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ORIGINAL ARTICLE

Leading the way – foreign direct investment and dairy value chain upgrading in Uganda

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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 data collected at different nodes within the value chain to identify some of the key innovations in these value chains. This is done by comparing the area that received the bulk of FDI to a similar area that did not. Furthermore, we also provide an econometric analysis that focuses on the integration of value chain actors into modern value chains more broadly defined. We find that dairy value chains are transforming rapidly, but innovations are more pronounced in areas that received the bulk of FDI. Our analysis further 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 a modern export sector to emerge.

KEYWORDS
agricultural transformation, value chains, foreign direct investments, export, dairy, Uganda

JEL CLASSIFICATION
O33, O13, O17, Q13, Q17

1 | INTRODUCTION

Agricultural value chains are rapidly changing in developing countries, also in Africa (Jayne et al., 2019; Reardon et al., 2012, 2015), but the nature and causes of these changes—and especially the role of Foreign Direct Investment (FDI)—are not well understood. Various studies find that FDI has been a major diver of the upgrading of value chains in a number of developing countries, for instance through relaxing capital constraints and facilitating transfer of technology and know-how

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(Blalock & Gertler, 2008; Blomström & Kokko, 1998; Reardon & Barrett, 2000; Stokke, 2009). In the case of the dairy sector, investments by multinational companies can lead to important and quick upgrading of value chains (Farina, 2002), sometimes through vertical integration (Dries et al., 2009; Dries & Swinnen, 2004). Vandeplas et al. (2013) further show that in India, farmers supplying dairy multinationals are more efficient than farmers in domestic value chains.

In this article, we document trends in FDI, modernization, and innovation in the case of dairy value chain transformation in Uganda. Uganda is an interesting case as the dairy value chain has undergone substantial and rapid changes as seen by several indicators[1]. First, national production has increased by more than 50% 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 10 years. Third, while a decade ago, Uganda imported more dairy products than it exported, 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 (Francesconi et al., 2010; Ruel et al., 2017).

Interestingly, due to a combination of agglomeration effects and a comparative 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.

In this article, we set out to document the technological and institutional innovations that are associated with value chain upgrading. However, value chain transformation is an endogenous process. While it is not always clear what innovations are the cause or the result of value chain transformation, 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, and may shed some light on critical innovations by comparing technological, institutional and organizational features in these two locations. Generally, studies on value chain transformation in developing countries analyze either export-led chains for commodities with little or no local market (Maertens, 2009; Minten et al., 2009; Maertens & Swinnen, 2009) or domestic chains (Janssen & Swinnen, 2019; Minten et al., 2016). 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. At the same time, we acknowledge the limits of using exposure of value chain actors to FDI in the vicinity as a proxy for value chain transformation. 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 thus also present an alternative analysis where the focus is more on integration 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 an important facilitator of value chain upgrading. They help guarantee that processors can source the quantity of quality milk they need to compete on the international and modern local market. At the same time, they provide a stable outlet for producers (either directly or indirectly through middlemen). Often, these centers appear to do more than just bulking and chilling milk. They also provide a range of services to farmers that enable and sustain additional

[1] However, these changes have mostly gone unnoticed. The dairy subsector in Uganda was traditionally not considered a strategic sector. As a result, in the Bank of Uganda's statistics, dairy exports are amalgamated into a category together with other non-traditional exports, obscuring the evolution of the sector. Practitioners in the sector have been trying to get the attention of politicians through the local press (Van Klinken, 2019) and the research community also started to pick an interest in the evolution in the sector (Mbowa, 2019; Omondi et al., 2017).

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. While these innovations are most pronounced in the southwestern milk shed that received the bulk of FDI and is geared mostly toward export, some of these changes also seem to happen in the central milk shed that supplies the local market, albeit at a slower pace. This may indicate that also for the case of Ugandan dairy value chains, FDI facilitates transfer of technology and know-how, leading to a more efficient and inclusive sub-sector.

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, it 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 & Jayne, 2014). Second, we collected data on almost 100 milk collection centers, an institution that is specific to the sub-sector. In most other value chain studies, the sample size for similar value chain actors is generally much lower[2]. Third, 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. Finally, and more broadly, the important role that aggregators and other actors in the midstream play in facilitating farmer access to training and other services is yet to be well established in the development literature, broadly and agricultural economics more specifically. The role that midstream actors play in facilitating technology adoption and upgrading supports some key considerations highlighted in several recent papers (Ruben et al., 2018) and also several chapters of the 2019 Africa Agriculture Status Report (Liverpool-Tasie et al., 2019; Reardon et al., 2019). This article contributes to this literature with a specific country case study based on rigorous empirical analysis.

