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STRATEGY SUPPORT PROGRAM | WORKING PAPER 77 APRIL 2026

Vertical Integration and the Modernization of Staple Food Value Chains

Evidence from Myanmar's Rice Sector

Joseph Goeb, Bart Minten, Thomas Reardon, A Myint Zu, and May Thet Htar

Australian Centre for International Agricultural Research

Australian Aid

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ABSTRACT

Increased vertical integration and coordination are defining features of transforming and modernizing agricultural value chains in low- and middle-income countries, with important implications for market efficiency and farm-level transformation. However, research documenting these processes in modernizing domestic value chains is limited, and tends to focus on foreign direct investment and high-value food products. We study the rice value chain – the most important staple in Southeast Asia – in Myanmar and use unique data from domestic rice mills and farmers to analyze millers' expansion into other businesses and services. We show that both modern and traditional mills serve as key nodes in local rice value chains, fulfilling diverse roles beyond processing at both the farm and post-farm levels and highlighting a co-development of modern processing and vertical integration. Yet, statistical tests that control for mill and farmer characteristics, respectively, show that modern mills are more engaged in vertical integration and coordination, particularly in post-farm value chain segments, highlighting the co-development of modern processing and business expansion. Consistent with this pattern in the miller data, farmers using a modern mill are more likely to receive complementary services – especially post-farm – and to adopt modern production practices more broadly. However, this expansion is uneven, reaching large farms more frequently than small and medium farms.

1. INTRODUCTION

Increased vertical integration and coordination are defining features of transforming and modernizing agricultural value chains (AVCs) in low- and middle-income countries (Barrett et al., 2022). As agricultural economies grow and markets expand (both for export and domestic consumption), there is a rising importance of the midstream segments of AVCs, in processing and wholesale, that intermediate between farms upstream and retailers (and their consumer clients) downstream.

There has been substantial research showing that in the modern stage of AVC transformation, large-scale processors vertically coordinate with farmers, for example via contracts with volume, quality, and safety requirements. To support the coordination with farmers, modern, large processors have been shown to further coordinate with other firms such as input suppliers and logistics providers, or even vertically integrate into services that support the farmers in meeting the requirements. The processors undertake those services driven by the needs to (i) maximize their capacity utilization and thus their survival and profitability, (ii) meet rising modern market demand for food quality and safety, and (iii) resolve factor market imperfections that impede their suppliers from meeting the requirements, such as inadequate access to finance, inputs, and logistics. Such developments can reduce costs and improve efficiency in the midstream of AVCs by resolving idiosyncratic market failures facing their suppliers such as farmers facing constraints of access to farm inputs and credit and increasing farmer access to output markets (Swinnen and Maertens, 2007). This support can be provided to farmers in formal contracts or in informal “relational contracts” (Macchiavello et al., 2022).

There is an abundant literature on small farmers’ relations with large processors such as in differentiated quality rice in India (Mishra et al., 2018). Less common but still with a substantial body of literature are studies of modern processors backward integrating into or collaborating with other midstream and upstream firms to provide support services in inputs, credit, and logistics in “resource provision” contracts in LMICs. Examples include: (i) large dairy processors in Poland (Dries and Swinnen, 2004) and FDI processors in Uganda (van Campenhout et al., 2021); (ii) large sugar processors in Slovakia (Gow and Swinnen, 1998); (iii) large fishmeal processors in Peru facing quality premiums (Hansman et al., 2020); and (iv) large vegetable exporters/processors in Latin America (e.g., Key and Runsten, 1999) and Africa (e.g., Minten et al., 2009).

By contrast, there is much less research on MSMEs (micro, small, and medium enterprises) in the food processing sector in developing regions, particularly from the perspective of vertical coordination, diversification, and collaboration to provide support services to farmers – outside of government programs or donor projects or NGO initiatives. This gap in the literature is important for two reasons.

First, there has been a rapid proliferation of MSMEs, for example in rice processing in developing regions, especially in Asia. Reardon et al. (2014) show for Bangladesh, China, India, and Vietnam, and Minten et al. (2023) for Myanmar, that there has been rapid development and transformation of rice mill MSMEs alongside the emergence of modern larger rice milling companies. That emerging literature on recent transformation of rice mills in Asia has focused on the firms’ investments in processing and packaging/branding, its product differentiation beyond a purely commodity phase into product differentiation, and its institutional arrangements such as disintermediation (away from village traders), establishment of own-agent networks, and relational contracts with retailers and farmers.

But this literature has tended to neglect an exploration of vertical integration and diversification into support services in the way or to the extent that the literature on large non-staple firms has done (as illustrated above), and when it has, it has focused only on the large-scale sub-segment and even

that mainly on contractual relations with farmers or supermarkets (e.g., in China, Reardon et al. 2014) rather than service provision to farmers. There remains a gap in terms of what MSMEs do to provide services, and how MSMEs compare with large firms in that domain.

Second, while the literature (e.g., Swinnen and Maertens, 2007) presents a strong exposition of the large food company's motivations and capacities in providing support services in contract farming settings, we believe a parallel case can be made for expecting MSMEs will be similarly motivated. This is supported in general by a scoping review that covered MSME interactions with small farms and found that firms, including MSME processors, often provide small farms with complementary services such as input provision, credit, information, and logistics, in a manner parallel to that found in the literature on large food companies (Liverpool-Tasie et al., 2020). This point is reinforced as part of the broader literature on relational contracts (Macchiavello et al., 2022).

Moreover, economic theory points to the decision problem for a firm (including an MSME) whether to supply a service or an input needed by its suppliers in the event that the latter face idiosyncratic market failures to access those services or inputs. In the case of a rice mill, this could include: (i) farm inputs ranging from land to equipment to non-labor variable inputs even to skilled or unskilled labor provision (such as for harvest); (ii) midstream between the farm and the mill, including logistics (storage and transport) and pre-processing (drying and parboiling); and (iii) downstream (such as further processing by-products of the paddy milling and adding payment to farms for this value added, or final products such as noodles that can further add value to differentiated product from the farm).

There may be constraints on the supply and demand for these services, in the form of generally missing markets (such as before the emergence of third-party logistics) or idiosyncratically failing markets. On the supply side for example, this could include input firms that avoid incurring risk or transaction costs to sell to small farmers in more remote regions. While on the demand side, this could include farms that cannot afford or have the information to access the services. In these market situations, and in the settings where mills depend on accessing a broad range of farmers (procurement shed) to operate at high capacity-utilization, we expect MSME processors to offer these services, either by "making" them (in vertical integration) or buying them in coordination from third parties.

This paper addresses the above gaps by exploring vertical integration and coordination in Myanmar's rice value chain, focusing on small- and larger-scale rice mills. Rice is the most important staple food in Myanmar, and for half of global population (Muthayya et al., 2014), and mills are central in its supply chains, processing farmer-produced paddy into consumer-ready rice. Myanmar's rice milling sector began modernizing rapidly with market-oriented reforms starting in 2003 (Okamoto, 2005) and expanding under a quasi-democratic government after 2010. A key component of this modernization has been domestically financed modernization through investment in modern milling equipment and machinery and a shift away from older, traditional mills (USDA, 2020; Goeb et al., 2024).

Using unique data from both rice mills and farmers in Myanmar, we document millers' expansions into other businesses and services along the rice value chain. We compare modern mills (those that are relatively large-scale and use modern machinery fit for that scale) to traditional mills in their engagement in vertical integration and coordination using regression and propensity score matching methods that control for firm and farmer characteristics. Because miller adoption of modern technologies and broader vertical integration and coordination are part of a co-developing AVC, our empirical strategy is not designed to identify causal effects, but rather to characterize patterns of co-development across firms and farmers.

Our analysis proceeds along three analytical dimensions that are particularly interesting in the developing country context. First, we provide evidence on the co-development of modern (large) and MSME processing and vertical integration and coordination. Existing literature in this space is rare, and is primarily centered on high-value products and tends to focus directly on FDI. Second, we broaden the scope of value chain research by providing key insights on the less discussed transformation in domestic staple food products which have far-reaching implications for local consumers and producers. Third, we combine study of a large suite of both farm-facing and post-farm activities undertaken by the processors, and the demand for and benefit from those services by farms. That combination in one analysis of both the supply-side (i.e., mills) and the demand-side (i.e., farm households) is rare in research on vertical integration and coordination.

Our results show that both modern (relatively large) and traditional (MSME) mills extend far beyond rice processing, operating diverse sets of businesses along the rice value chain. However, modern mills are more engaged in vertical integration, particularly in post-farm activities including trading (66 percent of modern mills), byproduct manufacturing (42 percent), providing drying (44 percent) and storage services (18 percent), transport (27 percent), and rice retailing (28 percent). Farmer-level evidence further shows that those using modern mills (39 percent of all rice farmers) are more likely to access complementary services from mills and adopt modern practices more broadly. These findings point to the co-development of processing modernization and expanded vertical integration, though services are not everywhere inclusive, reaching large farms more often than small and medium farms, and services are relatively more often provided by relatively bigger mills.

The paper proceeds with background context on Myanmar's rice value chain in Section 2. Section 3 describes our data and methods in detail, discussing our regression and propensity score matching methods. Section 4 presents our results, first from the miller side, then from the farm side. Section 5 concludes by summarizing our results and briefly discussing their implications.

