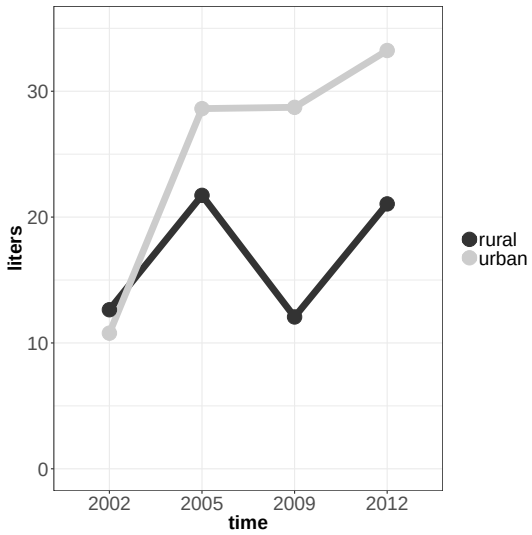

Figure 1: Consumption of liquid milk (liters per capita per year; source: Uganda National Household Surveys, multiple years)

milk. As a result, the consumption of dairy products is likely to be substantially higher than what is reported in Figure 1.

2.1.2 Export sector

Not only national consumption has increased. Over time, and especially since 2014 after the establishment of various processing plants in the southwestern milk shed, dairy exports have increased exponentially (Figure 2). The latest available data, obtained from the Dairy Development Authority, show that US$ 130 million worth of dairy products have been exported in 2017. The Dairy Development Authority reports that almost half of the export value, US$ 55 million, was exported by a single processor (See Table 1). This processor exports mostly milk powder to countries on the Arabian peninsula, but also to Nigeria. About 20 percent of the total export value is exported to mostly neighboring countries through Brookside Ltd. Birunga Dairies Industries, located in the Southwestern tip of Uganda (and outside our study area), exports about US$ 18 million worth of milk to the Democratic Republic of Congo, Burundi and Rwanda. Amos Dairies Ltd focuses on casein exports to the United states (US$ 11 million). Smaller processors such as Lakeside Diaries Ltd. specialize in other locations such as South Sudan.

The success of dairy as an export commodity came as a surprise. For instance,

Table 1: Largest exporters in Uganda

Company	export value (million USD)	share in total	exports to	products
Pearl Dairy farmers Ltd	55	42	COMESA countries, West Africa, India, Nepal, UAE	milk powder
Brookside Ltd	25	20	Indian Ocean Islands, East Africa, Rwanda, Burundi	UHT milk
Birunga dairies industries	18	14	DRC, Rwanda, Burundi	UHT milk
Jesa farm dairy Ltd	15	11	Kenya	ESL (extended shelf life) milk
Amos	18	14	US	caseine
Total	130	100		

Note: Based on data obtained from the Dairy Development Authority

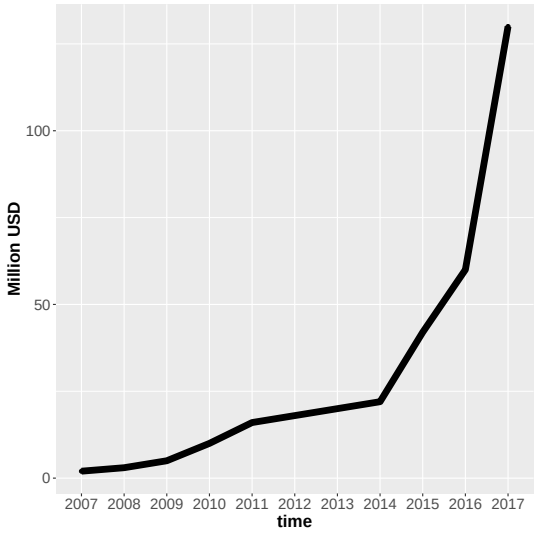

Figure 2: Export of dairy products (in millions USD; source: Dairy Development Authority)

Shepherd (2016) was hesitant about the future of the dairy sub-sector in Uganda as a strong export oriented sector, pointing out that informality of relationships constrained the development of contractual interactions, resulting in supply uncertainties at the level of the processors. Dairy was also not considered a priority sector for export by the government, yet today dairy has become the third most important export product, after coffee (US$ 555 million) and fish (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.

2.2 Institutional environment

The transformation of the dairy sub-sector in Uganda was also driven by a range of policy reforms. In the past, the (formal) dairy sector was heavily centralized, and all milk needed to pass through the National Dairy Corporation, a parastatal 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 was

established to create an enabling environment for the sector and assumed the dual role of both promoting dairy 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 (SAL) Ltd. As part of the deal, SAL also acquired all the coolers that were part of the cold chain. This left smallholder milk producers with few options other than selling to SAL at very low prices (Agriterra, 2012).

This monopoly did not last long. The government, with a president hailing from one of the most important milk producing areas in the country, actively promoted the development of the sector by encouraging dairy farmers to unite in cooperatives and set up their own milk collection centers. Furthermore, Uganda facilitated international trade relationships in different ways. Through various tax breaks (as well as giving free land), FDI into dairy processing capacity was lured in and they now make up the large majority of processing capacity in the country. Some of these investors were attracted by low production costs in Uganda but they were also interested due to problems for their operations in other countries. For example, Amos reportedly invested in Uganda given price wars in liquid milk markets in India leading to low margins in their domestic market (Kesireddy, 2015). The creation of the East African Community further meant easier trade with neighboring countries and had as a consequence that milk, which can be produced relatively cheaply in Uganda, was in high demand in neighboring countries, Kenya in particular. That said, there are still substantial policy related uncertainties. Tanzania, for example, keeps protecting its local dairy market with large import duties. Furthermore, during an extended drought in 2017, Kenya temporarily introduced duties on imported milk.

Uganda's privatization push also affected livestock farmers directly. Traditionally, livestock farmers in the cattle belt, a semi-arid area that stretches from the southwest all the way to the northeast, were nomadic pastorals. They roamed across communal land, seeking forage and water. Especially for the Ankole tribe of southwestern Uganda, livestock is an important part of their cultural identity, and prestige is derived from the size of the herd. The herd was depended upon for subsistence, and only if cash was needed, occasionally animals were sold. However, due to privatization, communal lands were fenced off, depriving nomadic farmers from grazing land and, more importantly, water sources. This gradually led to a shift away from livestock ownership as a store of wealth, toward a more commercially oriented, sedentary livestock sub-sector, where maximization of productivity of cattle became the main objective (Kisamba-Mugerwa, Pender,

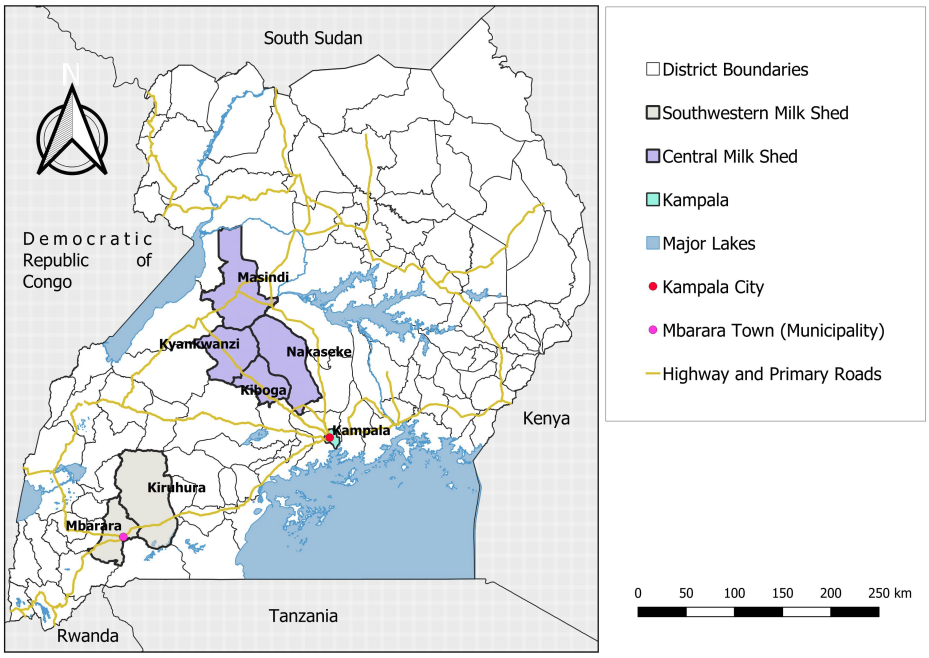

Figure 3: Map of Uganda and data collection sites

and Kato, 2006).