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 for considerable FDI. We then describe the structure of the value chain and explain 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 look at technology adoption among farmer, dynamics in value chain financing, feeding practices, and quality assurance. We also experiment with an alternative indicator of integration into modern dairy value chains and compare a range of innovations within this chain to traditional configurations 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 (DDA), 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 (Mbowa et al., 2012).

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[3]. Furthermore, in rural areas,

[2] For example, surveys cold storage facilities in the potato value chain in Bihar, India. However, they only interviewed 27 storage owners.

[3] Often, milk that is not sold is processed into bongo.

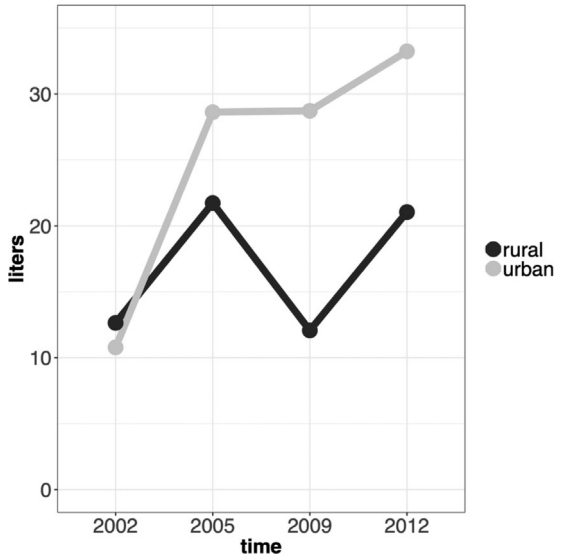

FIGURE 1 Consumption of liquid milk (liters per capita per year;
source: Uganda National Household Surveys, multiple years).

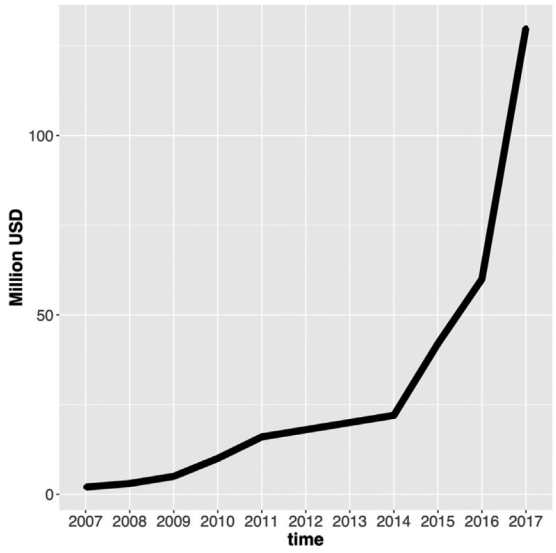

FIGURE 2 Export of dairy products (in millions USD; *source*: DDA).

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

More in general, providing reliable estimates of local dairy consumption is not straightforward. While the UNHS is arguable the most credible source when estimating consumption expenditure, dairy consumption in Uganda is very low, with most households reporting no consumption of milk in the last 7 days, which is the consumption recall period in the UNHS. Per capita consumption estimates quoted in the popular press or estimated in case studies often differ widely, with sources not always well documented. For instance, one of the figures mostly quoted is 62 liters per capita in 2017 (up from 25 liters in 1986). However, it is not clear how this was estimated and what data source was used.

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 DDA, show that US$ 130 million worth of dairy products have been exported in 2017. The DDA reports that almost half of the export value, US$ 55 million, was exported by a single processor (Pearl Dairy – See Table 1). This processor exports mostly milk powder to countries on the Arabian Peninsula, but also to Nigeria. About 20% 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, 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,

TABLE 1 Largest exporters in Uganda (2017)

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 self-life) milk
Amos	17	13	US	Caseine
Total	**130**	**100**		

Note: Based on data obtained from the DDA.

a parastatal dairy processor. 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 set up 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., and 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 most of the 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, because price wars in liquid milk markets in India led 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 of the country, 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, as a result of privatization and population pressure, 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 et al., 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 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.

