Chapter 7

AGRICULTURAL MECHANIZATION: DRIVERS AND CHARACTERISTICS

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Widespread agricultural mechanization is a very recent phenomenon in Myanmar. In 2010, just 0.5 percent of farm households in the Delta used combine harvesters, and only 6 percent used threshers (Win, Belton, and Zhang 2018). A study of farm production economics in the country's main agricultural zones in 2013/14 found that only 1 percent of paddy-cultivating households used combine harvesters. This was attributed to a combination of low wages and surplus labor in rural areas, poor infrastructure, a poor regulatory environment, and a lack of access to long-term capital among farmers (World Bank 2016).

However, Myanmar's policy reforms and reintegration into regional and global markets between 2011 and 2020 contributed to increasingly dynamic conditions, including economic growth averaging 7 percent per year (ADB 2018), accelerating out-migration from rural areas (Filipski et al. 2020), and rapid rural transformation (Belton and Filipski 2019). This context gave rise to rapid and widespread agricultural mechanization (Win, Belton, and Zhang 2018).

This chapter compares data from two pairs of complementary surveys to assess the effects of these economic changes on the uptake of agricultural mechanization. We combine demand-side (farm household) and supply-side (agricultural machinery retailer) surveys implemented between 2016 and 2018 across two major agroecological zones—a deltaic rice-growing environment (the Delta) and a rainfed semiarid zone (the Dry Zone). This approach allows for triangulation of results and captures variations in mechanization across geographies. In addition, we use data from multiple rounds of rapid assessments to evaluate the impacts of COVID-19 and other recent shocks.

The chapter thus offers a detailed descriptive analysis of the country's recent extraordinarily rapid and pervasive agricultural mechanization, which has not previously been documented systematically. We draw links between these changes and transformations in the economy and policy environment between 2011 and 2020. This enables us to consider the implications of these findings for the viability of smallholder agriculture and to identify a range of factors conditioning the uptake of agricultural machinery beyond the simple substitution of capital for labor.

The chapter is organized as follows. First, we analyze temporal changes in the ownership and use of agricultural machinery. Second, we present data on trends in the geographic spread of machinery supply businesses and the growth of machinery sales. Third, we evaluate evidence of demand- and supply-side factors influencing agricultural mechanization. Fourth, we discuss developments associated with the COVID-19 pandemic and political instability. The final section concludes by summarizing key findings.

Rapid growth period (2011–2019)

We present results from two household surveys and two machinery retailer surveys conducted under the Myanmar Food Security Policy Project (MFSPP). All household-level data presented in the tables and figures originate from these surveys of rural households in two of Myanmar's most important agricultural zones: the Ayeyarwady Delta and the Dry Zone (for details, see Belton et al. 2021).

Demand side

Sequence and timing of mechanization. Ownership of agricultural machinery has grown quickly in both the Delta and the Dry Zone from a very low base, accelerating particularly rapidly from 2010 onward. Consistent with the generalized sequence of mechanization, stationary "power-intensive" operations, such as pumping water and threshing, have been mechanized before mobile "control-intensive" operations, such as harvesting (Pingali 2007).

In the Delta, mechanization began with two-wheel tractors (power tillers, used mainly for land preparation in paddy cultivation) and water pumps (used for many purposes but most importantly, for irrigating dry season paddy). Ownership of these items grew little between 1996 and 2007 but subsequently increased sharply. Delta households began acquiring mechanical paddy threshers and *trawlerji* (farm vehicles running on two-wheel tractor engines) in the mid-2000s. Acquisition of four-wheel tractors increased markedly after 2008 but remained at a fairly low level. Combine harvesters—the most control-intensive machines used—did not appear until 2014 (Table 7.1).

Mechanization in the Dry Zone followed a generalized pattern similar to the Delta but with differences in the composition of machinery, reflecting

TABLE 7.1 Machines acquired per 10,000 landed households, by time period

Machine type	1996–1998	1999–2001	2002–2004	2005–2007	2008–2010	2011–2013	2014–2016
Delta							
Water pump	97	176	14	155	850	805	797
Two-wheel tractor	122	28	157	131	609	454	844
Thresher	0	3	112	193	171	160	275
Trawlerji	0	0	27	33	204	480	81
Four-wheel tractor	0	0	26	6	41	26	21
Combine harvester	0	0	0	0	0	0	107
Dry Zone							
Water pump	4	12	47	40	10	146	138
Two-wheel tractor	33	12	57	118	50	261	296
Thresher	0	9	36	66	43	12	12
Trawlerji	7	0	0	9	19	8	34
Four-wheel tractor	7	0	0	0	6	50	91
Combine harvester	0	0	0	0	0	0	0

Source: Myanmar Food Security Policy Project (MFSPP) surveys.
Note: Machine ownership rates per 10,000 households were estimated using survey weights.

differences in agroecology. As in the Delta, two-wheel tractors and water pumps were the first machines to be used widely and over a similar period. The number of water pumps acquired in the Dry Zone was about half the number of two-wheel tractors, unlike in the Delta, where the number of water pumps exceeded that of two-wheel tractors. This reflects the more limited availability of water in the Dry Zone. The timing of acquisition of threshers follows a similar trend in both zones. However, threshers account for a smaller share of machines owned in the Dry Zone than in the Delta, consistent with the lower prominence of paddy in Dry Zone farming systems (Table 7.1).

Acquisition of four-wheel tractors in the Dry Zone began later than in the Delta but has grown rapidly since 2010, in line with the uptake of these machines to cultivate non-paddy crops. None of the Dry Zone households surveyed had ever owned a combine harvester, reflecting the lesser role of paddy in the cropping systems of the townships surveyed. Ownership of large machines (four-wheel tractors and combines) remains rare in absolute terms, but recent growth in ownership has been rapid—more than half of all four-wheel tractors recorded in the Dry Zone were purchased in just two years, 2015 and 2016. Given the large engine sizes of these machines relative to two-wheel tractors, their uptake represents a massive increase in mechanical power available to farmers. The total value of purchased machines has also increased dramatically over time. By 2017, four-wheel tractors accounted for most of the capital invested in agricultural machinery in the Dry Zone, underlining the speed of the shift to mechanized traction. Similar trends were apparent in the Delta for combine harvesters.

Rental markets and farm size. Despite recent growth in agricultural machinery purchases, absolute ownership levels remain low for most machine types. The likelihood of owning a machine is highly correlated with landholding size. For example, in the Delta in 2016, only 1 percent of all surveyed households owned a four-wheel tractor or combine harvester. No households in landholding tercile 1 (the third of landed households with the smallest landholdings) owned a four-wheel tractor or a combine; this rose to 20 percent and 7 percent, respectively, among households in tercile 3 that used these machines. Similar results were evident for four-wheel tractor ownership in the Dry Zone (Table 7.2).

Ostensibly, this finding supports the conclusion that machines are "lumpy" inputs that require high levels of initial capital investment and "reach their lowest cost of operation per unit at relatively large areas," thus favoring adoption by large farms (van Zyl, Binswanger, and Thirtle 1995, 3). This logic led Pingali (2007, 2790) to argue, with reference to Southeast Asia, that "in the absence of land consolidation and the re-design of the rice land to form large contiguous fields, the prospects for large-scale adoption of the harvester-combines are limited."