3 Structure of the value chain

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 the central milk shed comprising of the districts Kyankwanzi, Kiboga and Nakaseke, are the two most important milk sheds (see Figure 3). While the agro-ecological conditions and farmer types are pretty similar between the two sheds, 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 base for the local dairy value chain that supplies Kampala to the central milk shed, leading to 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 rural areas. Small traders and transporters collect milk in villages at the farm gate daily, and transport this to milk collection centers using bicycles, motorbikes, or sometimes pick-up trucks. Milk collection centers bulk the milk in coolers for further transport to processors or consumer markets. There are also a range of actors that provide services related to the value chain, such as veterinary services, or sell inputs such as feeding supplements. Finally, milk is consumed in different forms and by 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 extracted from milk (glue, paint,...).

We collected survey data on three value chain actors. In total, we collected data on 1,600 milk producers, 700 traders and 100 milk collection centers. We started by selecting 14 subcounties from six districts (Mbarara, Kiruhura, Kyankwanzi, Kiboga, Nakaseke and Masindi). These subcounties were selected to reflect geographic dispersion of actors within the value chain. We proceeded with a two stage random sampling strategy, where first villages were selected with probability proportional to village size. In each selected village, we then consulted village household lists to randomly select farmers. The number of households selected within each village was again proportional to the total number of households residing in the village. Milk collection centers were selected through simple random sampling from the list of milk collection centers in each subcounty obtained from the DDA. Finally, traders and transporters were sampled using a systematic sampling technique where enumerators interviewed the "nth" trader that came to deliver milk to the center. Data in Kyankwanzi, Kiboga, Nakaseke and Masindi was collected in September and October 2018. Data in Mbarara and Kiruhura was collected in December 2018.

The data can be used to get an idea of the structure of the value chain, and how it differs between the central milk shed and the southwestern milk shed. 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 at the onset of the dry season). Most of this milk, 40 liters, is sold to traders. Farmers also sell 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)[3]. Finally, about 10 liters is sold directly to neighbours. Farmers in the

[3]As will be explained later, we differentiate between traders, who acquire ownership of the milk, and transporters, who provide the services of transportation against a fee.

southwestern milk shed sell double of what farmers in the central milk shed bring to the market (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 southwestern milk shed. Small quantities of milk are also directly sold to neighbours (6 liters) and to milk shops in the village or 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 villagers also seems not uncommon in the southwest (5 liters). Doing the same for transporters, we find that in both milk sheds, transporters deliver most of the milk to milk collection centers.

In the next step, we estimate how the quantities collected by milk collection centers (66 liter in the central shed and 122 liter in the southwestern shed) are disposed of. In both sheds, most milk goes to processors. 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). These traders generally take milk to the processor Brookside Ltd. in Kampala. 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). Finally, fierce competition for supplies in the southwest means that processors will also buy non negligible amounts of milk directly from traders (8 liters).

4 Innovations in dairy value chains

In this section, we document various innovations that characterize the dairy value chain transformation. We want to stress the endogenous nature of these innovations, where a particular innovation may both drive value chain upgrading and at the same time be a result of it. For example, 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 (Suri, 2011). Integration into modern value chains may make new technologies profitable for various reasons. The endogenous value chain dynamics make it difficult to identify causal relationships and so one should avoid attributing causality to the associations we uncover in the following sections.

In this section, we simply compare actors located and operating in the export oriented southwestern milk shed to the central milk shed to assess the importance of various innovations in modernizing the dairy value chain. We look in turn at milk collection centers as both actors and innovations, at technology adoption by farmers, at value chain financing, at feeding and water, and at sanitation throughout the value chain.

4.1 Milk collection centers

Milk collection centers are central actors in modern dairy value chains. They consist of structures that have the infrastructure in place to bulk and chill the milk as it waits for further transport. Generally, milk collection centers form the start of the cold chain. Often, these centers are located in rural 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 power their coolers using generators.

While milk collection centers have been in use for some time, the innovations lies in their increasing availability and scale, their changing role as midstream service providers, and the organizational form as farmer cooperatives. We discuss each in turn.

In the last decade, many new milk collections centers have been established,

especially in the southwestern milk shed[4]. In the central milk shed, there are, according to data obtained from district officials, about 60 milk collection centers. In the southwestern milk shed, there seem to be many more milk collection centers: in Kiruhura district alone, there are more than 160 centers, often with more than one cooler. The higher density of milk collection centers in the southwestern shed is also reflected in the farm level survey data. In the central milk shed, average distance to a milk collection center is 10 km, while this is only 5.4 km in the southwest.

Using the data we collected from a sample of milk collection centers, we can get a better idea of the evolution of milk collection centers over time. In particular, we asked when the milk collection centers were established. This can then be used to graph, separately for the southwestern and central milk shed, the share of milk collection centers that were established in each year over the last decade (Figure 4). The figure suggests an acceleration in the establishment of new milk collection centers in the southwestern milk shed between 2011 and 2015, which coincides with the influx of Foreign Direct Investment in the area. It also shows that in the last two years, the central milk shed has also started to establish new collection points.

The proliferation of milk collection centers does not only manifest itself at the extensive margin. Existing milk collection centers have also been expanding their capacity over time. We find that, on average, an extra capacity of about 750 liters per year was added over the last 10 years. However, there is no significant difference in the rate of capacity expansion between milk sheds.

Milk collection centers do more than just bulking and cooling the milk for further transport. They also appear to be important in mid-stream service provision. Figure 5 shows, for a range of services, what percentage of milk collection centers report providing this service, separately for each milk shed. For instance, we find that in the southwestern milk shed, more than 70 percent of milk collection centers say that they provide advances to their clients, and this is only slightly lower in the central milk shed. About half of the milk collection centers provide training on milk hygiene. Interestingly, in the southwestern milk shed, milk collection centers go further than only provision of training. Here, about 45 percent of centers also provide aluminum milk cans to their clients. This percentage is significantly

[4]In one noteworthy initiative, the Uganda Crane Creameries Cooperative Union (UCCCU), an umbrella organization that brings together dairy cooperatives in Uganda, 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 stainless steel milk storage cans, and 10 insulated milk tankers.