2. BACKGROUND

2.1. Rice value chain and modernization in Myanmar

Rice has long been the most important agricultural value chain in Myanmar across several dimensions including production, consumption, and exports. In 2017, 60 percent of all farm households produced paddy rice in the monsoon season (Minten et al., 2023) and national production volumes of milled rice are around 12 million MT annually (USDA, 2025), making it a critical crop for rural economies and household welfare. Rice is also the most important food in Myanmar with one of the highest per capita consumption rates in the world at an average of 170 kgs per capita per year (USDA, 2021), accounting for more than half of all calories consumed (Goeb et al., 2024). Finally, rice is a major export product with between two and three million MT exported annually (USDA, 2025), reaching an export value of USD 1.4 billion in 2023/24.

The rice value chain modernized and expanded with gradual market-oriented policy reforms in the early 2000s which expanded and accelerated under the quasi-democratic government between 2010 and 2020 (Okamoto, 2020). Banking sector and trade policy reforms (both exports and imports) led to increased investment in the rice value chain. Farmers rapidly adopted modern production practices and technologies including mechanization (e.g., tractors for plowing and combine harvesting), and modern inputs (e.g., pesticides) (Minten et al., 2025). Significant investments were also made in modern mills: Goeb et al. (2024) estimate that the share of farmers selling rice to modern mills increased by 29 percentage points between 2013 and 2022.

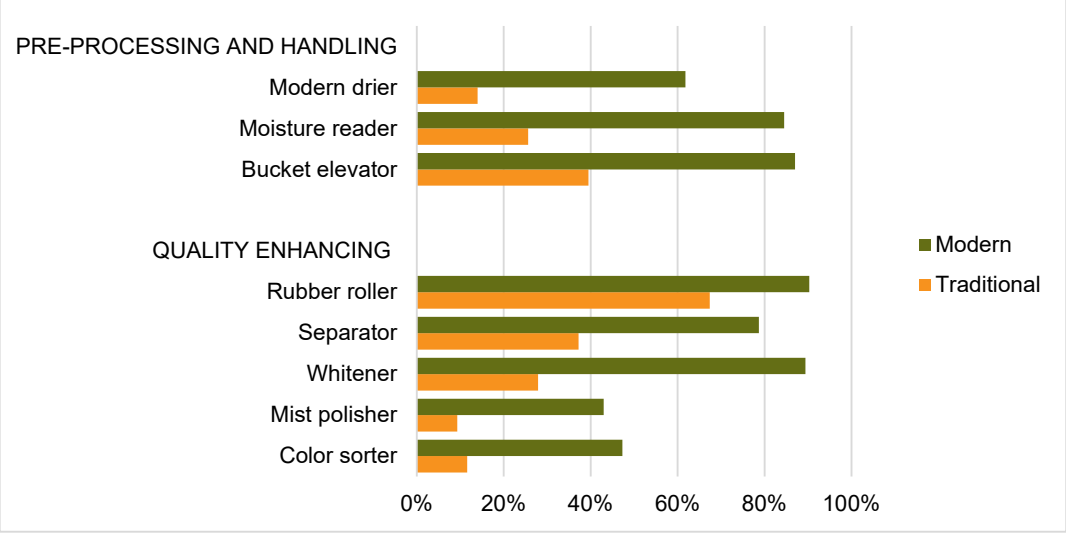
However, COVID-19 in 2020 and a military coup in 2021 – and the widespread conflict it engendered – had substantial impacts on Myanmar's economy, as GDP per capita contracted and fell off-pace with neighboring countries (Minten et al., 2025). While the rice sector and the agrifood system more broadly have shown resilience through these challenges (Boughton et al., 2021), there are still widespread disruptions throughout AVCs (Goeb et al., 2025) that stress modernization. Farmers in conflict-affected areas had lower adoption of modern practices (Minten et al., 2025) and lower fertilizer response rates (Takeshima et al., 2025). Poverty rates have increased (Boughton et al., 2023) and households are deploying both consumption- and asset-smoothing coping strategies (van Asselt et al., 2026). In the rice value chain, milling margins were initially stable after COVID-19 (Goeb et al., 2022), though conflict events after the coup have widened the gap between producer and consumer prices (Minten et al., 2023). National rice production has not been affected much by these conflicts as the Delta – the country's primary rice bowl – experienced less disruption compared to other agroecological zones (USDA 2025).

2.2. Rice milling technologies and operations

Myanmar's rice mills can be broadly categorized as either traditional or modern mills distinguished primarily by the core milling machinery used to separate rice from husks. Traditional mills use older single-pass machines (locally known as halar sat or nga pone sat), while modern mills use newer, multi-stage machines. This distinction between modern and traditional mills is well understood and recognized by both millers and farmers.

Most modern mills also utilize additional machinery as supplemental steps in the milling process to improve rice quality and consistency. Figure 1 illustrates the differences in mill ownership of additional machinery and equipment across mill types. Modern mills are more likely to own pre-processing equipment: 85 percent of modern mills own a moisture reader compared to just 26 percent of traditional mills, and 62 percent of modern mills own a modern drier compared to just 14 percent of traditional mills. These tools improve consistency in the moisture level of paddy entering the milling process, thereby improving rice quality in the end product. Modern mills are also more likely to use vertically-fed machines, which require bucket elevators to move paddy through the milling process.

Figure 1. Milling machinery and equipment ownership shares by mill type



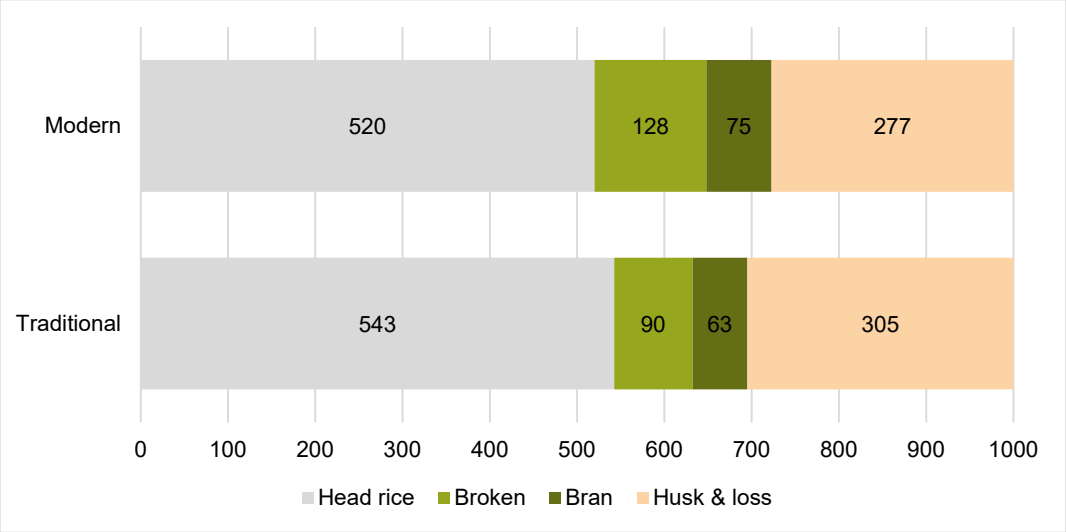
N=249. Source: Authors' calculations from Rice Miller Survey 2024.

Modern mills are also much more likely to utilize quality-enhancing machinery. Majorities of both modern and traditional mills own a rubber roller, which is gentler than the older stone rollers (and therefore produces less broken rice), but modern mills (86 percent) are still much more likely to use them than traditional mills (67 percent).The majority of modern mills also own separators (72 percent) – which filter out poorly milled paddy, removing it from the rice for additional processing – and whiteners (79 percent) compared to less than 40 percent each for traditional mills. Larger shares of modern mills also own mist polishers (43 percent) – which polish the final head rice to improve appearance – and color sorters (47 percent) – which ensure consistent appearance in the head rice – compared to about 10 percent each for traditional mills.

Investment in these machines for medium- and small-scale mills has been funded largely by domestic investments by the firms themselves. The limited FDI in the rice sector has been concentrated in very large-scale mills.[1] Our data show that local investment for both modern and traditional mills has slowed since COVID-19 and the military coup in 2021, falling to about 85 percent compared to pre-COVID investment rates.

The differences in machinery across modern and traditional mills lead to differences in not only quality but also the conversion quantities of paddy to head rice and byproducts. Figure 2 compares modern and traditional mills in their average conversion rates of paddy to (i) head rice (the main rice product for consumers), (ii) broken rice, (iii) bran, and (iv) husks and loss.

Figure 2. Milling output (kgs) from one metric ton of paddy, by mill type



N=249. Source: Authors' calculations from Rice Miller Survey 2024.

Interestingly, modern mills report lower head rice conversion rates than traditional mills on average, but they also report higher conversion rates to broken rice and bran. These milling byproducts are highly marketable with about three-quarters of mills selling them. As a result, a lower share of paddy is converted to husks (the lowest value and least marketable byproduct) and losses for modern mills. These conversion rates, in combination with higher quality and higher priced outputs – not only the head rice, which contains a lower share of brokens and is more attractive to consumers but also broken rice which is sold in different grades and sizes – ultimately result in higher returns per metric ton of paddy for modern mills.