To the contrary, our data show that the growth of outsourcing services has enabled farms to mechanize irrespective of machine ownership and independent of farm size. Eighty-nine percent of the agricultural machinery used by farmers in the Dry Zone and 60 percent in the Delta is rented. This regional difference reflects relatively high levels of ownership of two-wheel tractors in the paddy-dominated Delta, but in both zones, four-wheel tractors and combine harvesters are accessed almost exclusively through renting (Table 7.2). There is no statistically significant difference in the use of two-wheel and four-wheel tractors by landholding tercile in either the Delta or the Dry Zone, no difference for combine harvesters in the Dry Zone, and no difference for threshers in the Delta. We conclude that the likelihood of a household using these types of machines is largely independent of landholding size.

The rapid growth of machinery rental markets has enabled smaller landholders to access many of the benefits of agricultural machinery use—for example, labor savings and timely completion of activities—that machine

TABLE 7.2 Farm households using agricultural machinery in the past 12 months, by landholding size terciles and machine ownership status

	Share of farm households (%)											
	Tercile 1 (smallest)			Tercile 2			Tercile 3 (largest)			All terciles		
	Use	Own	Rent	Use	Own	Rent	Use	Own	Rent	Use	Own	Rent
Delta												
Two-wheel tractor	76	15	85	72	35	65	70	90	10	73	43*	57
Four-wheel tractor	18	0	100	23	8	92	24	20	80	21	10*	90
Thresher	41	3	97	47	15	85	41	56	44	43	23*	77
Combine harvester	43	0	100	49	0	100	62	7	93	51*	3*	97
Any machine	96	12	88	96	32	68	97	81	19	96	40*	60
Farm size, range (hectares)	<0.1–0.9			1.0–3.2			3.3–33.6			<0.1–33.6		
Farm size, mean (hectares)	0.7			2.2			7.1			4.1		
Households (number)	110			111			108			329		
Dry Zone												
Two-wheel tractor	30	11	99	26	29	71	26	60	40	27	30*	70
Four-wheel tractor	50	0	100	44	0	100	54	10	90	50	4*	96
Thresher	39	1	99	34	2	98	22	10	90	33*	3*	97
Combine harvester	8	0	100	11	0	100	9	0	100	9	0	100
Any machine	80	4	96	72	9	91	79	22	78	78	11*	89
Farm size, range (hectares)	<0.1–1.2			1.2–2.8			2.8–21.7			<0.1–21.7		
Farm size, mean (hectares)	1.8			2.0			5.9			2.8		
Households (number)	339			282			315			936		

Source: MFSPP surveys.

Note: Interviews were conducted in mid-2016 in the Delta and in mid-2017 in the Dry Zone. The recall period for data presented in this table is the 12 months preceding each survey. "Use" is the share of crop-farming households that used the type of machinery per group, whether owned or rented. "Own" and "rent" are the shares of using households that owned or rented the type of machinery per group, conditional on use. The asterisk indicates that, for this parameter, there was a statistically significant difference between terciles at $p < 0.05$ (for at least one of the possible pairwise tests, T1 vs. T2, T1 vs. T3, or T2 vs. T3).

owners with relatively large landholdings obtain. Our findings suggest that, where outsourcing services exist, land consolidation is not a precondition for widespread uptake of even quite large agricultural machinery. We also find no evidence of accelerated land consolidation occurring as a result of the introduction of agricultural machinery. Such a process might be expected if only large farms could utilize these technologies and gained an advantage by doing so. In fact, average farm sizes in both zones are falling due to subdivision at inheritance (Belton et al. 2021; Boutry et al. 2017).

A vibrant informal private sector dominates the outsourcing services market. The rapid emergence of these small businesses reflects the existence of dense kin and community networks that serve as conduits for information (Faxon 2020). This has been magnified by the spread of mobile phone and internet communications, which accelerated at extreme speed between 2014 and 2020 (Belton et al. 2021). The extent and strength of informal social ties contrast with generally low levels of trust in strangers and government institutions as a result of Myanmar's repressive political history.

Although the government's Agricultural Mechanization Department (AMD) offers some machinery rental services, none of the households surveyed in the Delta reported using them, and only nine farmers in the Dry Zone did so, making up less than 1 percent of all machinery rentals by farmers. Machine rental by formal private businesses, such as machinery retailers, is also limited. This pattern seems to reflect the advantages that informal outsourcers with well-developed social networks in rural communities have in terms of flexibility and responsiveness, compared with centralized models of service provision.

Decentralized private service provision may provide other advantages. In a detailed study of green gram (mung bean) producers in Yangon, Okamoto (2008) found that farmers favored rental services provided by four-wheel tractor owners over those offered by AMD or the Myanmar Economic Holdings company, a large military-owned enterprise. This was because of the poor maintenance of machines from the latter two sources and the "negligence" of their operators, ascribed to the low wages the operators received.

Interzone differences in the form and extent of mechanization. Despite similarities across zones in the timing and pace of agricultural mechanization, important zonal differences in agricultural machinery use reflect variations in agroecology and associated crop choices. Paddy cultivation has undergone, by far, the most complete mechanization. The most pronounced interzonal difference relates to how tractors have been used as a substitute or complement for animal draft power. In areas of the Delta surveyed in 2016, machinery had almost wholly replaced animal traction in farming—94 percent of farming households reported using machinery for land preparation in the 12 months preceding the survey, while only 12 percent reported using draft animals (Table 7.3).

TABLE 7.3 Use by farm households of machines and draft animals, by activity and year

	Share of farm households (%)				
	2007/8 Using machine	2012/13 Using machine	2016/17 Using machine	2016/17 Using animal	Sample size
Land preparation					
Delta	35	72	98	12	329
Dry Zone	11	32	74	83	1,024
Harvesting					
Delta	5	10	57	1.5	329
Dry Zone	<1	3	12	2	1,024

Source: MFSPP surveys.

These findings contradict the traditional view that most farm households in Myanmar still rely on buffalo to plow paddy fields (Woods 2013). Soe and Kyaw (2019) report a similar recent shift from animal to machine traction in the uplands of southern Shan State. Based on a survey of maize and pigeon pea farmers, they found that machines had nearly replaced draft animals in land preparation, with around 80 percent of surveyed households using only machines for this purpose and 10 percent using draft animals.

A contrasting scenario prevailed in the Dry Zone in 2017, where widespread uptake of tractors coexisted with the continued use of draft animal power for land preparation by almost all farmers. Three-quarters (76 percent) of farm households reported using machines and draft animals, 22 percent relied exclusively on draft animals, and just 2 percent used machinery only (Table 7.3). This pattern appears to reflect differences in crop choice and soil quality between the zones. In scoping interviews, farmers indicated that, particularly when cultivating sesame and groundnut, they used tractors primarily to break up hardened soils during initial plowing and preferred animal power for subsequent harrowing and inter-cultivation.

The type of machinery used is influenced strongly by the dominant cropping system. Two-wheel tractors are deployed mainly in rice cultivation for puddling flood-irrigated soils, because the heavier four-wheel tractors tend to sink into the muddy ground. Four-wheel tractors are preferred for preparing land for planting rainfed crops on soils that require more power to break apart on first plowing. As a result, in the Delta, 73 percent and 21 percent of farm households used two- and four-wheel tractors, respectively, whereas in the Dry Zone, the corresponding shares were 27 percent and 50 percent.