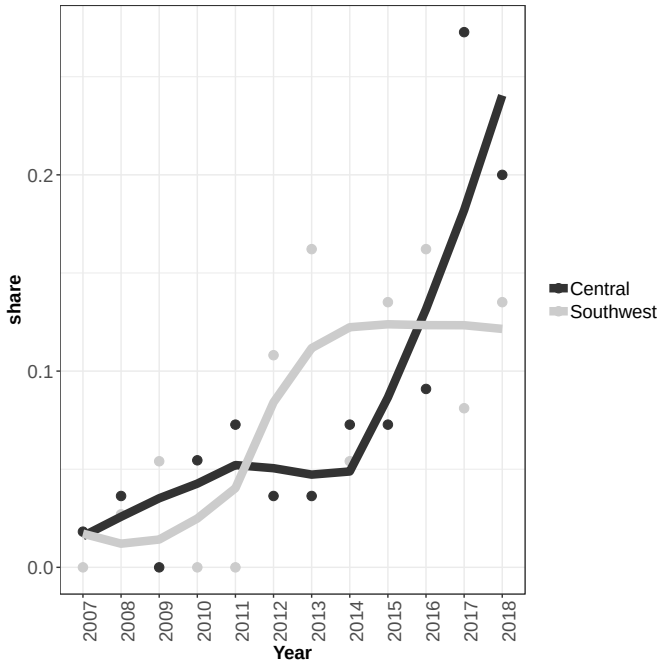

Figure 4: Evolution of milk collection centers

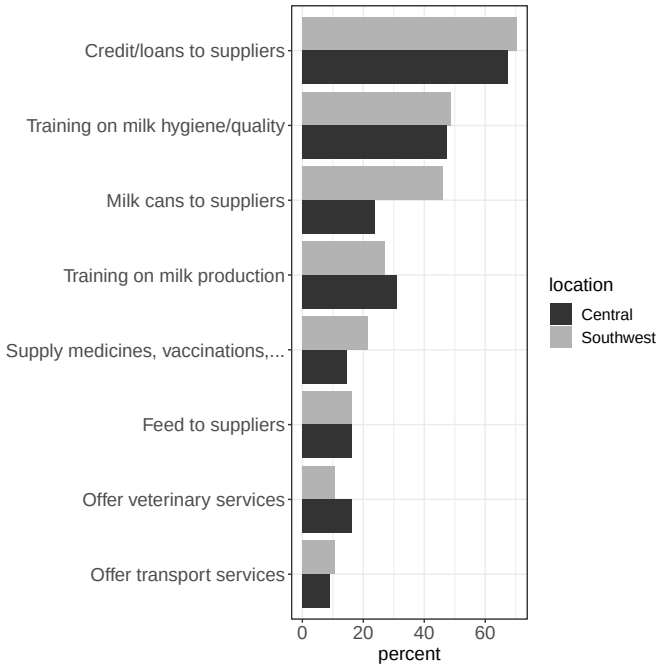

Figure 5: Services provided by milk collection centers

lower in the central milk shed. We also see that in the southwest, more milk collection centers supply veterinary medicines and vaccinations, which, as we will see below, is particularly important for cross-bred cows.

Not only do we see an evolution in the number of milk collection centers and the services they provide, we also find that more of these collection centers are organized as cooperatives. This may be partly explained by the fact that quality becomes more important in value chains: As many individual small producers supply a 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[5].

[5]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

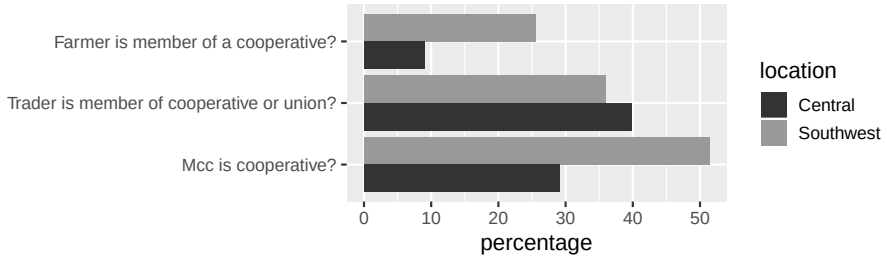

Figure 6: Cooperatives

In addition, cooperatives may also emerge as a response to issues related to excess demand for milk. Processors running below capacity compete for milk supplies. By offering services (such as training) or inputs (such as milk cans) to value chain actors upstream, processors try to increase the productivity of farmers, the quality of the milk they market, and enhance their loyalty as suppliers. However, with fierce competition between processors, dairy farmers also have more opportunities for side-selling and less incentives to maintain quality. In the context of a vibrant local market for milk with few standards or quality requirements, these problems are even more pronounced and processors will be reluctant to engage in mid-stream service delivery if they are unlikely to benefit from it (Swinnen et al., 2015). Cooperatives may be more appropriate vehicles to foster this loyalty and supply some of the services necessary to increase productivity and quality.

Figure 6 shows that in the export oriented milk shed, proportionally more producers report that they are a member of a cooperative milk collection center (p-value$<$0.001). This is not because, for some reason, cooperatives in general are more common in the southwest: about 20 percent of farmers report that they are (also) a member of non-dairy cooperatives, such as a village savings and loans association (VSLA), and this proportion is not different between the two areas (p-value = 0.374). At the trader level, we find that the share of traders that reports to be a member of a cooperative milk collection center is actually higher in the central milk shed, but the difference is not significant (p-value = 0.500). Finally, at the level of the milk collection centers, we see that cooperatives are more prevalent in the southwest (p-value = 0.053).

quality.

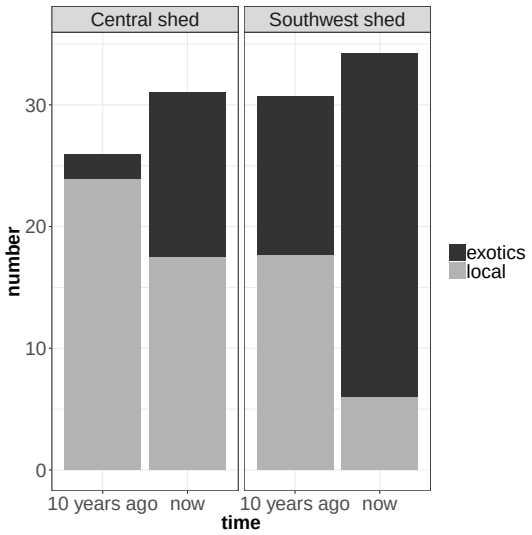

Figure 7: Adoption of crossbred cows

4.2 Adoption of improved breeds

An important technological innovation in dairy farming in Uganda is the introduction of improved breeds, mostly of the Fresian type. The adoption of higher yielding cows is necessary to increase the supply of milk. In our sample, an crossbred cow produces on average 5.7 liters of milk per day, while a local cow only produces about 3 liters. In addition, cross-bred cows are longer in milk than local cows. Figure 7 compares herd size and composition 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 from on average 26 cows to 31 cows in the central milk shed and from 31 to 34 in the central milk shed. In the southwestern milk shed, almost 87 percent of animals are of an improved breed. 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.

4.3 Value chain financing

We have already indicated above that milk collection centers provide advances to its clients. Such advances are often used for consumption expenditure. However,

Table 2: Value chain financing

	central shed	southwestern shed
	farmers	
Took loan to invest in dairy business	9.09%	19.60%
Amount borrowed (in USD)	594.85	1,409.42
Loan obtained from:		
Cooperative	24.35%	37.68%
Bank	26.09%	40.58%
Friends and family	46.09%	20.29%
Village Savings and Loans Association (VSLA)	48.69%	49.27%
	traders and transporters	
Took loan to invest in dairy business	20.89%	12.42%
Amount borrowed (in USD)	389.02	723.68
Loan obtained from:		
Cooperative	43.36%	31.58%
Bank	11.50%	47.37%
Friends	37.17%	21.05%
Village Savings and Loans Association (VSLA)	38.94%	21.05%

Note: Based on author's calculations

we also included questions in our survey that particularity look at credit obtained to invest in dairy related activities. Table 2 reports on value chain financing for both producers (top panel) and traders (bottom panel).