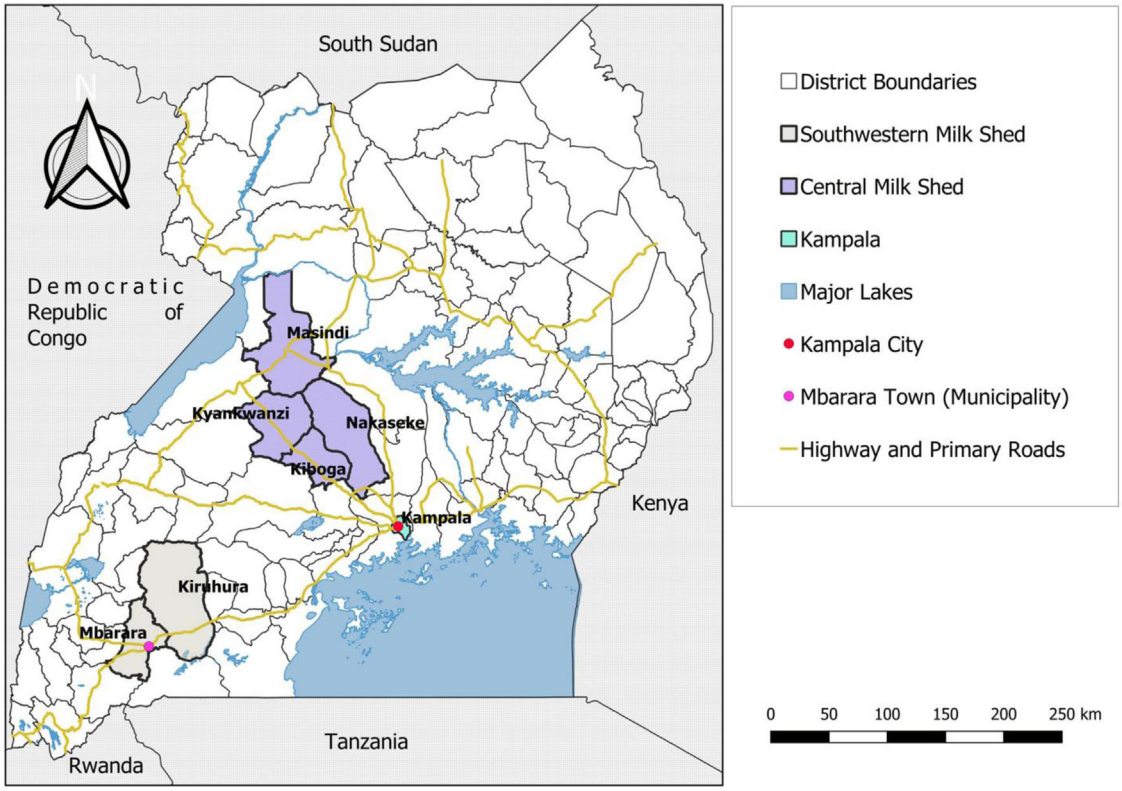

FIGURE 3 Map of Uganda and data collection sites [Color figure can be viewed at wileyonlinelibrary.com]

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 or motorbikes, or occasionally, a pick-up truck. Milk collection centers bulk the milk in coolers for further transport to processors or consumer markets. There is also a range of actors that provide services to the dairy supply chain, such as veterinary services, or inputs such as feeding supplements. Finally, milk is consumed in different forms and by different consumers, ranging from farmers and their 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 sub-counties from six districts (Mbarara, Kiruhura, Kyankwanzi, Kiboga, Nakaseke and Masindi). These sub-counties 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 the number of households residing in the village. 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[4]. Milk collection centers were selected through simple random sampling from the list of milk collection centers in each sub-county obtained from the DDA[5]. 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[6]. Data in Kyankwanzi, Kiboga, Nakaseke and Masindi was collected

[4] Most households in these areas own cattle. However, in case the randomly selected farmer in the list did not own dairy animals, the next household on the list was selected.

[5] Milk collection centers are fairly formal structures that are required to be registered with the DDA. This is because milk collection centers are inspected by DDA officials on a regular basis.

[6] In each milk collection center, about seven traders were selected. To do so, an interviewer went to the milk collection center early in the morning before it opened and collected information on the total number of traders that supply the center on an average day. From this, "n" was determined as the total number of traders divided by seven. However, sampling traders is hard due to their mobile nature and we agree that our approach has its weaknesses relative to other sampling strategies. The most important drawback is probably the fact that our method would lead to an overestimate of role and importance of traders that supply milk collection centers (as opposed to traders that supply processors directly, milk-shops,...).