1 The major investors are Wilmar International, headquartered in Singapore and one of Asia's leading agribusiness groups, and Posco International, a South Korean-based company.

3. DATA AND METHODS

3.1. Data

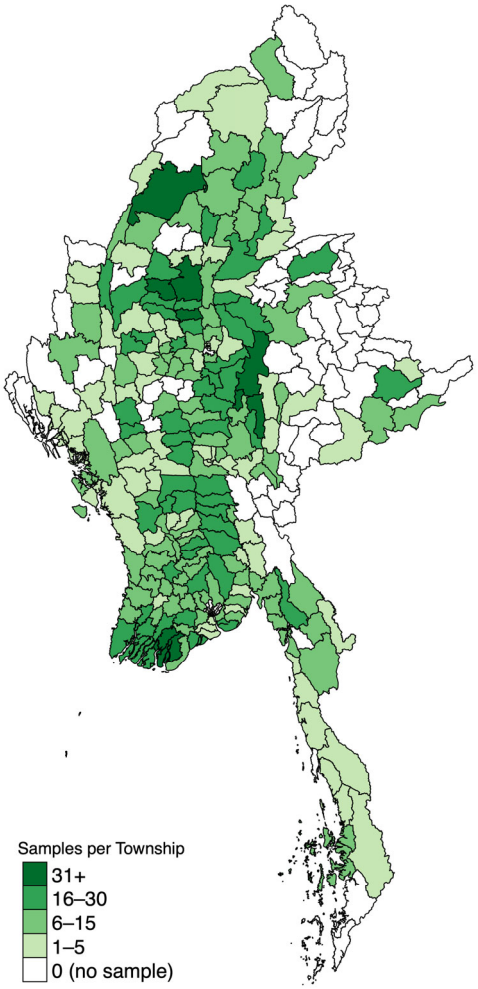
We utilize two sets of primary data for our analysis. The first is from a phone survey of rice millers conducted in September 2024, part of an ongoing project to monitor agrifood system performance in Myanmar. The sample for analysis consists of 249 mills distributed across Myanmar providing geographic coverage – though not nationally representative – with the highest concentration in the Delta agro-ecological zone, the main rice growing region of the country. The sample includes more modern mills (206) than traditional mills (46).

The Rice Miller Survey collected detailed data on mill characteristics and milling operations during the monsoon season – the main rice growing season in Myanmar. Critical to this research are data on vertical integration which were assessed by asking mills if they also operate a series of other businesses or services, in addition to their core milling operations. The list included seven farm-facing services provided to paddy farmers during the cultivation and production of paddy. These include contracting with farmers to buy paddy, selling paddy seed, selling other (non-seed) inputs, providing extension advice to farmers, providing credit, and providing tractor plowing and combine harvesting services. The complementary business list also included nine post-farm businesses and services related to marketing, processing, and handling. On the marketing side we asked about trading paddy/rice, contracting with buyers to sell rice, paddy/rice transport services, and selling retail rice to households. On the processing and handling side we asked about paddy/rice storage services, paddy drying, selling ready-to-eat foods (e.g., prepared meals or snacks), and manufacturing feed or other byproduct goods. Finally, we asked if the mills also operated a paddy farm or if they operated another business not mentioned in the lists, either in the rice value chain or unrelated to rice.

Our second dataset, complementing the mill-level data, is from the farm-level Myanmar Agricultural Performance Survey (MAPS). MAPS is designed to be representative at the state/region level and has been conducted by phone annually since 2021. We utilize the 2024 survey round and focus on rice farmers. Our sample for analysis is 2,375 farmers distributed across Myanmar (Figure 3).

MAPS captures detailed information on agricultural production. In the 2024 survey, several questions were included to capture farmer engagement with rice millers. We asked farmers what types of mill – modern or traditional – were used in the year prior to survey, and included several questions about availability and use of several complementary services from these mills. We captured farmer use of both farm-facing services (extension advice and credit) and post-farm services (selling paddy, transport, paddy drying, storage, and buying retail rice) provided by rice millers.

Figure 3. Rice farmer sample distribution, number of observations by township



3.2. Methods

We make three sets of statistical comparisons to understand the extent of vertical integration between modern and traditional mills. Using the Rice Miller Survey data, we assess whether modern mills are more or less likely to provide farm-facing and post-farm services. We then use MAPS data to assess whether farmers that use modern mills are more or less likely to utilize miller-provided complementary services. The comparison methods are analogous across the two datasets, with differences only in the unit of observation and outcome variables, as described below.

Our objective is not to estimate causal effects of modern milling and vertical integration or service provision. Rather we seek to identify systematic differences between modern and traditional mills while controlling for observable characteristics that may jointly influence both processing modernization and expansion into complementary businesses and services. Taken together, the three comparisons characterize systematic differences in complementary service provision in a modernizing rice value chain.

3.2.1. Simple mean comparison

The first statistical comparison method is a simple regression-based means test estimated by ordinary least squares with robust standard errors. In the miller case, we compare the mean participation rates in vertical coordination and vertically integrated businesses across modern and traditional mills. Specifically, the dependent variables include indicators and counts of mill-operated

businesses and services: farm-level activities (contracts farmers, sells paddy seed or other paddy inputs, provides extension advice, credit provision, tractor plowing, combine harvesting, and the count of such farm services), post-farm activities (storage, paddy drying, paddy/rice trading, rice retail shop, contracts with buyers, ready-to-eat food sales, manufacture of animal/fish feed or other byproducts, transport services, and the count of post-farm services), and other businesses (farming paddy, other rice businesses, other non-rice businesses, and their total count), as well as the total number of businesses operated.

In the farmer case, we compare mean use rates of miller-provided businesses and services across farmers that primarily used a modern or traditional mill. Specifically, the dependent variables capture farm-level services (credit for inputs or mechanization, extension advice, and the count of such farm services), post-farm services (paddy sales to the mill, transport services, paddy drying, storage services, retail rice purchases, and the count of post-farm services), and the total number of mill services used.

3.2.2. Covariate-controlled mean comparison

The second comparison method extends the simple mean comparison by controlling for observable characteristics that may confound the relationship of mill modernization and service/business expansion. This approach assesses whether modern mills are more or less engaged in vertical integration after accounting for differences in scale, manager characteristics, location, and operating conditions.

Using the miller data, we apply the following model:

$$Y_i = \beta_0 + \beta_1 Modern_i + \boldsymbol{X_i'}\boldsymbol{\alpha} + \varepsilon_i \,, \qquad (1)$$

where Y_i is the measure of complementary service provision for mill i (the same outcomes discussed above), $Modern_i$ is an indicator for modern mill [2], and $\boldsymbol{X_i'}$ are controls for mill characteristics (mill throughput, education level of the mill manager, manager gender, manager years of experience, the age of the mill, and perceived insecurity)[3] and location variables (whether the mill is located in the Delta, or in an urban area). β_1 is our coefficient of interest, capturing the difference in mean participation between modern and traditional mills conditional on the covariates.

We use a similar specification for the farmer data with the dependent variables being measures of use of mill-provided services (as described in section 3.1). The modern variable is an indicator for if the farmer used a modern mill in the past year. Covariate controls include farm and farmer characteristics (education level of the farmer, farmer gender, household size, acreage of paddy cultivated, and perceived insecurity) and location variables (agroecological zone, and a measure of farm remoteness). β_1 is again our coefficient of interest, here showing the conditional mean difference in farm use of additional mill-provided services between those that used modern and traditional mills.

3.2.3. Matching balanced-sample comparison

The third comparison method utilizes propensity score matching to construct a sample of modern and traditional mills that are more comparable across observable characteristics. This approach further controls for business scale, management, and location.

We first estimate propensity scores – the probability that a mill is modern – using a logit model with the same set of explanatory variables included in equation (1). Conditioning on these observed variables allows us to create matched samples of modern and traditional mills that are similar across

[2] We also conduct a robustness check on the definition of modern mills, discussed in section 4.3.

[3] The full list of explanatory variables with descriptive statistics for both the miller- and farmer-level comparisons are in Table A1 in the appendix.

factors that might influence both modernization and incentives to expand into other services along the value chain. It is important to note that, as with any matching approach, this method cannot account for unobservable differences between mill types.

We match each modern mill to a traditional mill with similar observable characteristics using nearest neighbor one-to-one matching with replacement. We allow for replacement given the relatively smaller number of traditional mills in the sample. We restrict our analysis to the region of common support to ensure that each modern mill has a comparable traditional mill counterpart. We assess covariate balance before and after matching to evaluate the extent of bias reduction achieved. The final tests of interest are mean comparisons in vertical integration participation (using the same outcome variables discussed in 3.2.1) for the modern mills and their matched traditional counterparts. We apply an analogous matching method for our farm-level data, using the same set of explanatory variables and the same outcome variables mentioned above to compare farmers using modern and traditional mills.

Taken together, these three comparisons provide complementary descriptive evidence of systematic differences between modern and traditional mills in their propensities to vertically integrate and coordinate. By controlling for important characteristics and constructing matched samples, these methods reduce the likelihood that observed differences are driven by firm-scale, managerial characteristics, or location. The results characterize patterns of co-development between modern processing and vertical integration and coordination.