The table shows that among dairy farmers in the central milk shed, about 10 percent reported to have taken a loan in the previous year and invested this money into dairy farming. This percentage is double in the southwestern milk shed. We also find that the average amount borrowed was much higher in the southwestern milk shed. We also show where loans are typically obtained from. Village Savings and Loans Associations (VSLAs) are important sources for credit in both milk sheds. More interestingly, in the central milk shed, farmers also rely to a large extent on friends and family for credit. In the southwestern milk shed, banks are relatively more involved in financing producers. Cooperatives are also more likely to provide loans to dairy farmers in the southwest than in the central shed. The farmers used the money to get treatment for their animals (44 percent) or to buy improved cows (34 percent). Less than 5 percent of farmers report that they used it for artificial insemination.

From the bottom panel of Table 2, we find that traders are more likely to take out loans in the central milk shed than in the southwestern milk shed (p=0.025). However, the average amounts taken out by traders are still larger in the southwestern milk shed. Also interesting to see is that both dairy cooperatives and VSLAs seem to be more important as a source of loans for traders in the central milk shed than in the export-led dairy value chain. Family and friends are also important in the central shed, and in the southwest, banks are also important sources of midstream credit. Most traders use the credit as working capital, to buy more milk from farmers or provide upfront payments (about 30 percent). About 27 percent of traders indicate that they used the money to buy a motorbike. There are also many traders that indicate that they used the money to buy cows. This may mean that traders are also dairy farmers themselves or that they want to become dairy farmers in the future.

4.4 Feeding and water

In section 2.2, it was noted that the intensification process, whereby local breeds are replaced by cows that produce more milk, is partly driven by privatization of pastures. We find that the average farmer in the central region has about 45 acres of land that he or she can use for grazing the animals. This is slightly lower in the southwest. However, in the southwest, about 93 percent of farmers report that (at least part) of this land is fenced. In the central region, this is only 64 percent. Consistent with this, 80 percent of farmers in the central milk shed report that they rely on free range for grazing the animals, while in some cases the cows are tethered. In the southwest, on the contrary, almost half of the farmers report that they use paddocking, a much more controlled way of rotational grazing. Supplemental feeding was virtually non-existent.

A more sedentary livestock production system in the southwest also affects water provision on the farm. In the central region, 12 percent of farmers relies on dams as a source of water for the animals. In the southwest, almost 70 percent of farmers report that they rely on dams that they constructed on their land. This also results in differential access to water. In the southwest, 71 percent of farmers report they either have no problems or only occasional problems in sourcing sufficient amounts of water. This is ten percentage points lower in the central milk shed. In the central milk shed, 12 percent of farmers report that they always have trouble getting sufficient water for their dairy activities, while this is only 8 percent in the southwest.

Table 3: Use of milk containers

	central shed	southwestern shed
	farmers	
Uses stainless steel or aluminum bucket or container	19.46%	64.49%
Number of stainless steel or aluminum buckets	0.46	1.31
Number of stainless steel or aluminum milk cans	0.16	1.28
	traders and transporters	
Uses only milk cans	10.35%	58.82%
Number of milk cans	1.08	4.41
	milk collection centers	
Uses only milk cans	62.26%	83.78%
Number of milk cans	5.33	34.68

Note: Based on author's calculations

4.5 Milk handling and sanitation

Another set of important innovations is related to milk handling and sanitation. The use of stainless steel or aluminum buckets and milk cans is very important to safeguard the quality of the milk. However, farmers often use plastic buckets during milking. More problematic is the use of plastic jerry cans by transporters and traders. Plastic jerry cans are difficult to clean and the surface is easily scratched. This increases the likelihood of microbial contamination. Jerry cans easily heat up in the sun, accelerating bacterial growth. Table 3 shows that, throughout the dairy value chain, custom aluminum milk containers are becoming the norm in the export-led milk shed. The central milk shed is still far behind, especially upstream. For instance, while we find that almost 65 percent of farmers in the southwest use stainless steel or aluminum buckets or containers to collect and store the milk, this is only 20 percent in the central milk shed. Here the majority of farmers report they are using plastic buckets or plastic jars. We also find that farmers typically have at least one stainless steel or aluminum bucket and one stainless steel or aluminum milk can in the southwest. In the central milk shed, almost no farmer has a milk can.

About 60 percent of the traders that were interviewed in the southwest reported that they only use proper milk cans for their business. This was only 10 percent in the central region ($p<0.001$). A trader in the southwest has on average 4.4 milk cans. Most of these are 25 liter cans. The differences are smaller at the milk collection center level. In the central milk shed, 62 percent of milk collection centers reported to be using only stainless steel or aluminum containers. In the

southwest this is 84 percent. Milk collection centers in the southwest have on average 35 milk cans. This is consistent with the fact that in the southwest, milk collection centers assist their clients with milk cans (see Figure 5).

Milk sanitation is not only determined by the type of containers in which it is stored and transported. Another key determinant of milk quality is the time between milking and chilling. Milk that reaches the milk collection center too late generally does not pass the alcohol test. In this context, the adoption of light Indian or Chinese made motorbikes by traders is also a relevant innovation within the dairy value chain. We find that while about 72 percent of traders use a motorcycle in the central milk shed, this percentage increases to 84 in the southwestern milk shed, and this difference is significant (p=0.003).

5 Innovation and integration into modern dairy value chains - econometric analysis

The previous section explored how key innovations within the dairy value chain differ between export-led and local value chains by simply comparing the southwestern milk shed to the central milk shed. However, it may be that in the central milk shed, some actors are also integrated in modern value chains in which part of the production is exported. For instance, many farmers from the central region supply milk collection centers that ship to Brookside in Kampala, which exports substantial parts to Kenya. Also, Jesa Dairy Ltd in Wakiso procures most of its milk from the central shed. According to DDA statistics, Jesa also exports considerable amounts of milk. At the same time, not all actors located in the southwest produce for the export market. Also here, there is a sizable local market. Simply comparing actors in the southwest to actors in the central region may thus not accurately capture differences between modern value chains involving complex products that are able to compete in export markets and value chains geared towards local consumption of less processed commodities.

In this section, we construct a slightly different indicator, now focusing more on participation in modern value chains (including export-led value chains, but also comprising of the local value chains that supply pasteurized milk to the local market). For farmers, we create an indicator of integration within the modern dairy value chains that is true if the farmer delivered milk to a milk collection center every day during the week before the survey. This could either be deliveries made directly, or indirectly through a trader or a transporter. Using this definition,

we find that half of the farmers in our sample are integrated into modern value chains. As expected, there is a clear difference between the sheds: in the central region, only about 40 percent is part of a modern value chain. In the southwest, this is almost three quarters of the farmers that were interviewed. For the trader or transporter, we create an indicator of integration within modern dairy value chains that is true if the trader or transporter reports delivering exclusively to a milk collection center or directly to a processor. According to this definition, about 43 percent of traders are integrated into modern value chains. As for traders, there is also a difference between the sheds, with about 38 percent of farmers integrated in modern chains in the central region, while this is 62 percent in the southwestern region. Finally, for milk collection centers, the indicator is based on whether they report to be delivering to processors or not. Here differences between milk sheds are smaller: according to this definition, 78 percent of milk collection centers located in the central milk shed are integrated into modern value chains, while this goes up to 81 percent in the southwestern milk shed.