Even more pronounced differences are found in harvesting and threshing. In the Delta, the use of machinery for this purpose is almost as widespread as its use for land preparation. Half of farm households (51 percent) surveyed in 2016 used a combine harvester, while 43 percent used mechanical threshers—that is, at least 90 percent of farms used machinery for harvesting or threshing, given that combines also thresh. In contrast, one-third of farm households surveyed in the Dry Zone reported using mechanical threshers for harvesting crops, and only 11 percent used a combine harvester. Phyo and colleagues (2019) report similar levels of combine harvester use, based on a survey conducted in 2017. They found that 55 percent of farm households in the Delta and 10 percent in the Dry Zone had used a combine harvester that year, up from 11 percent and 2 percent in 2014.

Nearly all crop-farming households in the Delta grow paddy, compared with only half in surveyed areas of the Dry Zone, and paddy occupies a much larger share of cultivated land in the former. To date, with the partial exception of green gram, there is little mechanized threshing and no mechanized harvesting of any crop other than rice in the two zones. As a result, the pool of harvesting and threshing machinery users is much smaller in the Dry Zone than in the Delta.

The extent of mechanization in paddy production varies by season in both zones. In the Delta, 19 percent of farm households used combines to harvest the monsoon paddy crop in 2015, compared with 35 percent of households that used combines during the following dry season.[1] In the Dry Zone, only 13 percent of paddy farming households used a combine during the monsoon season in 2016, compared with 41 percent of households that grew paddy during the following dry season (though far fewer households grew dry season rice).

Interseasonal variation is partly explained by the spatial concentration of paddy cultivation and harvesting services in irrigated or naturally well-watered areas, where large contiguous paddy areas give outsourcing service providers access to high concentrations of customers. Higher rates of combine harvester use during the dry season may also be linked to the ability to harvest and thresh paddy quickly, making it possible to plant the subsequent monsoon paddy crop in time. Respondents in the Dry Zone reported that combine harvesting could reduce the palatability and volume of rice straw used as fodder for draft animals, leading some farmers to be unwilling to use combines on

1 Most farm households in the Delta grow a monsoon rice crop followed by a post-monsoon pulse crop. In low-lying areas that are inundated by monsoon flooding, most households grow a single post-monsoon rice crop. Few households double-crop rice, and not all of these use a combine harvester in both seasons. The share of farm households using a combine harvester to harvest rice in any season is 51 percent.

monsoon paddy, which provides the bulk of the straw used as fodder (Mather and Belton 2018).

Supply-side trends

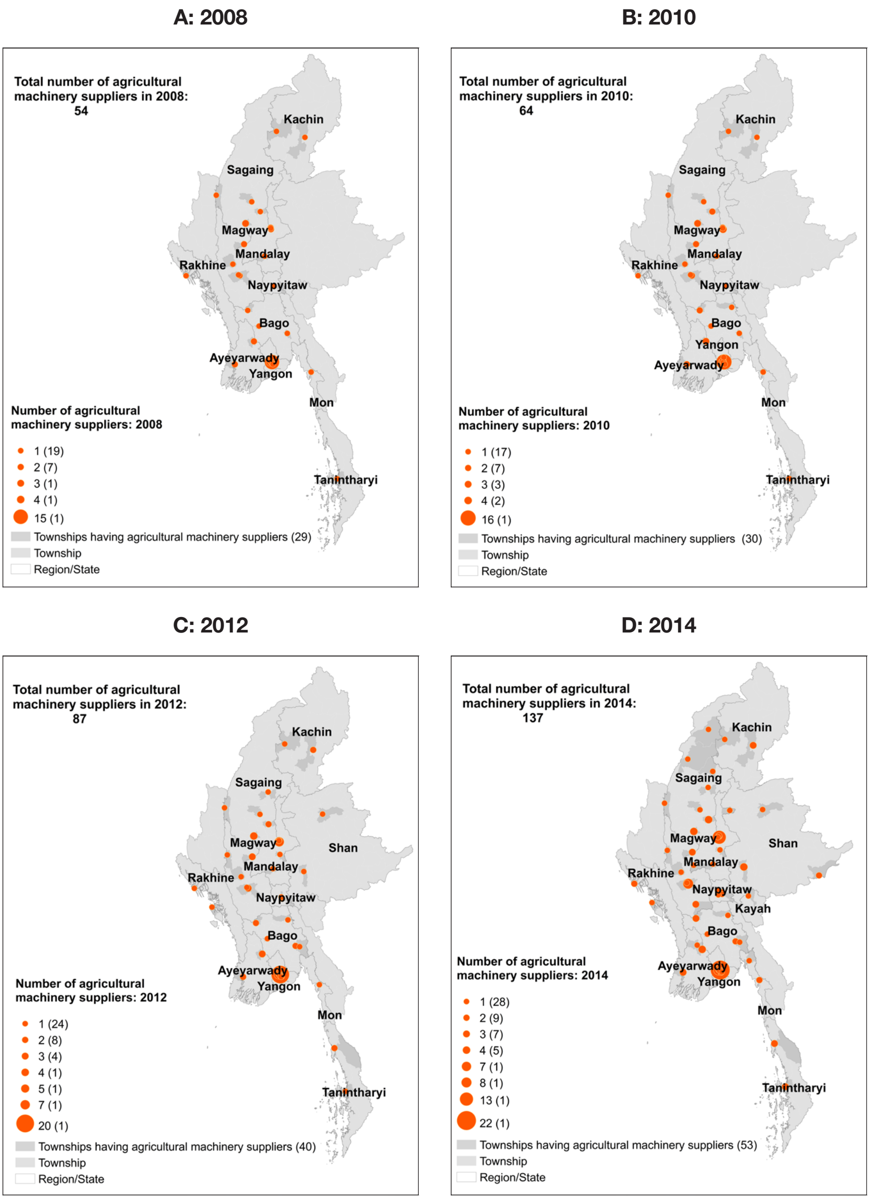
This section focuses on the supply side of agricultural mechanization, tracking the spatial and temporal spread of machinery supply businesses and growth and regional variation in machine sales.

Spatial and temporal spread of machinery retailers. Machinery supply businesses were first established in urban centers adjacent to the "core" rice-growing regions that were the first to begin the process of mechanization. Over time, retail outlets have radiated outward to reach parts of the Dry Zone specializing in non-rice crops, finally extending to more "peripheral" zones in upland and border areas. The number of machinery supply outlets jumped 338 percent between 2008 and 2018, up from 72 to 315, while the number of townships that machinery retailers served rose from 36 to 88 (27 percent of townships in the country) (Figure 7.1). As a result, agricultural machinery has become locally available for purchase over progressively greater swathes of Myanmar, contributing to accelerating uptake. We recognize the potential for some "survivor bias" in our sampling methodology, as it was impossible to include enterprises that had gone out of business prior to the survey. However, given the extremely rapid growth of machinery retail businesses in the years immediately preceding the surveys and the close match between results in the supply- and demand-side studies, we are confident these trends are not inflated.