4. RESULTS

4.1. Rice millers' vertical integration and coordination

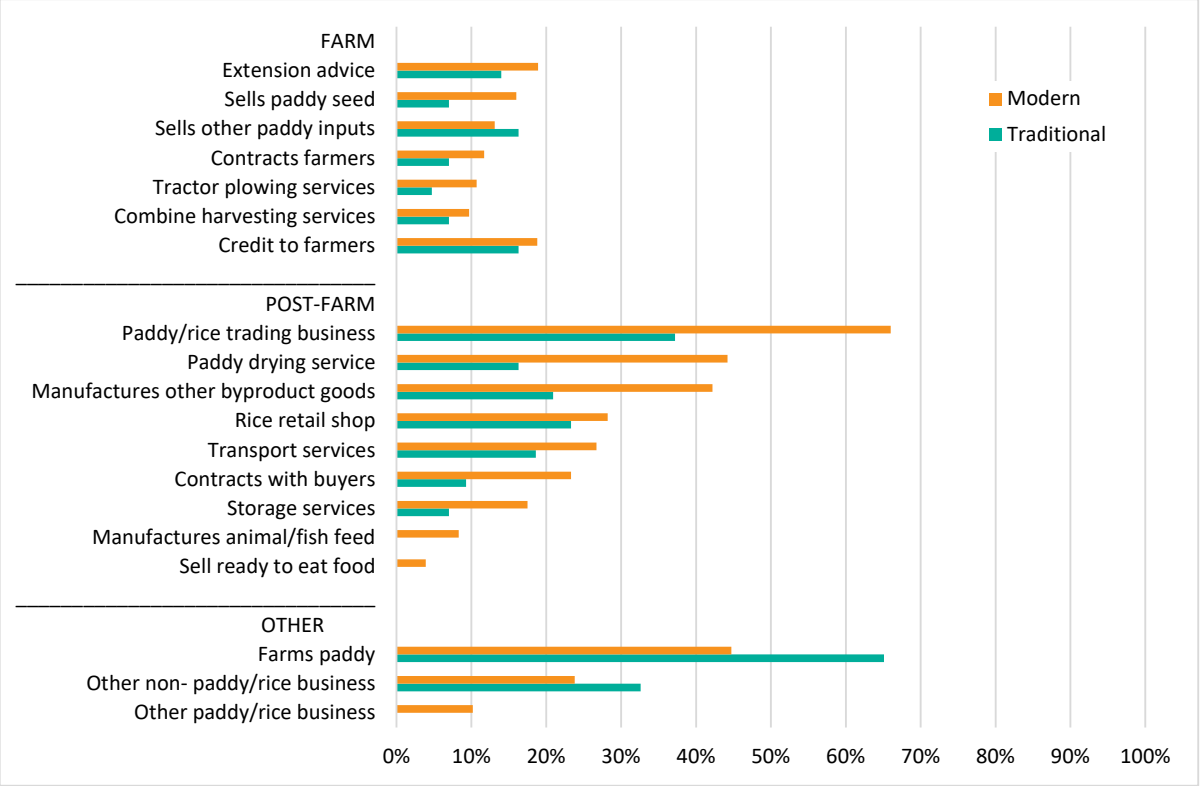
Moving beyond the core milling operations, mills are engaged in a range of both farm-facing and post-farm complementary services and businesses (Figure 4). This highlights broad vertical integration and coordination efforts by mills as they expand to different operations within the rice supply chain and serve as key nodes in rural agricultural economies.

Mills operate more post-farm businesses than those that directly engage farmers in production, and each post-farm business is more commonly provided by modern mills. Two thirds of modern mills operate a paddy or rice trading business, while just 37 percent of traditional mills do so. Other prominent post-farm businesses include paddy drying services (44 percent of modern mills; 16 percent of traditional mills), manufacturing byproduct goods (42 percent; 21 percent), rice retail shops (28 percent; 23 percent), transport services (27 percent; 19 percent), contracting with paddy buyers (23 percent; 9 percent), and storage services (28 percent; 7 percent).

Farm-facing services and businesses, while less common, are still conducted by meaningful shares of mills, though the differences between modern and traditional mills are less pronounced. Modern mills are more likely to provide extension advice than traditional mills (19 percent; 14 percent), to sell paddy seed (16 percent; 7 percent), to contract with farmers for paddy purchases (12 percent; 7 percent), provide credit to farmers (19 percent; 16 percent) and to provide services for tractor plowing (11 percent; 5 percent) and combine harvesting (10 percent; 7 percent).

However, traditional mills are slightly more likely to sell other (non-seed) paddy inputs. Traditional mills are also much more likely to operate a paddy farm (65 percent of traditional mills; 45 percent of modern mills), and to operate a business unrelated to the rice value chain (33 percent; 24 percent). Thus, modern mills are more focused on the rice value chain, while traditional mills are more likely to diversify outside of the rice value chain.

Figure 4. Shares of mills offering complementary services and operating other businesses by mill type



N=249. Source: Authors' calculations from Rice Miller Survey 2024.

We now turn to statistical comparisons of modern and traditional mills in their expanded operations into other businesses and services. Table 1 reports our three sets of mean comparisons: (i) simple unadjusted differences, (ii) differences controlling for key covariates, and (iii) estimates after sample matching.

After matching, the sample balance in covariates is improved greatly, but prior to matching there are some significant differences across mill types. In the full sample, comparisons show that modern mills have significantly higher throughput, are more concentrated in the Delta and in urban areas, and have higher education (Appendix Table A.2). The differences in mill age, female ownership, experience, and insecurity are insignificant. Yet, the significant differences highlight the importance of controlling for some of these factors in regressions, and with matching to better isolate the modern mills' propensities to provide these services from other factors that might affect incentives to expand operations such as their location and characteristics of the owner/manager.

Table 1 shows that, in the farm-facing businesses and services, the differences between modern and traditional mills are small and mostly statistically insignificant. Estimates of selling seed are an exception and show a consistently significant difference across the three estimates with modern mills being 9 to 13 percentage points (pp) more likely to do so. Interestingly, in the matched sample comparisons, modern mills are statistically less likely to sell other inputs, provide credit, and they provide fewer farm-facing services overall.

Table 1. Differences in services and businesses offered by mills, modern mills compared to traditional mills

Business/service operated by mills	Traditional mean	Differences (Modern – Traditional)								
		Simple difference			Controlling for co-variates			Matching		
FARM										
Contracts farmers	0.07	0.05	(0.045)		0.02	(0.056)		0.07	(0.067)	
Sells paddy seed	0.07	0.09	(0.047)	*	0.11	(0.059)	*	0.13	(0.065)	**
Sells other paddy inputs	0.16	-0.03	(0.061)		-0.10	(0.075)		-0.30	(0.072)	***
Extension advice	0.14	0.05	(0.060)		0.01	(0.081)		-0.15	(0.141)	
Tractor plowing services	0.07	0.06	(0.039)		0.07	(0.057)		-0.06	(0.078)	
Combine harvesting services	0.07	0.03	(0.044)		0.08	(0.071)		-0.06	(0.082)	
Credit to farmers	0.16	0.03	(0.063)		-0.02	(0.081)	***	-0.26	(0.078)	***
N farm services/businesses	0.72	0.26	(0.192)		0.15	(0.251)		-0.62	(0.237)	***
POST-FARM										
Storage services	0.07	0.10	(0.047)	**	0.04	(0.053)		0.15	(0.063)	**
Paddy drying service	0.16	0.28	(0.066)	***	0.05	(0.074)		-0.01	(0.164)	
Paddy/rice trading business	0.37	0.29	(0.081)	***	0.25	(0.093)	***	0.14	(0.144)	
Rice retail shop	0.23	0.05	(0.072)		0.01	(0.082)		0.07	(0.085)	
Contracts with buyers	0.09	0.14	(0.053)	***	0.13	(0.061)	**	0.19	(0.065)	***
Sell ready to eat food	0.00	0.04	(0.014)	***	0.04	(0.023)	*	0.04	(0.013)	***
Manufactures animal/fish feed	0.00	0.08	(0.019)	***	0.10	(0.037)	***	0.08	(0.020)	***
Manufactures other byproduct goods	0.21	0.21	(0.071)	***	0.17	(0.084)	**	0.32	(0.072)	***
Transport services	0.19	0.08	(0.067)		0.09	(0.085)		-0.25	(0.161)	
N post-farm services/businesses	1.33	1.26	(0.247)	***	0.87	(0.281)	***	0.73	(0.321)	**
OTHER										
Farms paddy	0.65	-0.20	(0.081)	**	-0.10	(0.096)		-0.02	(0.108)	
Other rice business	0.00	0.10	(0.021)	***	0.12	(0.041)	***	0.10	(0.021)	***
Other non-rice business	0.33	-0.09	(0.078)		-0.03	(0.090)		-0.07	(0.096)	
N other businesses	0.98	-0.19	(0.111)	*	-0.01	(0.129)		0.01	(0.110)	
N total businesses	3.02	1.33	(0.377)	***	1.00	(0.429)	**	0.12	(0.491)	

Number of observations for comparisons is 249, but 12 observations are dropped in matching common support. Robust standard errors in parentheses. * p<0.1; ** p<0.05; ***p<0.01.