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TABLE 2 Shares of sales of farmers, traders and milk collection centers to different market channels

	Central shed	Southwestern shed	Central shed	Southwestern shed	p-value difference
	Liters		*Shares*		
Farmers					
Traders	40 L	86 L	47.6%	52.8%	0.088
Transporters	15 L	26 L	17.9%	15.9%	0.404
Milk collection centers	18 L	42 L	21.4%	25.8%	0.084
Neighbors	10 L	6 L	11.9%	3.7%	0.000
Milk shops	2 L	4 L	2.4%	2.4%	0.939
Total	**84 L**	**163 L**			
Traders and transporters					
Milk collection centers	48 L	80 L	87.3%	71.4%	0.000
Milk shops	3 L	19 L	5.4%	17.0%	0.000
Processors	3 L	8 L	5.4%	7.1%	0.431
Neighbors	1 L	5 L	1.8%	4.5%	0.060
Total	**55 L**	**112 L**			
Milk collection centers					
Processors	46 L	98 L	69.7%	80.3%	0.255
Large trader	6 L	21 L	9.1%	17.2%	0.246
Neighbors	14 L	3 L	21.2%	2.5%	0.010
Total	**66 L**	**122L**			

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, by looking at average quantities and associated shares of sales of the various actors to the different market channels (Table 2). The average farmer in the central milk shed sells about 84 liter of milk per week (measured in the week before the survey, which was at the onset of the dry season). Just under half of this, 40 liters or about 48%, is sold to traders. Farmers also sell milk to milk collection centers, either directly (18 liters of 21% of sales), or by contracting a transporter to take the milk from the farm-gate to the milk collection center (15 liters or about 18%)[7]. Finally, about 10 liters, corresponding to almost 12% of all milk marketed, is sold directly to neighbors. Farmers in the 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 or almost 53% of all milk marketed). This share is significantly higher than in the central shed (at the 10% significance level – p-value: 0.088). One quarter of the milk is directly sold to milk collection centers (42 liters per week or 26%), and this share is also significantly lower in the central milk shed (p-value: 0.084). The use of transport services is, relative to the central shed, somewhat less important in the southwestern milk shed, but the difference is not significant. Consistent with our expectations of finding a more informal supply chain in the center, direct sales to neighbors are significantly lower in the southwestern milk shed.

We next estimate how much of the quantities that traders and transporters procure (55 liters in the central shed and 112 liters in the southwestern shed) is distributed over actors further downstream. In the central milk shed, traders almost exclusively ship to milk collection centers (48 liters, amounting to 87% of milk procured). The remaining 7 liters is shared between processors (3 liters), milk shops (3 liters), and direct sales to villagers (1 liter). Trader behavior is clearly different in the southwestern milk shed. Apart from supplying milk to milk collection centers (80 liters, which is proportionally less than in the central shed), relatively more milk is delivered to milk shops (19 liters). Traders selling to villagers also seem not uncommon in the southwest (5 liters).

In the next step, we estimate how the quantities collected by milk collection centers (66 liter in the central shed

[7] 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.

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% of the milk is sold to villagers (14 liters). In the southwestern milk shed, sales by milk collection centers to villagers are marginal (3 liters). In the southwest, milk collection centers also often sell to large traders (21 liters, representing 17% 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% 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 reiterate 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 et al., 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.

4.1 | Descriptive analysis – export-led versus local demand-led value chains

We start by comparing 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. As mentioned above, the two milk sheds are both located in the cattle belt and share the same agro-ecology. According to the DDA, they are also very similar in aggregate production: the southwestern milk shed produces 25% of all milk, while this is 24% for the central milk shed. Our data also suggests that farmer typology is similar in both sheds: the average farmer has about 30 cows and has access to about 45 acres of land. However, we do not have accurate data on differences in infrastructure between the two sheds. In fact, some data we collected in our survey that may be useful to get a sense of differences in infrastructure suggests there may be some. For instance, we find that the average distance from a household to the nearest all weather road is significantly higher in the central milk shed than in the southwestern milk shed. Therefore, it bears repeating that the innovations we document below may also be the consequence of differences in infrastructure (or any other unobserved confounder) between the two milk sheds.