5.1 Farmers

We start with the analysis of the farmer level data and compare a range of innovations between farmers that are part of modern value chains to those that operate more in a more traditional context. We present results for three different models: simple differences-in-means, conditional means that also control for a range of observables, and difference-in-means after making both groups more comparable using propensity score matching (Rosenbaum and Rubin, 1983). Results are in Table 4. The different innovations are indicated in the left column. For instance, we look at mid-stream service delivery (such as the provision of training, inputs and credit), adoption of improved animals, adoption of improved pasture management and innovations in the sphere of milk sanitation. In the first column (1) of the table, means of each innovation in the subgroup of farmers that are not integrated in modern value chains (the control group) are reported for reference. The second column (2) shows a simple differences between the average among farmers that are integrated in modern value chains and the control group that is not for each of the innovation indicated in the left column. The third column (3) in Table 4 also shows for each innovation the difference between the subset of farmers that are part of a modern value chain and the control group, but now estimated in a regression framework, where we control for a range of farmer and context characteristics. In particular, we add controls for the age of the household head, sex of the household head, household size, whether the household head has attended

at least secondary school, the distance of the farm to the nearest neighbour, distance to a shop where veterinary supplies can be bought, access to credit, and the size of land that can be used for grazing the animals. We also include a set of dummy variables that indicate the district the farm is located in[6]. Full results for the regressions in this column are presented in the Appendix (Tables A.1 to A.3).

Finally, in the last column (4) of Table 4 we present results for the difference in average adoption rates between the two groups after making both groups more comparable using propensity score matching. To estimate the propensity score, we use the same variables as the ones we used in the regression models. We use nearest neigbour matching with a caliper of 0.05[7]. Doing so, we were able to match 373 farmers that participate in modern value chains to 373 traditional farmers. Appendix Table A.4 shows that this procedure considerably improves balance between the sample of farmers that is integrated in modern value chains and those that are not.

As mentioned in section 4.5, an important innovation in the dairy value chains is mid-stream service delivery by milk collection centers. More in particular, Figure 5 shows the various services that milk collection centers report they provide to their clients. Here, we look at services received from the person or organization they sell to, as reported by the farmers. The first row is general and asks if any service is provided by the buyer. We find that, about 14 percent of farmers in local value chains report that they have received some kind of assistance from the buyer (columns 1). This is almost 5 percentage points higher among farmers that are integrated in modern value chains (column 2). If we control for a range of other observable characteristics, the difference is almost 6 percentage points (column 2). Full results for the regression in Appendix Table A.1 also show that the likelihood that farmers receive assistance is higher among better educated farmers and farmers that have access to credit. Interestingly, larger farms appear less likely to receive assistance. Finally, column 4 in Table 4 reveals that the difference becomes insignificant after matching.

The following three rows (training/advice, inputs and advances) look at services provided by buyers in greater detail. We find that very few farmers receive training from downstream value chain actors, and that this is only slightly higher

[6]Note that this implicitly means we also control for milk shed, as 2 districts form the south-western milk shed and the other four districts belong to the central milk shed.

[7]This means that only comparison units within a certain width of the propensity score of the treated units get matched, the distance threshold being .05 standard deviations of the propensity score. While this reduces the number of observations that can be matched, it greatly increases balance.

Table 4: Innovations in modern value chains - farmer level

	(1)	(2)	(3)	(4)
		farmers		
Does the buyer assist you in any way? (yes/no)	0.14	0.048*	0.058*	0.035
		0.019	0.022	0.027
- Training/advice (yes/no)	0.02	0.015+	0.020+	0.021
		0.009	0.011	0.014
- Inputs (yes/no)	0.10	-0.037**	-0.025	-0.040*
		0.014	0.017	0.020
- Advances (yes/no)	0.03	0.094**	0.072**	0.059**
		0.013	0.016	0.020
Is member of dairy coop	0.08	0.085**	0.029	0.013
		0.016	0.019	0.024
Adoption of improved breeds	0.39	0.269**	0.124**	0.125**
		0.019	0.020	0.028
Has taken loan to invest in dairy	0.08	0.066**	0.031+	0.032
		0.016	0.019	0.025
Uses paddocking	0.14	0.055**	-0.000	-0.021
		0.018	0.021	0.027
Use dam as water supply	0.45	0.272**	0.176**	0.212**
		0.024	0.028	0.034
Use of aluminum buckets and cans	0.16	0.275**	0.145**	0.172**
		0.022	0.024	0.033
Number of observations	830	1,614	1,484	746

Note: First column (1) reports averages of the variables indicated in the first column among farmers that are integrated in traditional value chains. Second column (2) shows the difference between farmers that are part of modern value chains and those that are part of traditional value chains. Third column (3) shows the difference between farmers that are part of modern value chains and those that are part of traditional value chains after controlling for a range of farmer and context characteristics, and last column (4) shows the difference between farmers that are part of modern value chains and those that are part of traditional value chains after matching. + denotes significance at 10 percent level, * at 5 percent, and ** at 1 percent.

in modern value chains. Input provision by the buyer is more common. Surprisingly, input provision seems more common in traditional value chains. Finally, about 3 percent of farmers mention that they received advances from actors down the value chain in traditional value chains. This percentage increases to 12 in modern value chains if we consider the simple difference (column 2). If we consider the matching model as the preferred model, the difference is only about 6 percentage point, but still significant at the 1 percent level. Full regressions in Appendix Table A.1 shows consistent positive correlations between education level and assistance received from downstream actors.

An important institutional innovation was the cooperative. Therefore, we compare levels of cooperative membership among farmers between traditional and modern dairy value chains. We find that in the control group, about 8 percent of farmers report to be a member of a dairy cooperative. Judged by a simple difference in means, we find this proportion to be more than double in modern value chains. However, the difference becomes insignificant once we include controls or match on observables. Most likely, the observed difference in column 2 is explained by the fact that cooperatives are much more prevalent in the southwestern milk shed.

The adoption of improved cows is another important innovation at the producer level. Table 4 shows that in the control group of farmers that are integrated in traditional dairy value chains, about 40 percent of cows are of an improved type (column 1, row 6). Adoption of improved cows increases by almost 27 percentage points among farmers that are integrated in modern value chains. Accounting for a range of other observables, either in a regression or through matching, reduces this difference. However, it remains substantial and significant at the 1 percent level.

Value chain financing is another important innovation that was highlighted in the previous section. We asked if farmers obtained a loan in the previous year that was invested in the dairy business. Table 4 shows few farmers in the control group reported that they took a loan (8 percent). Simple differences reveal that this is almost 15 percent in the group of farmers that are integrated in modern value chains. After correcting for household and contextual characteristics, the difference reduces and eventually becomes statistically indistinguishable from zero.

The next two rows present results for innovations in feeding practices. In particular, we look at improved pasture management and the construction of dams for access to water. We find that 14 percent uses rotational grazing through paddocking in the control group and that this is higher among farmers that are in modern

value chains. But again, the difference disappears entirely if controls are added in a regression or through matching. Again, this is probably because paddocking is especially prevalent in the southwest; farmers here seem to engage in paddocking even if they are supplying the local market. About 45 percent of farmers in the control group reports they use a dam as a source of water for the animals. Here, we find that this percentage is significantly higher among farmers that are in modern value chains, and the difference remains stable and significant across specifications.

Finally, the introduction of aluminum buckets and cans to increase the quality of milk is also an important innovation. We find that only 14 percent of farmers in the tradtional dairy sector use proper equipment for milking. We register a large increase in this proportion among farmers that are integrated into modern value chains. The difference remains significant even after accounting for other factors such as the milk shed or scale of the farm.