The post-farm services, in contrast, show several significant differences, each with modern mills showing a greater propensity to provide them. Of the nine post-farm services and businesses, seven show significantly higher adoption by modern mills in simple means comparisons, while five do so when we control for covariates and when we use matching. Some of the largest differences with at least 10 pp differences across estimates are in paddy/rice trading businesses, manufacturing other (non-feed) byproduct goods, and contracting with buyers. Operating a rice retail shop shows insignificant differences across estimation methods. Providing paddy drying services shows insignificant differences when controlling for covariates and in matching, while there are insignificant differences in providing transport services in the simple and controlled means estimates, but a negative and weakly significant relationship in the matched sample. This latter estimate offsets some of the positive differences leading to an insignificant difference in the count of post-farm businesses operated, while the simple and controlled means estimates show a significantly greater number of these businesses for modern mills.

In other businesses, modern mills are 10-12 pp more likely to operate another business in the paddy/rice value chain (e.g., exporting rice or importing inputs) (significant at the 1 percent level in

all three estimates), but they are less likely to operate a paddy farm, though the differences are smaller and insignificant when controlling for covariates and in matching.

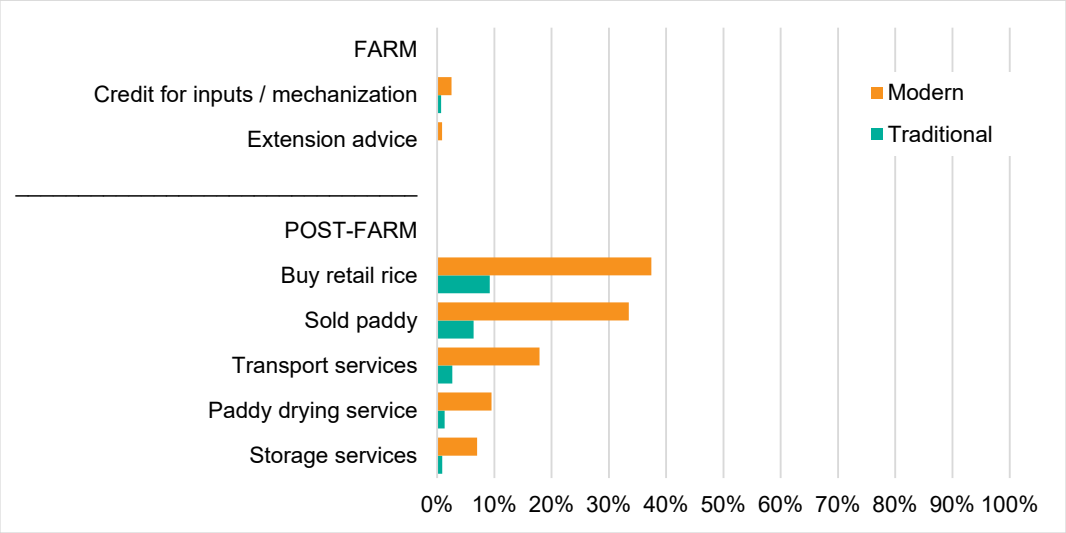
The covariate relationships (from the covariate-controlled estimation) also show some interesting patterns (Appendix Table A.3, Table A.4, Table A.5). First, mills with managers that have high education are more likely to vertically integrate in farm-facing businesses, specifically selling paddy seed and other inputs. Second, larger mills are more likely to vertically integrate in post-farm businesses including drying services, trading businesses, contracting with rice buyers, and transport services. Third, mills in urban areas are more likely to operate other businesses either outside or within the rice value chain.

4.2. Farmer use of miller-operated complementary services and businesses

Having analyzed rice mill vertical integration at the mill level, we now turn to the demand side using household-level survey data to explore farmer use of services provided by mills. We analyze farmer propensities to use several miller services by whether or not the farmer used a modern mill for milling their paddy to rice in the past year. In our sample of paddy farmers, 39 percent used a modern mill in the year prior to the survey.

Figure 5 shows the shares of farmers utilizing additional services provided by mills, comparing those that used a modern mill to those that used only traditional mills. Overall, farmers show limited use of mill-provided farm-level services. Just 1 percent of our sample received farm credit from mills and less than 1 percent received extension advice from mills. This is in contrast with other value chain agents, such as agro-input retailers, that are much involved in these services (Goeb et al., 2026). However, post-farm services were much more common. In the full sample, 20 percent of farmers purchased rice at retail from a miller, 17 percent sold paddy to a mill, and 9 percent used mill-provided transport services. Smaller overall shares used mill services for drying (4 percent) and storage (3 percent).

Figure 5. Farmer use of additional mill services by type of mill used



N=2,375. Source: Authors' calculations from MAPS 2024.

Each service is more commonly utilized by farmers that used modern mills. Those using only traditional mills show less than 10 percent using each service, with rice retail and selling paddy as

the most common. While farmers using a modern mill show meaningful shares using mill services including rice retail (37 percent), selling paddy (33 percent), and transport services (18 percent).

These simple farmer usage comparisons do not control for differences in farmer characteristics that could affect both farmer use of modern mills and their use of miller services. To better isolate the relationships between modern mill use and use of mill services, we again turn to statistical comparisons that control for covariates and separately use matching to achieve more similar samples across covariates (Table 2).

Table 2. Farm-level differences in mill services and businesses used, farmers using modern mills compared to traditional mills

Business/service received from mill	Mean for farmers using traditional mills	Differences (modern – traditional mill use)								
		Simple difference			Controlling for covariates			Matching		
FARM										
Credit for inputs	0.01	0.02	(0.006)	**	0.02	(0.006)	***	0.02	(0.005)	***
Extension advice	0.00	0.01	(0.003)	**	0.01	(0.003)	**	0.01	(0.004)	
N farm services	0.01	0.03	(0.007)	***	0.03	(0.007)	***	0.03	(0.007)	***
POST-FARM										
Sell paddy	0.06	0.27	(0.017)	***	0.27	(0.017)	***	0.28	(0.018)	***
Transport services	0.03	0.15	(0.013)	***	0.15	(0.014)	***	0.15	(0.014)	***
Paddy drying service	0.01	0.08	(0.010)	***	0.08	(0.010)	***	0.08	(0.011)	***
Storage services	0.01	0.06	(0.009)	***	0.06	(0.009)	***	0.06	(0.010)	***
Buy retail rice	0.09	0.28	(0.018)	***	0.29	(0.018)	***	0.28	(0.020)	***
N post-farm services	0.20	0.85	(0.043)	***	0.86	(0.043)	***	0.84	(0.047)	***
N of mill services	0.21	0.87	(0.044)	***	0.88	(0.044)	***	0.87	(0.048)	***

Number of observations for each comparison is 2,375. Zero observations are dropped in matching common support. Robust standard errors in parentheses. * p<0.1; ** p<0.05; ***p<0.01.
Source: Authors' calculations from MAPS 2024.

As with mill-level estimates, matching strongly improves sample balance across farmer covariates (Appendix Table A.6). Prior to matching, comparisons of the full sample show several covariates with significant differences, implying that farmers with different covariates are more or less likely to use a modern mill. Farmers in the Dry Zone were more likely to use a modern mill, while those in the Delta and Coastal regions were relatively less likely. Farmers in more remote areas were much less likely to use a modern mill, while better educated farmers were more likely to use a modern mill. After matching, there are no significant differences across the covariates.

Table 2 shows that, overall, farmers using modern mills utilized an average of 0.87-0.88 more total services from mills, the bulk of which were in post-farm services (0.84-0.86), with only a small difference (0.03) in farm-level services. While use of farm-level services show small differences in magnitudes – just 1 to 2 pp – farmers using modern mills are both more likely to receive credit and extension advice, and all but one estimated difference is statistically significant. The exception being in receiving extension advice in the matching estimation.

As with the mill-level estimations, there are much larger differences in post-farm mill services utilized by farmers. Those using modern mills are statistically more likely to utilize each post-farm mill service, and the magnitudes of differences are similar across the three comparisons. The largest differences are in buying retail rice (28-29 pp higher for those using modern mills), selling paddy to

mills (27-28 pp), and using transport services (15 pp). Using paddy drying services and storage services show smaller, but still statistically significant differences.

The covariate relationships show that large farms (tercile 3) are significantly more likely than small farms (tercile 1) to utilize six of the seven milling businesses, with the exception being buying retail rice at a mill (Appendix Table A.7).

4.3. Extensions and robustness checks

The preceding analysis shows that rice mills – and modern mills in particular – provide a range of complementary services. Yet mills are only one component of a modernizing, dynamic rice value chain in Myanmar. Use of these other modern services is likely expanding as part of a co-developing and modernizing system. In this context, we extend our analysis to examine whether farmers that use modern mills are also more likely to adopt other modern rice production practices. This analysis provides information on how the use of modern mills relates to broader farm-level engagement in the modernizing rice value chain and characterizes the depth of modernization in paddy production.