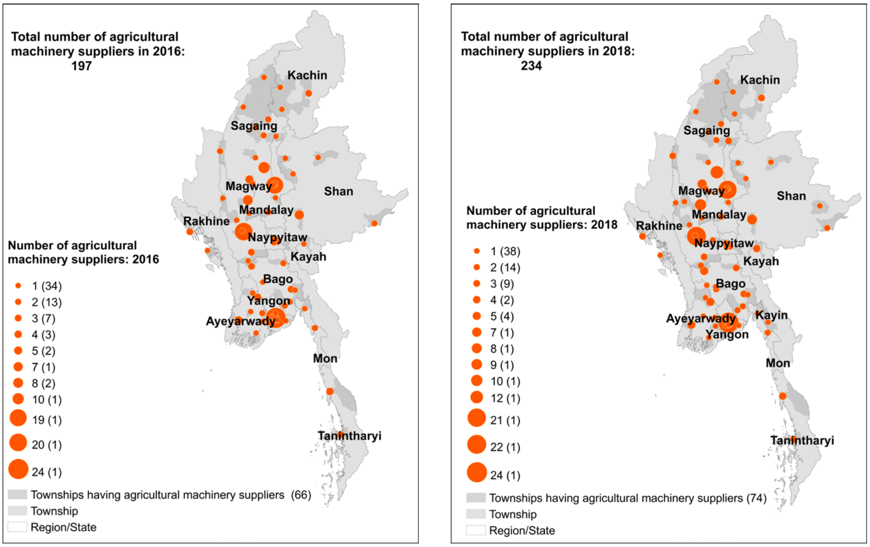
During the 1980s and 1990s, machinery retail businesses were concentrated in Yangon. The number of machinery retailers grew slowly during this period. From 2000 to 2010, their numbers increased gradually in the Delta, the Dry Zone, and southern Shan. However, machinery retailers remained concentrated in the Delta, especially in Yangon. The Delta accounted for more than half of all outlets during this time. The first machinery supply businesses outside of these three zones were established in 2006 in the Hills/Borders states of Mon, Tanintharyi, and Rakhine. New businesses opened in all zones from this time, resulting in the Delta's share of the national total of agricultural machinery retailers falling from 42 percent in 2012 to 34 percent in 2018.

The Dry Zone experienced an explosion in the number of machinery enterprises from 2015, as widespread uptake of agricultural machines advanced beyond pockets of irrigated paddy to rainfed areas dominated by pulse and oilseed production. Retailers opened branches in "new" hinterland areas to extend their customer base as markets for machinery in the country's

FIGURE 7.1 Location and number of machinery supply businesses over time, 2008–2018



E: 2016 F: 2018



Source: Belton, Win, Zhang, and Filipiski (2021), using data from MFSPP surveys.

TABLE 7.4 Machinery businesses by geographic zone over time, 2000–2018

	Share of businesses (%)						
Zone	2000	2003	2006	2009	2012	2015	2018
Delta	61	63	57	50	42	32	34
Dry Zone	14	20	24	29	34	43	43
Hills/Borders	25	18	19	21	24	25	23

Source: MFSPP surveys.

Note: Delta = Ayeyarwady, Bago, and Yangon. Dry Zone = Magway, Mandalay, Naypyidaw, and Sagaing. Hills/Borders = Kachin, Kayah, Mon, Rakhine, Shan, and Tanintharyi.

agricultural heartland started to mature. Numbers of machinery supply businesses in the Hills/Borders states also grew, though more slowly than in other zones, accounting for 23 percent of the national total in 2018. Mechanization in the Hills/Borders is concentrated in upland maize cultivation, for which two-wheel tractors and maize threshers are commonly used (Soe and Kyaw 2019) (Table 7.4).

Meanwhile, the machinery retail sector has become more concentrated over time. In 2003, retailers with a single outlet operated 38 percent of outlets,

TABLE 7.5 Total annual sales of surveyed agricultural machinery supply businesses in Yangon (2012–2016) and the Dry Zone (2013–2017)

	Number					
Machine type	2012	2013	2014	2015	2016	2017
Yangon						
Four-wheel tractor	275	420	870	1,662	3,200	—
Two-wheel tractor	4,959	6,450	7,457	8,772	13,824	—
Water pump	960	1,035	2,551	2,585	4,150	—
Engine/ dynamo	4,025	10,512	60,255	56,518	94,876	—
Combine harvester	0	40	237	955	2,372	—
Reaper	305	335	860	1,351	1,244	—
Thresher	0	30	220	167	46	—
Trawlerji	1,692	1,840	2,500	2,500	3,700	—
Dry Zone						
Four-wheel tractor	—	1,045	1,320	2,771	4,278	3,584
Two-wheel tractor	—	440	2,678	1,978	3,338	3,190
Water pump	—	110	155	130	171	146
Engine/ dynamo	—	480	2,690	2,002	1,969	2,672
Combine harvester	—	0	15	140	523	407
Reaper	—	10	10	229	248	273
Thresher	—	0	10	21	31	56
Trawlerji	—	5	263	345	349	553

Source: MFSPP surveys.
Note: — = data not available. NA = not applicable.

and retailers with 2–10 branches operated the remainder. By 2018, retailers with a single outlet operated only 16 percent of outlets, while retailers with more than 10 branches operated almost half—the largest operated 45 branches nationwide.

Composition of and growth in machine sales. Growth in sales by machine supply businesses between 2012 and 2016 occurred simultaneously with the upsurge in machine ownership reported in the previous section. The most rapid sales growth occurred between 2014 and 2015, when large numbers of new machinery supply outlets were established, particularly in the Dry Zone. More than one-third (37 percent) of all machinery supply businesses in the Dry Zone were established during these two years alone.

% change						
2012–13	2013–14	2014–15	2015–16	2016–17	2012–2016	2013–2017
53	107	91	93	—	1064	—
30	16	–28	18	—	179	—
8	146	–6	1	—	332	—
161	473	303	–6	—	2257	—
NA	493	303	148	—	NA	—
10	157	57	–8	—	308	—
NA	633	–24	–72	—	NA	—
9	36	0	48	—	119	—
—	26	110	54	–16	—	243
—	509	–26	69	–4	—	625
—	41	–16	32	–15	—	33
—	460	–26	–2	36	—	457
—	NA	833	274	–22	—	NA
—	0	2190	8	10	—	2630
—	NA	110	48	81	—	NA
—	5160	31	1	58	—	10960

The assortment of products stocked by machinery retailers matches regional customer preferences. For instance, four-wheel tractors were stocked by 95 percent of Dry Zone businesses, but only 44 percent of those in the Delta. Since 2012, small machines used in rice cultivation (water pumps, two-wheel tractors, and two-wheel tractor engines) have accounted for the bulk of sales for machinery retailers based in Yangon (Table 7.5). Sales of four-wheel tractors and combine harvesters grew particularly rapidly after 2014. Annual sales of combine harvesters by machinery retailers in Yangon increased nearly 6,000 percent (from an extremely low base) in four years, with 90 percent of sales occurring in 2015 and 2016. In the Dry Zone, four-wheel tractors and their attachments (disc plows and rotary tillers) are the most important items in terms of total sales. Dry Zone machinery supply businesses reported high, briskly growing sales of four-wheel tractors and their attachments throughout

2013–2017, roughly matching sales of two-wheel tractors. Sales of combine harvesters in the Dry Zone accelerated particularly rapidly from 2015 (Table 7.5).