5.2 Traders

Table 5 shows results for a similar analysis using the trader data. Also here, we show averages in the sub-sample of traders that are integrated in tradtional value chains (column 1) and differences with those that are integrated in modern value chains (column 2). We then add conditioning variables in column 3. Full results for these regressions can be found in the appendix (Table A.5). We control for the age of the trader, whether he or she has finished secondary education, whether he or she is the head of a household, the sex of the trader and the household size of the household the trader belongs to. We also control for years of experience as a dairy trader and whether the trader reports to have access to finance. We also include dummies for the district the trader operates in. In column 4 we show differences between traders in the two types of value chains after matching (Appendix Table A.6 reports balance before and after matching).

We start by looking if there is a difference between cooperative ownership between traders that are operating within modern value chains versus those that are working in traditional chains. We see that cooperative membership is fairly high among traders: 41 percent of traders respond that they are a member of a cooperative. We do not find that cooperative membership differs between the two types of value chains, which is consistent with the fact that we also find little difference in cooperative membership of traders between the two milk sheds we study.

We also found above that traders in the central milk shed are more likely to

Table 5: Innovations in modern value chains - trader level

	(1)	(2)	(3)	(4)
		farmers		
Is member of dairy coop	0.41	-0.042	-0.060	-0.061
		0.038	0.037	0.043
Has taken loan to invest in dairy	0.20	-0.034	-0.038	-0.016
		0.030	0.030	0.034
Use of aluminum buckets and cans	0.20	0.026	-0.026	-0.008
		0.031	0.028	0.034
Use motorbike for transport	0.74	0.012	-0.011	-0.029
		0.033	0.034	0.039
Number of observations	406	693	685	486

Note: First column (1) reports averages of the variables indicated in the first column among traders that are integrated in traditional value chains. Second column (2) shows the difference between traders that are part of modern value chains and those that are part of traditional value chains. Third column (3) shows the difference between traders that are part of modern value chains and those that are part of traditional value chains after controlling for a range of trader and context characteristics, and last column (4) shows the difference between traders that are part of modern value chains and those that are part of traditional value chains after matching.

take out a loan to invest in their business, even though the amounts are smaller than the average amount borrowed in the southwestern milk shed. Using integration into modern value chains as a conditioning variable, we now find that about 20 percent of traders that are working in the traditional milk sub-sector have borrowed to invest in their business, and their is no significant difference between traders in the traditional and modern sub-sector.

The last two rows in table 5 look at innovations in quality preservation of milk. We see that about 20 percent of traders in local dairy value chains use only aluminum cans for transporting milk. While we found a sizable difference in these proportions between the two milk sheds, this difference disappears when we compare modern and traditional value chains. This seems to suggest that enforcement of policies and regulations by the DDA, and in particular the ban on transporting milk in inappropriate containers, is particularly enforced in the southwest. About 74 percent of these traders use a motorbike, reducing the time between milking and chilling. Also here, while the difference was significant if we compared milk sheds, there is no difference if we define integration in modern milk sheds as delivering exclusively to a milk collection center or processor.

5.3 Milk collection centers

Finally, we also look at innovations using the data that was collected on milk collection centers. Results are presented in Table 6. As in previous tables, the first column shows averages for milk collection centers that do not deliver to processors. Note that we only have 19 such milk collection centers. The second column reports differences between milk collection centers that deliver to processors and those that do not. In the third column, we augment the models with additional controls. In particular, we control for the number of years the center has been operating, its capacity in liters, whether the milk collection center is a sub-center of a larger one, as well as a dummy for the southwestern milk shed. Column 3 in Table 6 only shows coefficient estimates on the indicator for the milk collection center being part of a value chain linking producers to processors; full results can be found in Appendix Table A.7. We also provide results based on matching in column 4. Appendix Table A.8 shows balance on the covariates before and after matching[8].

For the milk collection centers, we start by looking if there is a difference in organizational structure depending on whether the milk collection center supplies the traditional market or the modern market. We find that about 36 of the milk collection centers that supply the local market are cooperatives. This proportion seems to be slightly higher in value chains where collection centers supply processors, but the difference is not statistically significant. From Appendix Table A.7, we confirm that cooperative membership is significantly higher in the southwestern milk shed. The table also shows that a collection center is less likely to be a cooperative if it is a sub center. This is probably because many of the collection centers from the privatized National Dairy Corporation are still in use and are classified as sub collection center.

The next eight rows in Table 6 concern services that milk collection centers report that they provide, and corresponds to the results presented in Figure 5. For all but one of the services, we find that it does not matter whether the milk collection center supplies to the local market or to processors. In fact, we find that milk collection centers that produce for local markets claim they are more likely to provide veterinary services. Full results in Appendix Table A.7 show that, consistent with Figure 5, milk collection centers in the southwestern milk shed

[8]Note that our sample size is very small for matching. Even more, we only have 19 milk collection centers in the group of milk collection centers that are supplying local markets. We therefor match two milk collection centers that supply to processors to each milk collection center that supplies the local market. Still, we only remain with 42 observations.

Table 6: Innovations in modern value chains - milk collection centers

	(1)	(2)	(3)	(4)
	farmers			
Mcc is cooperative	0.36	0.015	0.054	0.074
		0.126	0.125	0.160
Technical training/advice on milk production	0.32	-0.028	-0.004	-0.081
		0.118	0.116	0.145
Technical training/advice on milk hygiene and quality	0.42	0.072	0.094	0.091
		0.130	0.129	0.164
Credit/loans to suppliers	0.74	-0.066	-0.052	-0.148
		0.121	0.125	0.162
Equipment/feed to suppliers	0.16	0.006	0.013	0.052
		0.096	0.100	0.123
Milk cans to suppliers	0.21	0.146	0.133	0.170
		0.121	0.114	0.150
Offer veterinary services	0.26	-0.153	-0.173^{+}	-0.193^{+}
		0.089	0.090	0.111
Offer transport services/milk trucks	0.05	0.057	0.037	0.007
		0.077	0.077	0.085
Medicines, vaccinations	0.16	0.020	0.032	-0.052
		0.099	0.101	0.123
Uses only milk cans	0.67	0.056	0.037	0.098
		0.121	0.120	0.153
Number of observations	19	92	92	42

Note: First column (1) reports averages of the variables indicated in the first column among milk collection centers that are integrated in traditional value chains. Second column (2) shows the difference between milk collection centers that are part of modern value chains and those that are part of traditional value chains. Third column (3) shows the difference between milk collection centers that are part of modern value chains and those that are part of traditional value chains after controlling for a range of milk collection centers and context characteristics, and last column (4) shows the difference between milk collection centers that are part of modern value chains and those that are part of traditional value chains after matching. + denotes significance at 10 percent level.

report that they are more likely to provide milk cans to their supplies. Finally, the higher use of milk cans by milk collection centers also seems to be the same irrespective of whether the milk collection center is integrated in the modern sector or not. The difference found in Table 3 is again due to the milk shed (see Appendix Table A.7).

6 Conclusions

As a result of increased demand for dairy products, both locally and from abroad, and facilitated by privatization and liberalization, the dairy sub-sector in Uganda has transformed substantially. Using data collected from three key value chain actors–farmers, traders and milk collection centers–we explored patterns in key innovations that are both a cause and consequence of transforming value chains. We did this by highlighting some of the differences and similarities between the central milk shed that caters for the local market and the southwestern milk shed that supplies the processors that produce mainly for the export market. However, defining an actor's integration within a value chain based on location alone may not be fully satisfactory. Indeed, some farmers in the central region also supply processors that export, and not all farmers in the southwest supply milk collection centers that in turn supply processors that export. We thus also constructed an indicator that captures integration in modern value chains more generally, and compared these value chains to more traditional chains.