4.1.1 | 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 are certainly not new or even unique to Uganda (Kilelu et al., 2017), the innovation 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[8]. 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 tank. 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, aver-

[8] 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, 1500 stainless steel milk storage cans, and 10 insulated milk tankers.

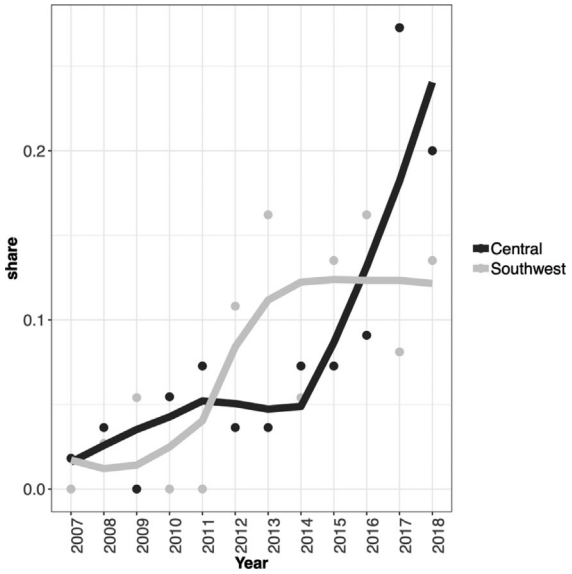

FIGURE 4 Evolution of milk collection centers

age 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 FDI in the area. It also shows that in the last 2 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% 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% of centers also provide aluminum milk cans to their clients. This percentage is significantly lower in the central milk shed (p-value = 0.044). 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. However, apart from the supply of aluminum milk cans, none of these differences is statistically significant.

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[9].

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. This is consistent with the findings in Chagwiza et al. (2016) that cooperatives are strong in facilitating technological transformations and commercialization, but do not offer better prices.