Table 3 presents mean comparisons similar to Table 2, but the dependent variables are indicators of modern practices and services used from the broader value chain (i.e., not limited to those provided directly by mills). Farmers that use modern mills are significantly more likely to purchase new paddy seed, use modern machinery for plowing and harvesting, and to receive formal extension advice. Thus, the farmers that use modern mills are more likely to participate more broadly in a modernizing rice value chain where modern milling and other modern practices are co-developing. Farm credit is an exception, with differences in receiving agricultural credit – from both formal and informal sources – small and mostly insignificant.

Table 3. Farm-level differences in modern practices and services used, farmers using modern mills compared to traditional mills

Modern practice or service used	Mean for farmers using traditional mills	Differences (modern – traditional mill use)								
		Simple difference			Controlling for covariates			Matching		
Purchase new seed	0.18	0.10	(0.018)	***	0.07	(0.018)	***	0.08	(0.022)	***
Tractor plow (4-wheel)	0.35	0.17	(0.021)	***	0.13	(0.021)	***	0.15	(0.026)	***
Combine harvester	0.45	0.09	(0.021)	***	0.06	(0.019)	***	0.06	(0.022)	***
Formal credit	0.34	0.03	(0.020)		0.03	(0.020)	*	0.03	(0.024)	
Informal credit	0.13	-0.01	(0.014)		0.00	(0.014)		0.02	(0.015)	
Formal extension	0.28	0.08	(0.020)	***	0.06	(0.020)	***	0.08	(0.023)	***

Number of observations for each comparison is 2,375. Zero observations are dropped in matching common support. Robust standard errors in parentheses. * p<0.1; ** p<0.05; ***p<0.01.
Source: Authors' calculations from MAPS 2024.

As another extension of our farm-level analysis, we test for heterogeneous differences in the use of mill services by interacting the modern mill use variable with (i) farm size terciles, and (ii) remoteness. These tests help us understand if farm size or remoteness are driving factors in the observed differences in the use of complementary milling services across mill type.

We observe that medium sized farms that use modern mills have similar propensities to use mill services to the small-farm group – coefficient magnitudes are small and all but one estimate is statistically insignificant (Appendix Table A.8, Panel A). Remoteness also shows insignificant and small heterogenous effects (Appendix Table A.9).

However, there are meaningful differences for the large-farm group (Appendix Table A.8, Panel B). Larger farmers that use modern mills use significantly more farm-facing and post-farm services

from mills compared to the small-farm group. From the millers' perspectives, engaging larger farmers may come with lower risk and lower transaction costs per unit of volume, and could be a strategy to stabilize paddy throughput in the core milling operation. On the farm side, the differences suggest that access to the modern mill services may not be the same across farm scale, and that the vertical integration/coordination of modern mills may not be inclusive of smaller farms.

Lastly, while the definition of modern mills is broadly understood in our context to be the type of core milling machinery used, there are other modern machines utilized by mills. As a robustness check on our definition, we conduct the same set of mean comparisons in mill provision of complementary services with modern defined, not by the core milling machine used, but by the use of at least one value-added processing machine (whitener, mist polisher, or color sorter). Using this alternative definition, we see similar integration patterns (Appendix Table A.10). The differences in farm-facing services are again small and, in some cases, negative (i.e., modern mills are less likely to participate than traditional mills), while differences for post-farm activities are larger and positive.

5. DISCUSSION

Our results point to a pattern of co-development in which investments in modern milling machinery are closely linked with widening business operations in Myanmar's rice value chain, making mills central participants in Myanmar's agricultural transformation. Modern mills are more likely than traditional mills to vertically integrate and coordinate, even when controlling for factors that might otherwise affect incentives like business scale and manager characteristics.

Most of mills' expanded enterprises are in post-farm activities, such as rice trading, paddy drying, and manufacturing goods from milling byproducts. These activities have strong complementarities with the core processing business through improved quality consistency, reduced transaction costs, and increased margins. Results from representative farm household data support this pattern as farmers are much more likely to utilize post-farm, rather than farm-facing, services from mills and farmers using a modern mill utilize mill-provided post-farm services more often.

Expansion into farm-facing activities, though still conducted by meaningful shares of mills, is more limited with smaller differences between modern and traditional mills. Coordinating and transacting with many small-scale producers likely has high transaction costs and our data show that larger farms – which can supply higher volumes – are more likely to receive several of these farm-facing services from mills. Thus, while operations are expanding along the value chain, access to these services is uneven, suggesting that these transformations do not automatically translate into broad-based inclusion.

By documenting these patterns in Myanmar's rice sector, this study extends evidence beyond high-value, export, and FDI-driven contexts, showing how domestically financed enterprises can drive staple food value chain modernization. Overall, our results suggest that modernizing agricultural processors can play a catalytic role in AVC transformation, primarily by expanding operations into post-farm activities with strong complementarities to processing.

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APPENDIX

Table A.1. Regression variable definitions and descriptive statistics

Panel A: Rice miller data					
Variable	Definition	Traditional mills		Modern mills	
		Mean	SD	Mean	SD
Location					
Delta AEZ	Mill located in the Delta agro-ecological zone	0.42	(0.50)	0.88	(0.32)
Urban	Mill located in an urban area	0.07	(0.26)	0.41	(0.49)
Mill characteristics					
Throughput(ln)	Natural log of mill throughput during the marketing season	4.27	(2.10)	6.16	(2.55)
Old mill	Mill began operating more 10 years ago	0.58	(0.50)	0.47	(0.50)
Miller characteristics					
High education	Education greater than median (>Grade 11)	0.40	(0.49)	0.55	(0.50)
Female	Mill manager/owner is female	0.28	(0.45)	0.19	(0.39)
High experience	Manager experience greater than median (>14 years)	0.40	(0.49)	0.51	(0.50)
Insecure	Perceive local area as insecure	0.09	(0.29)	0.10	(0.30)

Panel B: Rice farmer data					
Variable	Definition	Use traditional mill		Use modern mill	
		Mean	SD	Mean	SD
Location					
AEZ					
Hills	Farmer lives in the agro-ecological zone	0.24	(0.43)	0.21	(0.41)
Delta		0.36	(0.48)	0.49	(0.50)
Dry Zone		0.33	(0.47)	0.29	(0.45)
Coastal		0.06	(0.25)	0.01	(0.10)
Remote	Farmer travel time to nearest town is greater than median	0.52	(0.50)	0.36	(0.48)
	Paddy area cultivated terciles				
Small	<= 2.5 acres	0.38	(0.49)	0.35	(0.48)
Medium	>2.5 acres, <=5 acres	0.33	(0.47)	0.34	(0.48)
Large	> 5 acres	0.29	(0.45)	0.31	(0.46)
Farmer Characteristics					
High education	Education greater than median (>Grade 6)	0.42	(0.49)	0.47	(0.50)
Female	Female household head	0.16	(0.37)	0.16	(0.37)
HH size	Number of household members	4.56	(1.81)	4.57	(1.64)
Insecure	Perceive local area as insecure	0.33	(0.47)	0.30	(0.46)

Table A.2. Mill sample balance comparisons, unmatched and PSM matched

Variable	Unmatched				Matched				Change in | percent bias|
	Modern	Traditional	| percent bias|	p-val	Modern	Traditional	| percent bias|	p-val	
ln_throughput	6.18	4.27	82.1	<0.001	6.08	6.17	3.8	0.682	-78.3
delta	0.88	0.42	110.7	<0.001	0.88	0.87	1.2	0.879	-109.5
urban	0.41	0.07	86.0	<0.001	0.37	0.37	0.0	1.000	-86.0
highEd	0.55	0.40	30.8	0.068	0.53	0.55	3.1	0.761	-27.7
fem	0.19	0.28	21.1	0.186	0.19	0.23	8.5	0.383	-12.6
ageMill10	0.47	0.58	23.1	0.170	0.49	0.45	9.3	0.361	-13.8
highExp	0.50	0.40	22.0	0.193	0.50	0.54	7.2	0.478	-14.8
insecure	0.10	0.09	3.0	0.860	0.09	0.07	5.2	0.575	2.2

Table A.3. Full covariate-controlled regression results – Farm-facing businesses and services

	Contracts farmers	Sells paddy seed	Sells other paddy inputs	Extension advice	Tractor plowing services	Combine harvesting services	N farm services/businesses
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Modern	0.018	0.112*	-0.104	0.009	0.069	0.078	0.173
	(0.056)	(0.059)	(0.075)	(0.081)	(0.057)	(0.071)	(0.195)
Ln(throughput)	0.004	0.004	-0.008	0.014	-0.002	-0.005	0.01
	(0.006)	(0.006)	(0.011)	(0.011)	(0.006)	(0.008)	(0.028)
Delta AEZ	-0.019	-0.150**	0.106*	0.001	-0.091	-0.088	-0.242
	(0.051)	(0.068)	(0.056)	(0.073)	(0.063)	(0.074)	(0.197)
Urban	0.076*	0.03	0.038	0.009	0.066	0.005	0.231
	(0.045)	(0.050)	(0.049)	(0.055)	(0.045)	(0.041)	(0.168)
High education	-0.01	0.114**	0.156***	0.015	0.046	0.008	0.320**
	(0.042)	(0.046)	(0.042)	(0.051)	(0.040)	(0.037)	(0.147)
Female	-0.052	-0.071	0.001	-0.128***	-0.033	-0.005	-0.28
	(0.042)	(0.049)	(0.056)	(0.049)	(0.041)	(0.047)	(0.170)
Old mill	-0.013	0.02	0.043	0.07	-0.021	0.026	0.119
	(0.042)	(0.049)	(0.045)	(0.052)	(0.036)	(0.038)	(0.147)
High experience	-0.012	0.073	0.058	0.039	0.014	-0.008	0.156
	(0.041)	(0.050)	(0.045)	(0.053)	(0.039)	(0.038)	(0.153)
Insecure	0.142	0.037	-0.046	0.112	0.055	0.021	0.325
	(0.088)	(0.080)	(0.063)	(0.093)	(0.071)	(0.067)	(0.279)
Constant	0.075	0.043	0.043	0.043	0.08	0.111	0.391*
	(0.066)	(0.062)	(0.068)	(0.070)	(0.056)	(0.068)	(0.218)
N	249	249	249	249	249	249	249
R-sq	0.044	0.058	0.091	0.056	0.035	0.018	0.058