We found that a key innovation happened midstream, with the proliferation of milk collection centers. These institutions collect and bulk milk from numerous small farmers sometimes, directly, but mostly through small milk traders. They form the start of the cold chain and are central to quality control and preservation. However, we found that milk collection centers also provide a range of services to their suppliers. In doing so, these centers enabled and supported a range of other innovations throughout the value chain.

At the farmer level, integration into export-led and modern dairy value chains was correlated with increased adoption of cross-bred cows. Adoption of higher yielding animals is important to meet the demand from the sector. However, many farmers do not invest in improved animals because of their higher susceptibility to pests and diseases[9]. East Coast fever in particular, a tick-borne disease caused by the protozoan parasite, *Theileria Parva*, was reported to be killing many animals.

[9]Other reasons included intensive management requirements, no feeding industry, and lacking or poor quality artificial insemination services.

Milk collection centers, to some extent, support farmer by providing them with acaricides and sometimes even veterinary services.

Cutting across the entire value chain, we found evidence of increased attention to quality and milk sanitation, especially in export-led value chains. However, up to now, this seemed to be especially through enforcement of a ban on transporting milk in jerry cans by the Dairy Development Authority. Currently, the Authority focuses on policing the southwestern milk shed, but this may become too costly at a larger scales. In addition, milk quality involves much more than just using proper milk cans. A better way to increase milk sanitation would be to incentivize quality through a premium on the price. According to our data, price premia for quality do not exist in Uganda, possibly because milk collection centers do not have the tools and the capacity to accurately determine quality. We found that milk collection centers support quality preservation within the dairy value chain through the provision of milk cans and by providing training to their suppliers.

In export-led value chains, we also documented a shift in value chain financing from friends and family towards more formal financing through financial institutions. However, most of the financing seemed to go to preserving the animal stock (farmer level – buying medicine and paying for veterinary services) and to increasing working capital (trader level), as opposed to investment. Longer run credit with better interest rates are likely to further upgrading of the value chain. Milk collection centers seem to provide credit to their suppliers, and traders also use most of the credit they get to pay advances to farmers to secure more milk. However, such advances are most likely used by farmers to finance immediate consumption needs. Credit is perhaps better supplied by a third party to avoid situations where farmers work themselves into debt and are then locked into a situation where milk collection centers or traders force farmers to supply milk at low prices.

Finally, we also found signs that rotational grazing is taking off in export-led value chains, and that farmers in such value chains constructed dams to get a stable water supply. However, this is only a start. To come to substantial productivity gains, the water will also need to be distributed within the farms to avoid cows from having to walk long distances. The use of additional feeding practices, such as hay making and silage, is not very common.

While we highlighted some key innovations and pointed out the importance of milk collection centers in mid-stream service provision, we also think the sector stands to gain from further development of the dairy service sector. Services provided by milk collection centers related to animal health, generally limited to the supply of acaricides seem insufficient at present. Ticks become quickly resis-

tant to the acaricides, and some farmers are disadopting cross-bred cows because they are simply dying. Clearly, milk collection centers do not have the capacity to carry out research on resistance to acaricides. More generally, many services would benefit from the development of a specialized dairy service sector supporting milk producers. For instance, (cross-bred) cows produce much less than what would be possible because of the absence of a modern feed sector. Our data also suggests that artificial insemination is almost non-existent. But the lack of a supporting service sector also constrains the further development of the sector at higher levels. For example, processors complain that a lacking industrial base in Uganda means that have to import all packaging material, reducing margins and making their products less competitive on the international market. While we found that milk collection centers engage in service provision to some extent, more will be needed for further upgrading of the value chain.

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Table A.1: Regressions for farmer

	Dependent variable:			
	any assistance	assist in training	assist in inputs	assist with advances
Export indicator (yes/no)	0.058**	0.020*	−0.025	0.072***
	(0.023)	(0.011)	(0.017)	(0.016)
Age head (years)	−0.001	0.00003	−0.0002	0.00000
	(0.001)	(0.0003)	(0.0005)	(0.0005)
Head is woman (yes/no)	0.037	0.009	−0.0001	−0.0005
	(0.028)	(0.013)	(0.021)	(0.020)
Household size	0.010***	0.001	0.003	0.006**
	(0.003)	(0.001)	(0.002)	(0.002)
Head finished secondary (yes/no)	0.112***	0.033***	0.035**	0.063***
	(0.024)	(0.011)	(0.018)	(0.017)
Nearest neighbor (km)	−0.006	0.008	−0.008	−0.007
	(0.014)	(0.007)	(0.011)	(0.010)
Distance to agro-input shop (km)	−0.001	−0.0003	−0.0001	0.0002
	(0.001)	(0.001)	(0.001)	(0.001)
Access to finance (yes/no)	0.065***	0.019*	0.027*	0.064***
	(0.020)	(0.010)	(0.015)	(0.015)
Landsize (acres)	−0.0004**	0.00004	−0.0003**	−0.0001
	(0.0002)	(0.0001)	(0.0001)	(0.0001)
Constant	0.171***	0.048*	0.189***	−0.023
	(0.052)	(0.025)	(0.039)	(0.038)
Observations	1,485	1,485	1,485	1,485
R^2	0.053	0.040	0.035	0.067
Adjusted R^2	0.044	0.031	0.025	0.058
Residual Std. Error	0.372	0.179	0.278	0.271
F Statistic	5.845***	4.369***	3.756***	7.482***
Note:				*p<0.1; **p<0.05; ***p<0.01

Table A.2: Regressions for farmer (cont)

	Dependent variable:		
	member of cooperative	percentage of cross-breds	use controlled grazing
Export indicator (yes/no)	0.029	0.124***	−0.0003
	(0.019)	(0.021)	(0.021)
Age head (year)	0.001	−0.002***	−0.001**
	(0.001)	(0.001)	(0.001)
Head is woman (yes/no)	−0.003	−0.035	−0.072***
	(0.024)	(0.025)	(0.026)
Household size	−0.003	0.0002	0.001
	(0.003)	(0.003)	(0.003)
Head finished secondary (yes/no)	0.001	0.002	0.020
	(0.020)	(0.022)	(0.022)
Nearest neighbor (km)	−0.001	−0.016	0.026**
	(0.012)	(0.013)	(0.013)
Distance to agro-input shop (km)	−0.001	−0.004***	−0.001
	(0.001)	(0.001)	(0.001)
Access to finance (yes/no)	0.130***	0.073***	−0.055***
	(0.018)	(0.019)	(0.019)
Landsize (acres)	0.0004***	0.0002	−0.00001
	(0.0002)	(0.0002)	(0.0002)
Constant	0.063	0.402***	0.210***
	(0.044)	(0.047)	(0.048)
Observations	1,485	1,478	1,485
R^2	0.121	0.297	0.165
Adjusted R^2	0.113	0.291	0.157
Residual Std. Error	0.318	0.339	0.350
F Statistic	14.498***	44.245***	20.729***
Note:			*p<0.1; **p<0.05; ***p<0.01

Table A.3: Regressions for farmer (cont)