By 2017, more retailers offered a wider assortment of agricultural equipment than ever before. At least 12 types of agricultural machines and equipment were available from Dry Zone retailers. In contrast, in the early 2000s, only engines, light trucks, and four-wheel tractors were sold. The number of businesses marketing each type of machine also increased sharply, with all items except trucks available from at least 10 surveyed businesses. Available brands of machinery also proliferated as retailers sought to differentiate themselves. For instance, from 2013 to 2017, the number of four-wheel tractor brands for sale grew from 6 to 24, while the number of combine harvester brands grew from 0 to 9.

However, the 2013–2016 boom in agricultural machinery sales appears to have peaked or plateaued in the Dry Zone in 2017. Sales of four-wheel tractors and combines by Dry Zone machinery retailers were 22 percent and 16 percent lower, respectively, in 2017 than in 2016.[2] This pattern was not yet apparent in Yangon at the time of the 2016 survey, however (Table 7.5).

Factors influencing mechanization

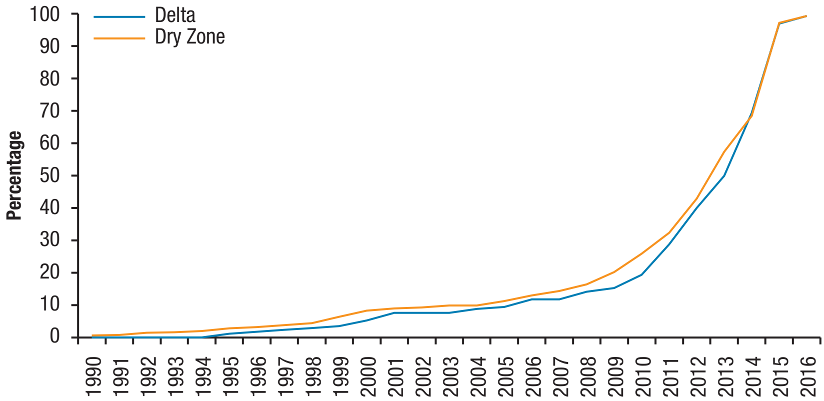
This section explains trends in farmer adoption of agricultural machinery with reference to key demand- and supply-side factors influencing adoption, including policies.

Structural transformation

We observe a strong correlation between the timing of rural–urban migration, rising rural wage rates, and the adoption of agricultural machinery in surveyed areas of Myanmar. The onset of agricultural mechanization coincides with an uptick in migration that began around 2010 and continued in parallel with rapid urbanization until 2020. Eighty percent of all individuals in surveyed areas of the Delta and Dry Zone who had ever migrated did so after 2010. In both zones, migration increased briskly but steadily from 2011 to 2014 before accelerating faster still. More than half of all reported migration in both zones occurred between 2013 and 2016 (Figure 7.2). Sixteen percent of households in surveyed areas of the Delta reported having at least one

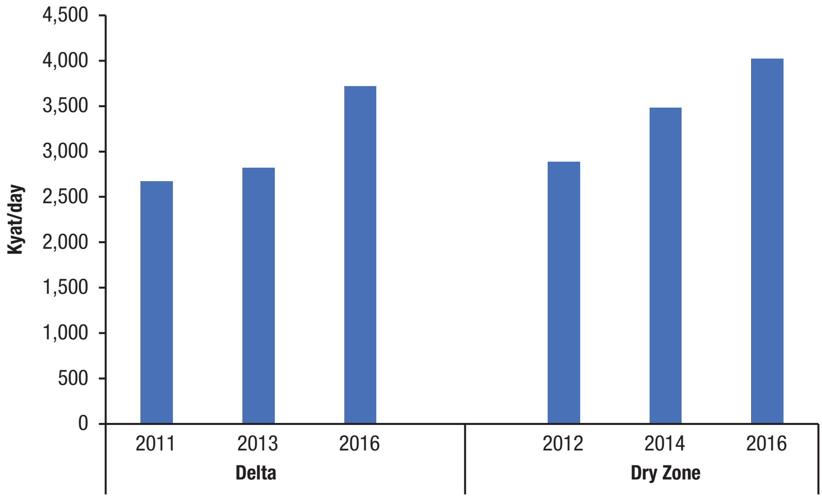
2 Sales figures were collected during December 2017, so they likely slightly underrepresent total sales for the full year.

FIGURE 7.2 Cumulative share of migrants from Delta and Dry Zone, by year of migration, 1990–2016



Source: MFSPP surveys.

FIGURE 7.3 Average daily wage rates for casual agricultural labor in the Delta (2011–2016) and the Dry Zone (2012–2016), kyat



Source: MFSPP surveys.

migrating member at the time of the interview. The figure for the Dry Zone was 24 percent. Other studies report similar figures (CHIME 2019; Filipski et al. 2021; Pritchard et al. 2017).

The average age of migrants when first migrating is in the early 20s, so they are concentrated disproportionately among the most economically active and productive segments of the labor force. This migration pattern resulted in a significant contraction in the pool of available agricultural workers during the period when the surveys were implemented, which our respondents mentioned frequently. In some cases, migrants' remittances provide money to purchase machinery or hire mechanization services (Faxon 2020).

Phyo and colleagues (2019) also report labor shortages at key times of the cropping calendar in both the Delta and the Dry Zone. They found that labor available for agriculture in these areas was insufficient to meet farms' requirements, estimating that farms double-cropping rice faced an average labor shortfall of 36 percent, while those growing rice followed by pulses faced a shortfall of 29 percent. They attributed these shortages to simultaneous increases in migration and nonfarm employment, noting that self-employment in nonfarm enterprises, services, and casual and salaried nonfarm work accounted for a substantial and growing share of employment in both areas.

These observations align strongly with results from MAPSA surveys, which indicate high levels of livelihood diversification and a proliferation of nonfarm enterprises in both the Delta and the Dry Zone over the same period as the upsurge in mechanization and migration. This pattern signals growing rural economic opportunities outside the sphere of agriculture and, with them, changing expectations, as nonfarm work is increasingly preferred to physical labor "under the sun" (CHIME 2019; Faxon 2020; Phyo et al. 2016). Improvements in access to post-primary education since 2011 have likely also reduced the supply of agricultural workers by delaying the age of first entry into the workforce. For example, in the rural Dry Zone, the share of 17-year-olds completing Grade 8 grew from 35 percent in 2010 to 60 percent in 2017 (Belton and Filipski 2019).

These changes appear to be responsible for a sharp increase in real agricultural wages. Recall data from our surveys show that real wages for casual farm workers (adjusted for inflation) increased by 37 percent in surveyed areas of the Delta from 2011 to 2016 and 39 percent in the Dry Zone from 2012 to 2016 (Figure 7.3). Hired labor is one of the largest categories of expenditure, even for small farms, amounting to between 20 and 30 percent of production costs depending on the crop. Almost all farms in the Delta (95 percent) and Dry Zone (93 percent) employ casual workers (Cho, Belton, and Boughton

2017; Mather et al. 2018). Increasing real wages, therefore, seems to have provided an important incentive for farmers to mechanize the most labor-intensive parts of their crop production where possible.

Timeliness, speed, drudgery, risk, and yields

Data from our survey of Dry Zone households point to a mix of benefits associated with mechanization beyond simple reductions in labor costs. These include (1) increased speed of operations and reduced drudgery, (2) enhanced timeliness of key activities, (3) improved ability to manage weather-related risks, and (4) reduced losses of grain during harvesting.