Table A.4. Full covariate-controlled regression results - Post-farm businesses and services

	Storage services	Paddy drying service	Paddy/rice trading business	Rice retail shop	Contracts with buyers	Sell ready to eat food	Manufactures animal/fish feed	Manufactures other by-product goods	Transport services	N post-farm services/businesses
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Modern	0.045	0.045	0.250***	0.012	0.131**	0.040*	0.104***	0.167**	0.094	0.868***
	(0.053)	(0.074)	(0.093)	(0.082)	(0.061)	(0.023)	(0.037)	(0.084)	(0.085)	(0.281)
Ln(throughput)	0.017*	0.034***	0.031**	0.008	0.021***	0.005	-0.003	-0.006	0.033***	0.145***
	(0.009)	(0.012)	(0.013)	(0.010)	(0.008)	(0.004)	(0.009)	(0.014)	(0.009)	(0.046)
Delta AEZ	0.042	0.239***	-0.13	-0.041	-0.086	-0.049	-0.017	0.051	-0.127	-0.121
	(0.051)	(0.073)	(0.090)	(0.086)	(0.075)	(0.042)	(0.057)	(0.091)	(0.084)	(0.293)
Urban	-0.024	0.083	0.035	0.029	-0.005	0.016	-0.032	0.032	-0.075	0.075
	(0.052)	(0.068)	(0.067)	(0.062)	(0.057)	(0.028)	(0.037)	(0.068)	(0.062)	(0.212)
High education	0.047	0.079	0.095	0.155**	0.052	0.044**	-0.003	0.004	-0.044	0.408**
	(0.044)	(0.061)	(0.064)	(0.060)	(0.050)	(0.022)	(0.037)	(0.064)	(0.057)	(0.201)
Female	0.006	-0.082	-0.019	0.000	-0.039	0.01	-0.014	-0.107	-0.126**	-0.353
	(0.057)	(0.070)	(0.080)	(0.072)	(0.064)	(0.031)	(0.039)	(0.078)	(0.059)	(0.243)
Old mill	0.053	-0.036	-0.047	-0.024	0.035	-0.008	-0.01	-0.07	-0.062	-0.185
	(0.046)	(0.060)	(0.061)	(0.060)	(0.050)	(0.024)	(0.033)	(0.065)	(0.056)	(0.196)
High experience	0.144***	0.04	0.049	0.041	-0.004	-0.002	0	0.049	-0.026	0.274
	(0.046)	(0.064)	(0.065)	(0.064)	(0.053)	(0.025)	(0.039)	(0.068)	(0.057)	(0.205)
Insecure	0.104	0.063	0.123	-0.013	0.320***	-0.005	0.053	-0.023	-0.057	0.572*
	(0.090)	(0.094)	(0.094)	(0.099)	(0.104)	(0.045)	(0.067)	(0.107)	(0.086)	(0.325)
Constant	-0.135**	-0.098	0.258**	0.152*	-0.019	-0.017	0.028	0.264***	0.210**	0.635**
	(0.066)	(0.069)	(0.101)	(0.087)	(0.078)	(0.027)	(0.035)	(0.100)	(0.083)	(0.299)
N	249	249	249	249	249	249	249	249	249	249
R-sq	0.094	0.165	0.1	0.035	0.108	0.036	0.026	0.043	0.073	0.186

Table A.5. Full covariate-controlled regression results - Other businesses and services and total

	Farms paddy	Other rice business	Other non-rice business	N other businesses	Total number of businesses
	(1)	(2)	(3)	(4)	(5)
Modern	-0.099	0.121***	-0.029	-0.014	1.027***
	(0.096)	(0.041)	(0.090)	(0.129)	(0.387)
Ln(throughput)	0.001	-0.004	-0.011	-0.011	0.144**
	(0.013)	(0.008)	(0.011)	(0.019)	(0.067)
Delta AEZ	-0.216**	-0.088	-0.249***	-0.554***	-0.917**
	(0.095)	(0.057)	(0.092)	(0.146)	(0.391)
Urban	-0.006	0.071*	0.125**	0.195*	0.502
	(0.070)	(0.041)	(0.061)	(0.111)	(0.353)
High education	-0.022	0.053	0.069	0.092	0.820**
	(0.065)	(0.036)	(0.056)	(0.097)	(0.318)
Female	0.018	-0.056	-0.154***	-0.185	-0.817**
	(0.081)	(0.040)	(0.056)	(0.113)	(0.354)
Old mill	0.018	0.070*	-0.068	0.015	-0.051
	(0.067)	(0.038)	(0.055)	(0.101)	(0.316)
High experience	0.013	-0.005	0.031	0.033	0.463
	(0.069)	(0.038)	(0.058)	(0.107)	(0.340)
Insecure	0.063	-0.013	-0.094	-0.042	0.855*
	(0.110)	(0.062)	(0.084)	(0.168)	(0.507)
Constant	0.719***	0.004	0.518***	1.238***	2.265***
	(0.109)	(0.045)	(0.104)	(0.160)	(0.465)
N	249	249	249	249	249
R-sq	0.051	0.067	0.078	0.08	0.134

Table A.6. Farmer sample balance comparisons, unmatched and PSM matched

	Unmatched				Matched				Change in | percent bias |
Variable	Modern	Traditional	| percent bias |	p-val	Modern	Traditional	| percent bias |	p-val	
Dry Zone	0.49	0.36	26.3	<0.001	0.49	0.50	1.1	0.815	-25.2
Delta	0.29	0.33	9.3	0.029	0.29	0.29	0.0	1.000	-9.3
Coastal	0.01	0.06	29.2	<0.001	0.01	0.01	0.0	1.000	-29.2
Medium-size farm	0.34	0.33	2.0	0.634	0.34	0.34	1.4	0.768	-0.6
Large-size farm	0.31	0.29	4.4	0.297	0.30	0.31	0.7	0.879	-3.7
Remote	0.36	0.52	31.8	<0.001	0.36	0.36	0.0	1.000	-31.8
Insecure	0.30	0.33	5.1	0.23	0.30	0.30	1.2	0.799	-3.9
High Education	0.47	0.42	11.3	0.007	0.47	0.47	1.3	0.779	-10.0
Female	0.16	0.16	0.2	0.968	0.16	0.15	2.1	0.654	1.9
HH size	4.57	4.56	0.4	0.917	4.57	4.54	1.8	0.666	1.4

Table A.7. Full covariate-controlled regression results – Farmer use of milling businesses