	Dependent variable:		
	took loan for business	access to dam	uses only milk cans
Export indicator (yes/no)	0.031*	0.176***	0.145***
	(0.019)	(0.028)	(0.025)
Age head (year)	0.00001	0.001	−0.001*
	(0.001)	(0.001)	(0.001)
Head is woman (yes/no)	0.013	0.024	0.002
	(0.023)	(0.034)	(0.030)
Househols size	0.001	0.003	0.004
	(0.002)	(0.004)	(0.003)
Head finished secondary (yes/no)	−0.024	−0.006	0.012
	(0.019)	(0.029)	(0.026)
Nearest neighbor (km)	−0.004	0.057***	0.011
	(0.012)	(0.017)	(0.015)
Distance to agro-input shop (km)	−0.0003	−0.005***	−0.002
	(0.001)	(0.002)	(0.001)
Access to finance (yes/no)	0.177***	−0.006	0.052**
	(0.017)	(0.025)	(0.022)
Landsize (acres)	0.0001	0.001***	0.001***
	(0.0002)	(0.0002)	(0.0002)
Constant	0.014	0.205***	0.095*
	(0.043)	(0.063)	(0.056)
Observations	1,485	1,485	1,485
R^2	0.094	0.146	0.238
Adjusted R^2	0.085	0.138	0.231
Residual Std. Error	0.307	0.457	0.404
F Statistic	10.841***	17.923***	32.849***
Note:			*p<0.1; **p<0.05; ***p<0.01

Table A.4: Balance on covariates before and after matching - farmers

	before matching		*after matching*	
	means export	means local	means export	means local
Prop score distance	0.65	0.40	0.51	0.50
Age head (year)	47.76	47.98	47.03	46.73
Head is woman (yes/no)	0.14	0.15	0.16	0.16
Househols size	7.43	7.04	7.25	7.37
Head finished secondary (yes/no)	0.24	0.25	0.24	0.25
Nearest neighbor (km)	0.51	0.45	0.47	0.48
Distance to agro-input shop (km)	8.18	8.34	7.98	8.35
Access to finance (yes/no)	0.68	0.61	0.66	0.68
District=KIRUHURA	0.30	0.06	0.12	0.10
District=KYANKWANZI	0.13	0.26	0.22	0.19
District=MASINDI	0.24	0.37	0.35	0.42
District=MBARARA	0.04	0.07	0.06	0.08
District=NAKASEKE	0.25	0.09	0.17	0.16
Landsize (acres)	62.38	30.35	45.96	44.59

Note: Based on author's calculations

Table A.5: Regressions for trader

	Dependent variable:			
	member of cooperative	took loan for business	uses only milk cans	uses motorbike for transport
Export indicator (yes/no)	−0.060	−0.038	−0.026	−0.011
	(0.037)	(0.030)	(0.028)	(0.034)
Age of trader	0.002	0.003*	−0.0003	−0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Head finished secondary (yes/no)	0.047	0.019	0.018	0.053
	(0.039)	(0.032)	(0.029)	(0.036)
Trader is woman (yes/no)	0.014	−0.245	−0.012	−0.520***
	(0.210)	(0.174)	(0.159)	(0.194)
Trader is head of a household (yes/no)	0.058	−0.018	−0.027	0.113***
	(0.045)	(0.037)	(0.034)	(0.042)
Household size	0.007	0.005	−0.003	0.004
	(0.005)	(0.004)	(0.004)	(0.004)
Experience as trader (years)	0.007*	0.002	0.006*	0.007
	(0.004)	(0.004)	(0.003)	(0.004)
Access to finance (yes/no)	0.198***	0.201***	0.027	0.125***
	(0.038)	(0.031)	(0.029)	(0.035)
Constant	0.316***	−0.035	0.272***	0.573***
	(0.085)	(0.070)	(0.064)	(0.079)
Observations	685	685	685	685
R^2	0.143	0.090	0.295	0.086
Adjusted R^2	0.126	0.073	0.281	0.068
Residual Std. Error	0.456	0.378	0.346	0.421
F Statistic	8.606***	5.113***	21.576***	4.842***
Note:				*p<0.1; **p<0.05; ***p<0.01

Table A.6: Balance on covariates before and after matching - traders

	before matching		*after matching*	
	means export	means local	means export	means local
Prop score distance	0.45	0.39	0.43	0.42
Age of trader	30.27	30.01	30.12	30.38
Head finished secondary (yes/no)	0.28	0.35	0.28	0.28
Trader is woman (yes/no)	0.00	0.01	0.00	0.00
Trader is head of household (yes/no)	0.60	0.67	0.63	0.63
Household size	7.59	7.44	7.62	7.49
Experience as trader (years)	3.63	3.84	3.63	3.35
Access to finance (yes/no)	0.69	0.63	0.68	0.70
district=KIRUHURA	0.28	0.12	0.19	0.17
district=KYANKWANZI	0.22	0.21	0.23	0.24
district=MASINDI	0.04	0.06	0.04	0.04
district=MBARARA	0.02	0.03	0.03	0.02
district=NAKASEKE	0.31	0.39	0.36	0.38

Note: Based on author's calculations

Table A.7: Regressions for milk collection centers

	Dependent variable:									
	mcc = coop	training production	training quality	provides credit	provides equipment	provides milk cans	provides vet	provides transport	provides meds	uses only milk cans
Export indicator (yes/no)	0.054	−0.004	0.094	−0.052	0.013	0.133	−0.173*	0.037	0.032	0.037
	(0.125)	(0.116)	(0.129)	(0.125)	(0.100)	(0.114)	(0.090)	(0.077)	(0.101)	(0.120)
Age of mcc (year)	0.004	0.031***	0.017	0.006	0.007	0.002	−0.006	−0.001	−0.000	−0.011
	(0.012)	(0.011)	(0.012)	(0.012)	(0.010)	(0.011)	(0.009)	(0.007)	(0.010)	(0.011)
Capacity (liters)	−0.000	0.000	0.000*	−0.000	−0.000	0.000***	0.000**	0.000**	0.000	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Is sub center	−0.196*	0.001	−0.101	−0.013	0.003	−0.084	0.022	0.038	−0.108	−0.041
	(0.101)	(0.094)	(0.104)	(0.101)	(0.081)	(0.092)	(0.073)	(0.063)	(0.082)	(0.096)
Shed = SW	0.215**	−0.065	−0.005	0.026	−0.008	0.216**	−0.045	0.018	0.069	0.224**
	(0.102)	(0.094)	(0.105)	(0.102)	(0.081)	(0.093)	(0.074)	(0.063)	(0.082)	(0.096)
Constant	0.376***	0.137	0.276*	0.752***	0.127	−0.015	0.218**	−0.043	0.129	0.546***
	(0.137)	(0.127)	(0.142)	(0.137)	(0.110)	(0.125)	(0.099)	(0.085)	(0.111)	(0.131)
Observations	92	92	92	92	92	92	92	92	92	90
R^2	0.097	0.123	0.092	0.016	0.007	0.199	0.090	0.081	0.040	0.101
Adjusted R^2	0.045	0.072	0.040	−0.042	−0.051	0.153	0.037	0.028	−0.016	0.048
Res. Std. Error	0.477	0.441	0.492	0.477	0.381	0.434	0.344	0.294	0.384	0.445
F Statistic	1.850	2.409**	1.750	0.274	0.116	4.282***	1.696	1.525	0.719	1.890

Note: *p<0.1; **p<0.05; ***p<0.01

Table A.8: Balance on covariates before and after matching - milk collection centers

	before matching		*after matching*	
	means export	means local	means export	means local
Prop score distance	0.24	0.20	0.21	0.21
Age of mcc (years)	4.68	3.75	2.47	3.73
Capacity of mcc (liters)	4,840.00	5,506.99	4,950.00	4,959.83
Is subcenter (yes/no)	0.32	0.51	0.40	0.43
Shed = SW	0.37	0.41	0.33	0.47

Note: Based on author's calculations