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

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

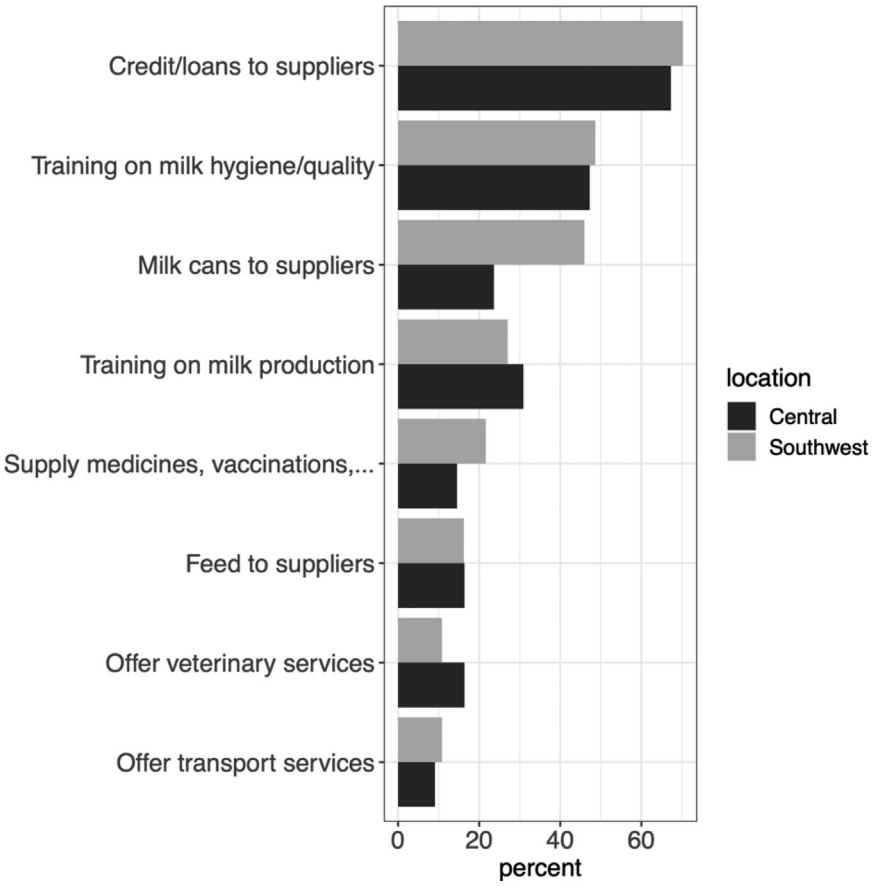

FIGURE 5 Services provided by milk collection centers

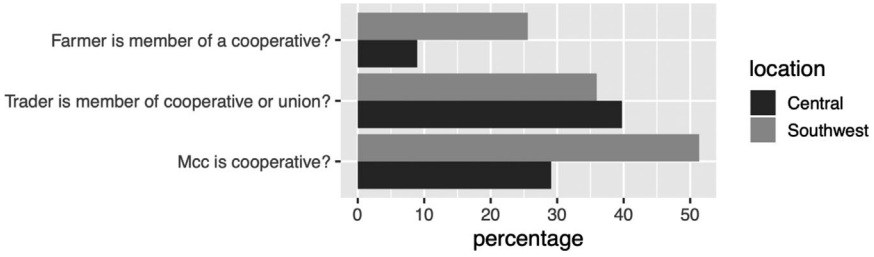

FIGURE 6 Cooperatives

general are more common in the southwest: about 20% 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).

4.1.2 | 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, a cross-bred 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% 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.

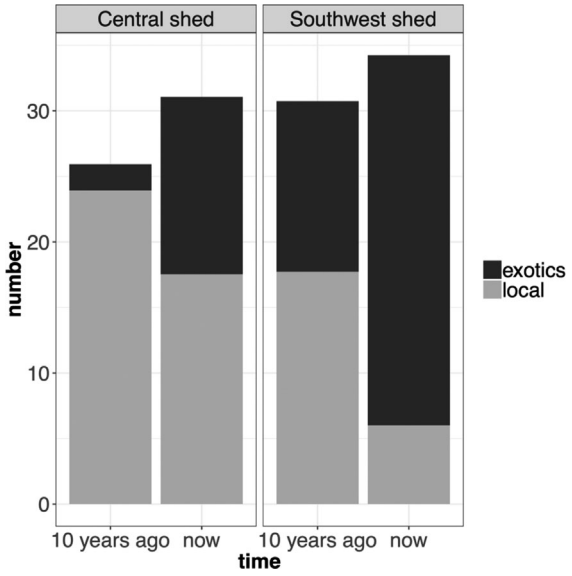

FIGURE 7 Adoption of crossbred cows

4.1.3 | Value chain financing

We have already indicated above that milk collection centers provide advances to their clients. Such advances are often used for consumption expenditures. However, we also included questions in our survey that particularity look at credit obtained in the last year to invest in dairy related activities. Table 3 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% 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%) or to buy improved cows (34%). Less than 5% of farmers report that they used it for artificial insemination.

From the bottom panel of Table 3, we find that traders are more likely to take out loans in the central milk shed than in the southwestern milk shed. However, the average amount borrowed by traders is 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 important in the central shed, and in the southwest, banks are 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%). About 27% of traders indicate that they used the money to buy

TABLE 3 Value chain financing

	Central shed	Southwestern shed	p-value difference
Farmers			
Took loan to invest in dairy business	9.1%	19.6%	0.000
Amount borrowed (in USD)	594.8	1,409.4	0.183
Loan obtained from:			
Cooperative	24.3%	37.7%	0.079
Bank	26.1%	40.6%	0.059
Friends and family	46.1%	20.3%	0.001
Village Savings and Loans Association (VSLA)	48.7%	49.3%	1.000
Traders and transporters			
Took loan to invest in dairy business	20.9%	12.4%	0.023
Amount borrowed (in USD)	389.0	723.7	0.029
Loan obtained from:			
Cooperative	43.4%	31.6%	0.476
Bank	11.5%	47.4%	0.001
Friends	37.2%	21.0%	0.270
Village Savings and Loans Association (VSLA)	38.9%	21.0%	0.214

TABLE 4 Use of milk containers

	Central shed	Southwestern shed	p-value difference
Farmers			
Uses stainless steel or aluminum bucket or container	19.5%	64.5%	0.000
Number of stainless steel or aluminum buckets	0.5	1.3	0.000
Number of stainless steel or aluminum milk cans	0.2	1.3	0.000
Traders and transporters			
Uses only milk cans	10.3%	58.8%	0.000
Number of milk cans	1.1	4.4	0.000
Milk collection centers			
Uses only milk cans	62.3%	83.8%	0.048
Number of milk cans	5.3	34.7	0.045

a motorbike. There are 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.