- Mechanization reduces the amount of time required to complete critical activities. Preparing 1 hectare (ha) of land for planting with draft animals takes an average of 31 hours, compared with 10 hours with a two-wheel tractor and 3 hours with a four-wheel tractor (Soe and Kyaw 2019). By shortening the duration of these tasks, mechanization reduces the amount of physically demanding work that members of farm households must perform. As the amount of hired labor and the opportunity cost of family labor that mechanized land preparation saves are quite small, the widespread uptake of machines for land preparation suggests farm households may consider their drudgery-reducing characteristics at least as important as pecuniary factors, such as lower expenses or higher margins (van der Ploeg 2013). A further advantage of mechanical tractors is that they require only occasional maintenance and outlay on fuel. In contrast, draft animals must be cared for constantly, with daily feeding, watering, and washing—requiring an average of 1.5 hours of labor each day. Fodder is often purchased, and hired labor and veterinary expenses may be required, equating to an average outlay of $58 per year by households owning draft animals (Soe and Kyaw 2019).
- Labor scarcity can make it difficult to marshal sufficient workers to perform time-dependent tasks. Some farmers seek to avoid this problem by offering advance wages to workers one to two months before harvest to guarantee their availability (Okamoto, Lwin, and Fujita 2021). Although this practice remains relatively common in the Delta and the Dry Zone, it can be difficult for farmers to raise sufficient funds to pay advances, so most workers are not contracted in advance. In contrast, our scoping interviews suggest that mechanization services can be scheduled some days or weeks in advance and that, particularly for harvesting, payment is often

made after crops have been sold, ensuring greater timeliness and reducing cash flow problems for farm households.

- Timeliness and speed of operations can facilitate risk management. In the Delta, timely harvesting of the monsoon rice crop is essential for farmers planting a post-monsoon pulse crop that relies on residual soil moisture. The timing of planting and harvesting is even more significant in the Dry Zone, where most farming is rainfed and weather patterns can be highly variable from year to year (Matsuda 2013). Excessive or inadequate rainfall early or late in the cropping cycle or heavy rain while the crop is drying cause sizable crop losses. One-quarter to one-half of Dry Zone farmers report weather-related yield losses for their major crops (Mather et al. 2018). Growers of dry-season paddy and groundnut who had used a tractor were less likely than those using only draft animals to report any pre- or postharvest crop losses, suggesting that mechanization may help moderate these risks. For example, 29 percent of dry-season paddy farmers who had used a tractor reported crop losses, compared with 40 percent of those who had not. Groundnut growers' shares were 16 percent and 33 percent, respectively.
- Farmers using combine harvesters report higher yields than those using mechanized threshers, and farmers using mechanized threshers report higher yields than those who thresh paddy manually. During the dry season, Dry Zone combine harvester users reported obtaining 640 kg more paddy per ha than did households practicing manual harvesting/threshing (a 19.5 percent yield difference). The yield gap between households using combines and those using mechanized threshers stood at 400 kg per ha, or 11 percent of the harvest (Mather and Belton 2018). Farmers interviewed during scoping research attributed these gains to reduced grain spillage during harvesting and threshing, implying higher realized yields through reduced waste rather than increases in biological productivity.

Financing and machinery prices

On the supply side, during the period covered by the surveys, increasing access to formal financial services made it easier for potential buyers to purchase agricultural machinery, while the real price of such machinery fell steadily following the removal of import restrictions. These developments placed agricultural machine ownership within the reach of a growing, though still relatively small, segment of the rural population.

At the time of the surveys, two main forms of consumer finance were available for agricultural machinery: (1) hire purchase loans offered by machinery retailers using their own working capital and (2) hire purchase arrangements offered by private banks and other commercial financial institutions in partnership with machinery retailers. Financing from banks helped overcome liquidity constraints for machinery retailers and their customers. Banking regulations prevent businesses from borrowing more than the value of their fixed assets, making it challenging for financial institutions to extend large volumes of credit, particularly for four-wheel tractors and combines, which cost between $13,000 and $31,000, depending on brand and country of origin. Under hire purchase arrangements offered by banks to customers, customers were vetted by machinery dealers, which served as guarantors to the bank. Customers made a down payment and repaid the remaining principal in installments with interest, usually over one to two years. Hire purchase loans thus removed the need for buyers to save the entire cost of a machine before making a purchase. Interest on loans issued by commercial lenders is capped at 13 percent per year. In contrast, informal lenders charge interest rates averaging around 5 percent per month (60 percent per year). Such terms make it unviable to fund machine purchases for either personal use or rental service provision, and respondents rarely reported using this source of credit.

Banks first began to offer hire purchase loans for agricultural machinery in 2013. The number of banks providing this type of finance increased quickly, from 5 in 2014 to 11 in 2017. Throughout this period, two banks, Yoma and Myanmar Citizens' Bank, dominated the provision of hire purchase finance. Yoma accounted for 41 percent of partnerships with machinery dealerships in 2014, rising to 48 percent in 2017, whereas Myanmar Citizens' Bank accounted for 23 percent of partnerships in 2014, remaining constant at 24 percent in 2017. The uptake of these financial services has been swift. Almost all (94 percent) machinery supply businesses surveyed in the Dry Zone in 2017 offered some form of hire purchase financing, among which 84 percent did so in partnership with banks. By 2016, hire purchase loans from banks financed most sales of combine harvesters and four-wheel tractors by retailers in Yangon (77 percent and 68 percent, respectively). Even higher levels of use were reported in the Dry Zone in 2017, where bank-supported hire purchases accounted for 98 percent of combine harvester sales and 62 percent of four-wheel tractor sales. In contrast, hire purchase finance direct from machinery retailers to customers accounted for just 5 percent and 2 percent of four-wheel tractor and combine harvester sales in Yangon in 2016, respectively, and 16 percent and 2 percent in the Dry Zone in 2017 (Table 7.6).

TABLE 7.6 Share of Yangon (2016) and Dry Zone (2017) machinery supplier sales, by source of finance and machine type

	Share of sales (%)		
Finance source	Combine harvester	Four-wheel tractor	Two-wheel tractor
Yangon			
Bank (hire purchase)	77	68	35
Dealership (hire purchase)	2	5	17
Customer (paid in full)	22	27	48
Dry Zone			
Bank (hire purchase)	98	62	74
Dealership (hire purchase)	2	16	17
Customer (paid in full)	0	22	9

Source: MFSPP surveys.

Over the same period, machinery—which is nearly all imported—became more affordable. This reflected the increased supply of machinery at competitive prices, primarily from neighboring China and Thailand, as well as Myanmar's policy of not levying tariffs on imports of agricultural inputs, including machines and machine parts. The real (inflation-adjusted) average cost of purchasing a water pump, as reported by households in the Dry Zone, dropped from $800 in 2007 to less than $300 in 2017, an average reduction of $50 per year, while the cost of a two-wheel tractor dropped from nearly $3,000 to well below $1,000 over the same period. Households in the Delta reported similar figures.

Policies and interventions

Changes in the accessibility of machines and finance for machine purchases stem mainly from policy changes implemented during the period of reforms from 2011 to 2020. Donor-supported interventions played a complementary role.