4.1.4 | 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. As mentioned above, the average farmer has about 45 acres of land that he or she can use for grazing the animals, and there is no difference between the two sheds. However, in the southwest, about 93% of farmers report that (at least part of) this land is fenced. In the central region, this is only 64%. Consistent with this, 80% 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% of farmers relies on dams as a source of water for the animals. In the southwest, almost 70% 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% 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% of farmers report that they always have trouble getting sufficient water for their dairy activities, while this is only 8% in the southwest.

4.1.5 | 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 4 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% of farmers in the southwest use stainless steel or aluminum buckets or containers to collect and store the milk, this is only 20% 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% of the traders that were interviewed in the southwest reported that they only use proper milk cans for their business. This was only 10% in the central region. A trader in the southwest has on average 4.4 milk cans. Most of these are 25 liter cans. The differences between the milk sheds are smaller at the level of the milk collection cen-

ters. In the central milk shed, 62% of milk collection centers reported to be using only stainless steel or aluminum containers. In the southwest this is 84%. 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% 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 ($p = 0.003$).

4.2 | Econometric analysis – Integration into modern dairy value chains

The previous section explored innovations within the dairy value chain by comparing the predominantly export oriented southwestern milk shed to the central milk shed that supplies the local market. In this section, we focus on integration into modern dairy value chains more generally. To do so, we define indicators of integration into modern value chains that cut across geographic location. Indeed, 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.

The indicator of integration in modern value chains includes export-led value chains, but also comprises 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 enables us to differentiate between commercially oriented farmers that produce for the market on a daily basis and farmers that mainly produce for own consumption but may sporadically sell when they have a surplus. Deliveries to milk collection centers can be made directly, or indirectly through a trader or a transporter[10]. Using this definition, we find that half of the farmers in our sample are integrated into modern value chains. As expected, there is a significant overlap of this indicator with the milk sheds: in the central region, only about 40% 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. More in particular, we first ask how much milk was collected from farmers on an average day during last dry season. We then probed for the share of milk that was delivered to different outlets on an average day during the last dry season. Farmers that supply 100% of collected milk to milk collection centers or processors were defined as being integrated into modern dairy value chains. According to this definition, about 43% of traders are integrated into modern value chains. As for traders, there is also a difference between the sheds, with about 38% of farmers integrated in modern chains in the central region, while this is 62% 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% of milk collection centers located in the central milk shed are integrated into modern value chains, while this goes up to 81% in the southwestern milk shed.

4.2.1 | 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 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 & Rubin, 1983). Results are in Table 5. The different innovations are indicated in the left column. For instance, we look at midstream service delivery (such as the provision of training, inputs and credit), adoption of improved animals, adoption of improved pasture management (paddocking) and

[10] We asked farmers different questions depending on where the trader or transporter would take the milk.

TABLE 5 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 aluminium 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% level, ** at 5%, and *** at 1%.

innovations in the sphere of milk sanitation. In the first column (1) of the table, means for 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 simple differences between the average among farmers that are integrated in modern value chains and the control group for each of the innovation indicated in the left column. The third column (3) in Table 5 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 neighbor, 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[11]. Full results for the regressions in this column are presented in the Appendix (Table A1 to Table A3).

Finally, in the last column (4) of Table 5 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 neighbor matching with a caliper of 0.05[12]. Doing so, we were able to match 373 farmers that participate in modern value chains to 373 traditional farmers. Appendix Table A4 shows that this procedure considerably improves balance between the sample

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

[12] 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.

of farmers that is integrated in modern value chains and those that are not.

As mentioned in section 4.1.5, 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% of farmers in local value chains report that they have received some kind of assistance from the buyer (column 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 3). Full results for the regression in Appendix Table A1 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 5 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 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% 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% 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% 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 dairy cooperatives are much more prevalent in the southwestern milk shed.

The adoption of improved cows is another important innovation at the producer level. Table 5 shows that in the control group of farmers that are integrated in traditional dairy value chains, about 40% 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% level.

Value chain financing was also highlighted in the previous section. We asked if farmers obtained a loan in the previous year that was invested in the dairy business. Table 5 shows few farmers in the control group reported that they took a loan (8%). Simple differences reveal that this is almost 15% 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% 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% 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% of farmers in the traditional 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.

4.2.2 | Traders

Table 6 shows results for a similar analysis using the trader data. Also here, we show averages in the subsample of traders that are integrated in traditional value chains (column 1) and differences with those that are

TABLE 6 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 aluminium 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.

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 A5). 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 A6 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% 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 take 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% of traders that are working in the traditional milk sub-sector have borrowed to invest in their business, and there is no significant difference between traders in the traditional and modern sub-sector.

The last two rows in Table 6 look at innovations in quality preservation of milk. We see that about 20% 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% 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.

4.2.3 | Milk collection centers

Finally, we also look at innovations using the data that was collected on milk collection centers. Results are presented in Table 7. 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 7 only shows coefficient estimates on the indicator for the milk collection center being part of a value chain linking producers to

TABLE 7 Innovations in modern value chains – milk collection centers

	(1)	(2)	(3)	(4)
Milk collection centers				
Milk collection center 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% level.

processors; full results can be found in Appendix Table A7 We also provide results based on matching in column 4. Appendix Table A.8 shows balance on the covariates before and after matching[13].

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 A7, 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 consistent with some processors maintaining their own collection centers.

The next eight rows in Table 7 concern services that milk collection centers report that they provide, and correspond 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 A7 show that, consistent with Figure 5, milk collection centers in the southwestern milk shed report that they are more likely to provide milk cans to their suppliers. 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

[13] 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.

found in Table 4 thus seems again due to the milk shed (see Appendix Table A7).

5 | 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 first highlighting some of the differences and similarities between the central milk shed and the southwestern milk shed. The southwestern milk shed has received substantial FDI in recent years, mainly in the form of processing capacity for the export market, while the central milk shed is quickly become the most important source of dairy products for the local market. In a second part of the article, we constructed an indicator that captures integration in modern value chains more generally across the two milk sheds, and compared characteristics of actors that are part of more traditional dairy supply chains.

We found that the proliferation of milk collection centers was an important innovation mid-stream. Milk collection centers 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.

By changing the incentives small dairy farmers face as well as providing them with support services, the rise of modern value chain actors in the midstream of the value chain appeared to enable smallholder farmers to upgrade their practices and increase their productivity as well. We found that farmers that were more integrated into export-led and modern dairy value chains reported higher adoption rates 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[14]. East Coast fever in particular, a tick-borne disease caused by the protozoan parasite, *Theileria Parva*, was reported to be killing many animals. Milk collection centers, to some extent, support farmer by providing them with acaricides and sometimes even veterinary services.

We found evidence of increased attention to quality and milk sanitation, especially in export-led value chains. This was especially the case at the farmer level, where the use of milk cans quickly becomes the norm. Even though not statistically supported (potentially due to smaller sample size), changes also seem to happen at the level of the trader and milk collection center. However, up to now, this seemed to be especially through enforcement of a ban on transporting milk in jerry cans by the DDA. Currently, the Authority focuses on policing the southwestern milk shed, but this may become too costly at a larger scale. In addition, milk quality involves much more than just using proper milk cans. An additional 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 needed for 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 modern 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 midstream 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

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

animal health, generally limited to the supply of acaricides, seem insufficient at present. Ticks become quickly resistant to the acaricides, and some farmers are switching back to local breeds because they are less prone to tick fever. 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 they 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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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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APPENDIX A

TABLE A1 Regressions for farmers

	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: all models include district fixed effects; * denotes significance at 10% level, ** at 5%, and *** at 1%.

TABLE A2 Regressions for farmers (cont.)

	Dependent variable:		
	number 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: all models include district fixed effects; * denotes significance at 10% level, ** at 5%, and *** at 1%.

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TABLE A3 Regressions for farmers (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)
Households 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: all models include district fixed effects; * denotes significance at 10% level, ** at 5%, and *** at 1%.

TABLE A4 Balance on covariates before and after matching: farmers

	before matching		*after matching*	
	means export	means local	means export	means local
Age head (year)	47.76	47.98	47.03	46.73
Head is woman (yes/no)	0.14	0.15	0.16	0.16
Households 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

TABLE A5 Regressions for traders

Dependent variable:				
	Number 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: all models include district fixed effects; * denotes significance at 10% level, ** at 5%, and *** at 1%.

TABLE A6 Balance on covariates before and after matching – traders

	before matching		***after matching***	
	means export	**means local**	**means export**	**means local**
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

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TABLE A7 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	use 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: all models include district fixed effects; * denotes significance at 10% level, ** at 5%, and *** at 1%.

TABLE A8 Balance on covariates before and after matching – milk collection centers

	before matching		*after matching*	
	means export	means local	means export	means local
Age of milk collection center (years)	4.68	3.75	2.47	3.73
Capacity of milk collection center (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