Prior to 2012, private banks were not allowed to extend credit to farmers (OECD 2014). Relaxation of these restrictions played a critical role in enabling the provision of formal finance for machinery purchases. Myanmar's Farmland Law, passed in 2012, played a complementary role. This law made agricultural land use rights transferable, allowing the utilization of land use rights certificates ("Form 7") as collateral for formal loans. This change overcame an important obstacle to accessing finance, at least in lowland regions, where a high percentage of farm households possess formal title to the lands they occupy (Boutry et al. 2017). However, ownership and use of two-wheel tractors have increased rapidly in Shan, where most land is untitled and, thus, inadmissible for use as collateral for bank loans (Soe and Kyaw 2019). This suggests that, while likely contributing to the acceleration of the mechanization process, particularly for larger and more expensive machines, formal land titling is not a precondition for widespread mechanization (see Chapter 6 for more details).

Many banks offered hire purchase loans for agricultural machinery, but Yoma Bank dominated the provision of hire purchase finance, accounting for almost half of partnerships with surveyed machinery retailers in 2017. Yoma Bank's prominence was linked to a program initiated by one of Myanmar's main development actors, the multi-donor Livelihoods and Food Security Trust Fund (LIFT). LIFT allocated $18 million to Yoma in 2016 to serve as a buffer against any losses incurred by its hire purchase portfolio for financing agricultural equipment. This investment encouraged Yoma to reduce the size of down payments on agricultural machinery and increase the average duration of loans from 1 year to more than 2.5 years. Sales made under the scheme from 2016 to 2018 totaled $122 million, including more than 4,000 tractors and almost 1,000 combine harvesters (Yoma Bank 2019). This is equivalent to 86 percent of the four-wheel tractors and 103 percent of the combine harvesters sold by machinery retailers surveyed in the Dry Zone in 2016 and 2017 (Table 7.5).

The exemption of agricultural equipment and machinery from import controls, which began in 2012, had a particularly significant effect on the purchase of agricultural machinery. Imports of agricultural inputs, including machinery, were, in fact, exempt from import tariffs even before 2011. However, until 2012, they, along with many other categories of goods, were subject to strict controls by the Ministry of Commerce. The Ministry would issue import licenses only if companies could produce export receipts of equal value to the items imported, severely restricting the scope for large-scale trade (Htay 2016; WTO 2014).

Except for the LIFT–Yoma scheme, the initiatives listed above were part of wider policy reforms that did not seek specifically to boost agricultural mechanization. Their effectiveness can be contrasted with attempts to intervene directly in the provision of machine rental services and marketing. From 2010 to 2017, AMD invested heavily in purchasing agricultural machinery with the intent of providing rental services to farmers. Expenditure on machines and associated costs accounted for 18 percent of the total budget of the Ministry of Agriculture, Livestock, and Irrigation by the end of this period. Despite this large investment, AMD could meet only a fraction of the total demand for mechanization services, and the machinery AMD offered often did not include brands most preferred by farmers. Moreover, accessing services through AMD was reported to be more complicated and time-consuming than doing so through private providers, which are numerous, highly decentralized, and flexible in responding to customer needs. A report by the World Bank (2017, 63) notes that "very few farmers have access to AMD's rental services." This observation is supported by our survey in the Delta, in which no respondents reported having used AMD's machine rental services.

The Department of Cooperatives has also sought to accelerate mechanization by providing hire purchase finance arrangements, using a $100 million loan from a South Korean company to finance the purchase of agricultural machinery. Machines distributed under this agreement were manufactured by the company that provided the loan (World Bank 2017). According to several respondents, the scheme had a preferential four-year hire purchase term and a low rate of interest. However, the manufacturer failed to provide spare parts or after-sales repair services, and the equipment was poorly suited to local conditions. Demand for the machines, particularly combine harvesters, was somewhat limited as a result.

Crisis period from 2020

Mechanization service providers and machinery retailers have faced multiple crises since 2020. The COVID-19 pandemic and measures to contain its spread resulted in movement restrictions and reduced economic activity, leading to the closure of many private businesses. Meanwhile, the military coup has led to conflict and insecurity throughout the country, the exit of foreign investment, and disruptions in the banking and financial sectors. Global shocks resulting from rising fuel prices and measures taken by the military regime to control foreign currency reserves have compounded these issues.

This section presents the findings of rapid assessment phone surveys we developed to identify the impacts of COVID-19 and other shocks on mechanization service providers and equipment retailers.

Mechanization is particularly sensitive to restrictions on mobility and trade flows. The economic viability of service providers, as capital-intensive operations, is highly sensitive to capacity utilization, which generates the cash flow needed to repay loans, import capital goods, and hire machine operators. Meanwhile, the business operations of machinery retailers can be particularly sensitive to bottlenecks in trade flows and internal logistical disruptions that affect their inventory. Given the close linkages between service providers and machinery retailers, the financial and logistical challenges that each face can have repercussions for the other.

Movement restrictions

The COVID-19 pandemic prompted movement restrictions within Myanmar to prevent the spread of the virus. These restrictions were non-uniformly implemented at the local government level and included measures such as a mandatory 14-day quarantine to enter a village tract or township. In November 2020, approximately three-quarters of machinery retailers surveyed reported disruptions to their operational logistics, with one-third stating that they were unable to deliver on orders because of business closures or movement restrictions (Takeshima, Zone, and Masias 2020a). Similarly, for approximately three-quarters of mechanization service providers, operations were restricted to the township (Takeshima, Zone, and Masias 2020b). While tractors tend to operate within their locality (IRRI 1983; Takeshima et al. 2015), other machines, like combine harvesters, need to operate more regionally to be cost-effective (Diao, Takeshima, and Zhang 2020; Zhang, Yang, and Reardon 2017).

COVID-related movement restrictions had eased by January 2021, but the insecurity that followed the military coup in February 2021 had similar effects. Local authorities implemented arbitrary rules such as curfews, and security checkpoints were set up throughout the country. Because mechanization service providers typically travel at night, reserving the daytime for servicing farms, the threat of harassment, rent-seeking, and risk to personal safety served as deterrents. In July 2022, 93 percent of tractor service providers and 59 percent of combine harvester providers surveyed were restricted to the township level (MAPSA 2021).

Trade flows

The disruptions to international trade as a result of the pandemic had negative implications for the availability and cost of machines, attachments, and spare parts. In January 2021, 45 percent of machinery retailers surveyed reported a decline in the availability of agricultural equipment, with 30 percent reporting price increases for the equipment available. These retailers attributed the lower availability and higher prices to a combination of low levels of equipment imports, a reduction in local production of manufactured parts, and restrictions on the movement of equipment. Consequently, by January 2022, more than 50 percent of mechanization service providers surveyed reported lower availability, and 100 percent reported higher prices for agricultural equipment.

Reduced availability and higher prices of agricultural equipment negatively affect the provision of mechanized services, likely leading to higher costs, lower revenues, and delays in service delivery. It is less clear what the impacts are on machinery retailers, as higher prices can reduce the likelihood of reduced revenues. However, retailers are likely to face increasing challenges in recovering loans from buyers or increased transaction costs owing to disruptions in their logistics or because they have to service more distant buyers (Takeshima et al. 2021).

These supply-side challenges are likely to worsen. In July 2022, the military regime restricted all imports, including those of machinery and spare parts, as part of efforts to control foreign exchange reserves. Moreover, the Myanmar kyat has depreciated approximately 50 percent since the military coup. This is all being compounded by the global increase in fuel prices due to the Russia–Ukraine conflict.

Financial outlook

These businesses have a gloomy outlook for the short term. Approximately 90 percent of service providers and 73 percent of machinery retailers expected their revenues in 2022 and 2021, respectively, to be lower than in 2019, with 97 percent of service providers expecting their costs to increase in 2022. Meanwhile, both groups reported reduced demand. Ninety percent of machinery retailers surveyed reported year-on-year reductions in agricultural equipment sales from 2020 to 2021, including a significant number indicating sales reductions of more than 50 percent. Similarly, approximately three-quarters of mechanization service providers reported year-on-year reductions in demand for services from 2020 to 2021 and again from 2021 to 2022. In July 2022, less than 10 percent of service providers reported having no financial challenges.

In April 2020, the democratically elected government introduced the COVID-19 Economic Relief Plan (CERP), intended to mitigate the economic impacts of the pandemic. This plan included loans for small and medium enterprises, which mechanization businesses initially sought to cope with the financial challenges they faced. However, CERP disappeared after the military coup, and businesses that had received loans were asked to repay them right away. The uncertainty created by the political situation made lenders less willing to restructure loans or accept late payments. While mechanization businesses used other means to cope, such as the sale of assets, personal loans, and other sources of income, the prolonged crises largely exhausted many of these means.

In July 2022, 43 percent of tractor service providers and 59 percent of combine harvester service providers surveyed reported knowing other service providers whose machines had been repossessed since the beginning of the COVID-19 outbreak—an increase of more than 20 percent from the year before. Farmers have also made fewer capital investments since the beginning of 2021, with only 3.2 percent of all two-wheeled tractor acquisitions and 3.8 percent of all four-wheel tractor acquisitions made in this period.

Conclusions

We draw the following conclusions from the analysis presented above. We find many similarities between Myanmar and other Asian countries where rapid agricultural mechanization has occurred. Key elements include tightening rural labor markets linked to urban growth and rural out-migration and expanding rural nonfarm employment in an agrarian context where large numbers of small farms are already well integrated into markets, including the market for farm labor. These changes tend to come bundled together with, and to be reinforced by, the development and expansion of rural transport and communications infrastructure, electrification, and access to education, and they contribute to innovation. This is especially evident in the case of rice harvesting, leading to cost savings or the release of family labor for other work.

However, a variety of demand-side factors also contribute to the appeal of mechanization for farmers. Mechanization is associated with quicker and more timely planting and harvesting. These advantages may assist farmers in managing risks that become more pronounced in a context of labor scarcity and climate variability. A further and somewhat overlooked aspect is the reduction in physically demanding work that farm households must perform, including caring for draft animals, in a setting in which agricultural work is increasingly viewed as undignified (Faxon 2020). Further, with the growth in outsourcing services and mobile communications, the convenience of summoning a machine operator by phone, rather than contacting and overseeing multiple casual workers, may provide as significant an incentive to use machines as a purely economic calculus. Rather than representing a single transformational change, mechanization's broad appeal to farm households seems to result from an accumulation of incremental, complementary advantages.

On the supply side, rapid mechanization has coincided with the growth in decentralized, self-organized, private outsourcing services provided primarily by rural machine owners. Mechanization on such a wide geographic scale within such a short duration, in an agrarian setting comprising mainly small and medium-sized farms, would likely have been impossible without the emergence of these actors. Services provided are tailored to the requirements of this client base, making machinery accessible to farms of all sizes at prices similar to or below those paid for manual labor or animal traction. Machine owners and outsourcers have benefited from the proliferation of agricultural machinery retailers throughout all major agricultural zones. Retailers have been enabled by a lack of barriers to the import of agricultural machinery and spare parts. Coupled with Myanmar's location bordering China and Thailand—both major agricultural equipment manufacturers—this ensures direct access to a range of relatively inexpensive "off-the-shelf" technologies developed to suit similar agrarian conditions.

Extremely high uptake levels within a short period in varied agroecological settings strongly suggest that farmers find machines useful and that the modalities by which they are accessed are appropriate to the contexts in which they operate. While mechanization alone may not be sufficient to guarantee the long-term viability of small farms, these farms would face greater difficulties responding to the challenges of labor scarcity, rising rural wages, and climate variability if they could not access machinery on demand. Importantly, while machine rental services may offer a pathway to accumulation for the larger farms that typically operate such businesses, our results do not suggest a zero-sum game in which smallholder users of these services are disadvantaged.

The most critical supply-side intervention was the liberalization of import restrictions on multiple categories of goods, including agricultural machinery. The lack of tariffs on imported agricultural equipment and spare parts is also helpful but less fundamental than the ability of retailers to import equipment on demand. Myanmar's location among countries that manufacture and export large quantities of relatively low-cost agricultural machinery of appropriate design has also contributed significantly to the rapid uptake of farm machines.

The decision to allow banks to offer hire purchase loans was a key policy change that facilitated access by farmers and agricultural machinery retailers to substantial amounts of formal credit. This affected both the demand side and the supply side, as machine owners are often simultaneously customers of machinery retailer businesses and providers of outsourcing services. Amendment of the Farmland Law to enable land use rights certificates to be used as collateral for bank loans was complementary to this move. These changes have been particularly consequential for large, expensive machines, such as combine harvesters and four-wheel tractors, and helpful but not a pre-condition for the uptake of smaller machines, such as two-wheel tractors, which have become increasingly affordable over time.

Broad macro-scale policy interventions aimed at enhancing the enabling environment have tended to bring about bigger responses than those specifically designed to promote agricultural mechanization. A notable exception is the LIFT–Yoma loan guarantee scheme, which accelerated an ongoing process of machine acquisition by lowering barriers to loan access. These more general efforts contrast with the limited success of attempts to intervene directly in machinery supply via public–private partnerships or direct provision of rental services. It is worth reiterating that very few farmers access mechanization via state-owned hire centers, even though significant resources have been spent promoting such schemes.

Before the crises, the loosening effect of extremely rapid mechanization on labor markets was offset by high rates of migration and growth in nonfarm work. The combination of these processes resulted in continued pressure to push up rural wages across the country—even as opportunities for casual wage labor in agriculture declined with increased uptake of machines by farmers, new economic opportunities created jobs for those displaced in agricultural labor markets, to the benefit of those workers (Belton and Filipski 2019).

Contrary to expectations, the growth of agricultural mechanization has continued apace since 2020 despite the severity of the economic downturn (MAPSA 2023). Rural labor scarcities have intensified as many rural areas have been depopulated by conflict and internal displacement, and migration to urban areas and abroad has accelerated as a strategy to mitigate economic hardship and escape political oppression. The adoption of labor-saving technologies, including mechanized harvesting, direct seeded rice, and herbicides, has grown steadily in response. In contrast, the use of yield-increasing technologies, including fertilizer, improved seeds, and transplanted paddy, has declined (MAPSA 2023). This scenario suggests that coping with labor scarcity is now a higher priority for most farmers than raising crop yields and implies that mechanization will become even more important in helping labor-constrained smallholders continue farming.

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