	Farm level			Post-farm level						
	Credit for inputs / mechani-zation	Extension advice	N farm services from mills	Sell paddy	Transport services	Paddy drying service	Storage services	Buy retail rice	N post-farm ser-vices from mills	**Total number of mill services**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Modern	0.019***	0.006**	0.026***	0.272***	0.152***	0.083***	0.062***	0.288***	0.858***	0.884***
	(0.006)	(0.003)	(0.007)	(0.017)	(0.014)	(0.010)	(0.009)	(0.018)	(0.043)	(0.044)
Delta AEZ	0.000	0.003*	0.004	0.005	0.007	0.005	-0.007	0.013	0.022	0.026
	(0.004)	(0.002)	(0.004)	(0.017)	(0.014)	(0.009)	(0.008)	(0.019)	(0.041)	(0.042)
Dry Zone AEZ	0.018***	0.002	0.020***	0.072***	0.013	0.045***	0.027**	0.165***	0.321***	0.341***
	(0.006)	(0.003)	(0.007)	(0.021)	(0.017)	(0.012)	(0.011)	(0.023)	(0.054)	(0.055)
Coastal AEZ	0.006	0.002	0.008	-0.007	0.018	0.015	-0.001	-0.003	0.022	0.03
	(0.010)	(0.001)	(0.010)	(0.026)	(0.023)	(0.015)	(0.012)	(0.027)	(0.067)	(0.068)
Medium farm (tercile 2)	0.001	-0.002	0.000	-0.005	0.009	-0.004	0.004	-0.019	-0.015	-0.015
	(0.004)	(0.002)	(0.005)	(0.016)	(0.013)	(0.009)	(0.007)	(0.018)	(0.040)	(0.041)
Large farm (tercile 3)	0.020***	0.007*	0.027***	0.072***	0.033**	0.024**	0.028***	-0.011	0.146***	0.173***
	(0.006)	(0.004)	(0.008)	(0.020)	(0.016)	(0.012)	(0.010)	(0.021)	(0.052)	(0.055)
Remote	0.003	-0.003	0.000	0.012	0.006	0.001	0.003	0.002	0.024	0.025
	(0.005)	(0.002)	(0.006)	(0.014)	(0.011)	(0.008)	(0.007)	(0.015)	(0.036)	(0.037)
Insecure	0.002	-0.004*	-0.002	0.001	-0.012	0.003	0.005	0.016	0.012	0.01
	(0.005)	(0.002)	(0.006)	(0.015)	(0.012)	(0.009)	(0.008)	(0.016)	(0.037)	(0.039)
High education	0.000	0.001	0.001	0.029*	0.008	0.011	0.01	0.005	0.062*	0.063*
	(0.005)	(0.003)	(0.006)	(0.015)	(0.011)	(0.009)	(0.007)	(0.016)	(0.036)	(0.038)
Female	0.006	-0.004***	0.002	-0.028	0.02	-0.009	-0.001	-0.026	-0.043	-0.041
	(0.007)	(0.001)	(0.007)	(0.018)	(0.016)	(0.010)	(0.009)	(0.020)	(0.046)	(0.048)
Household size	0.003	-0.001	0.002	0.000	-0.001	0.000	0.001	0.001	0.002	0.004
	-0.002	-0.001	-0.002	-0.004	-0.003	-0.002	-0.002	-0.004	-0.01	-0.01
Constant	-0.020**	0.00	-0.02	0.00	0.00	-0.02	-0.020*	0.03	0.01	-0.01
	(0.009)	(0.003)	(0.010)	(0.026)	(0.020)	(0.015)	(0.011)	(0.029)	(0.064)	(0.067)
N	2375	2375	2375	2375	2375	2375	2375	2375	2375	2375
R-sq	0.022	0.009	0.022	0.150	0.075	0.055	0.046	0.150	0.218	0.218

Table A.8. Farm-level differences in mill services and businesses used, interaction coefficients between modern mill use and farm size terciles (medium and large farms)

Panel A: Modern mill interactions with medium sized farms (tercile 2) Business	Simple difference			Controlling for co-variates			Matching		
FARM									
Credit for inputs / mechanization	0.00	(0.009)		0.00	(0.009)		0.01	(0.009)	
Extension advice	-0.01	(0.005)	*	-0.01	(0.005)		-0.01	(0.004)	
N farm services from mills	-0.01	(0.010)		0.00	(0.010)		0.00	(0.010)	
POST-FARM									
Buy paddy	-0.02	(0.038)		-0.02	(0.038)		0.00	(0.043)	
Transport services	-0.03	(0.031)		-0.03	(0.031)		-0.03	(0.033)	
Paddy drying service	0.00	(0.021)		0.01	(0.021)		0.02	(0.028)	
Storage services	0.02	(0.017)		0.02	(0.018)		0.02	(0.017)	
Rice retailing	-0.02	(0.041)		-0.01	(0.041)		0.01	(0.053)	
N post-farm services from mills	-0.06	(0.091)		-0.03	(0.091)		0.02	(0.111)	
Total number of mill services	-0.07	(0.093)		-0.03	(0.093)		0.02	(0.112)	
Panel B: Modern mill interaction with large sized farms (tercile 3) Business	Simple difference			Controlling for co-variates			Matching		
FARM									
Credit for inputs / mechanization	0.03	(0.016)		0.03	(0.016)	*	0.04	(0.015)	***
Extension advice	0.01	(0.010)		0.01	(0.010)		0.02	(0.010)	
N farm services from mills	0.04	(0.021)	*	0.04	(0.021)	*	0.06	(0.020)	***
POST-FARM									
Buy paddy	0.07	(0.043)		0.07	(0.043)	*	0.09	(0.058)	
Transport services	0.05	(0.034)		0.05	(0.034)		0.05	(0.036)	
Paddy drying service	0.08	(0.027)	***	0.09	(0.027)	***	0.10	(0.034)	***
Storage services	0.06	(0.023)	***	0.07	(0.023)	***	0.07	(0.027)	**
Rice retailing	0.00	(0.044)		0.01	(0.044)		0.02	(0.063)	
N post-farm services from mills	0.27	(0.112)	**	0.29	(0.110)	***	0.33	(0.141)	**
Total number of mill services	0.30	(0.118)	**	0.33	(0.116)	***	0.39	(0.146)	***

Table A.9. Farm-level differences in mill services and businesses used, interaction coefficients between modern mill use and remoteness

Business	Simple difference		Controlling for covariates		Matching	
FARM						
Credit for inputs / mechanization	-0.01	(0.011)	-0.01	(0.011)	0.00	(0.011)
Extension advice	0.00	(0.006)	0.00	(0.006)	0.00	(0.006)
N farm services from mills	-0.01	(0.014)	-0.01	(0.014)	-0.01	(0.014)
POST-FARM						
Buy paddy	0.00	(0.035)	0.00	(0.034)	-0.01	(0.042)
Transport services	0.00	(0.028)	0.00	(0.028)	0.01	(0.031)
Paddy drying service	0.02	(0.021)	0.02	(0.021)	0.03	(0.024)
Storage services	0.00	(0.018)	-0.01	(0.018)	0.01	(0.021)
Rice retailing	-0.01	(0.037)	-0.01	(0.036)	-0.02	(0.047)
N post-farm services from mills	0.01	(0.089)	0.00	(0.086)	0.03	(0.108)
Total number of mill services	0.00	(0.092)	-0.01	(0.090)	0.02	(0.111)

Table A.10. Alternative 'modern' mill definition: Differences in services and businesses offered by mills, modern mills compared to traditional mills

Business/service operated by mills	Traditional mean	Differences (Modern - Traditional)								
		Simple difference			Controlling for covari-ates			Matching		
FARM										
Contracts farmers	0.06	0.03	(0.040)		0.03	(0.041)		-0.20	(0.103)	*
Sells paddy seed	0.18	-0.05	(0.044)		-0.08	(0.049)	*	-0.36	(0.053)	***
Sells other paddy inputs	0.12	0.06	(0.044)		0.02	(0.048)		-0.07	(0.170)	
Extension advice	0.14	-0.02	(0.049)		-0.06	(0.056)		0.03	(0.169)	
Tractor plowing services	0.10	-0.02	(0.037)		-0.04	(0.043)		-0.04	(0.168)	
Combine harvesting services	0.08	0.02	(0.037)		0.04	(0.045)		-0.05	(0.169)	
Credit to farmers	0.10	0.06	(0.049)		0.05	(0.056)		-0.16	(0.113)	
N farm services/businesses	0.78	0.07	(0.169)		-0.05	(0.198)		-0.85	(0.425)	**
POST-FARM										
Storage services	0.04	0.09	(0.046)	*	0.04	(0.053)		0.08	(0.166)	
Paddy drying service	0.10	0.18	(0.061)	***	0.04	(0.068)		-0.20	(0.135)	
Paddy/rice trading business	0.44	0.17	(0.061)	***	0.12	(0.067)	*	-0.02	(0.202)	
Rice retail shop	0.28	0.02	(0.057)		-0.02	(0.062)		-0.16	(0.141)	
Contracts with buyers	0.14	0.12	(0.052)	**	0.11	(0.053)	**	0.16	(0.043)	***
Sell ready to eat food	0.00	0.04	(0.023)		0.03	(0.027)		0.03	(0.014)	**
Manufactures animal/fish feed	0.06	0.03	(0.032)		0.03	(0.037)		0.05	(0.033)	
Manufactures other byproduct goods	0.26	0.10	(0.062)		0.06	(0.068)		0.04	(0.091)	
Transport services	0.18	-0.02	(0.055)		-0.02	(0.061)		0.22	(0.045)	***
N post-farm services/businesses	1.50	0.69	(0.203)	***	0.36	(0.216)	*	0.19	(0.397)	
OTHER										
Farms paddy	0.74	-0.30	(0.061)	***	-0.26	(0.069)	***	-0.30	(0.054)	***
Other rice business	0.04	-0.06	(0.035)	*	-0.09	(0.042)	**	0.09	(0.022)	***
Other non-rice business	0.32	-0.13	(0.054)	**	-0.11	(0.058)	*	0.15	(0.040)	***
N other businesses	1.10	-0.50	(0.092)	***	-0.46	(0.105)	***	-0.06	(0.070)	
N total businesses	3.38	0.27	(0.338)		-0.15	(0.379)		-0.72	(0.618)	

Number of observations for comparisons is 249, but 23 observations are dropped in matching common support. Robust standard errors in parentheses. * p<0.1; ** p<0.05; ***p<0.01.
Modern is defined by the mill using one or more modern value-added machine (whitener, mist polisher, or color sorter).

ABOUT THE AUTHORS

Joseph Goeb is an Adjunct Professor in the Department of Agricultural, Food, and Resource Economics at Michigan State University and a Visiting Professor at Kasetsart University, based in Thailand. **Bart Minten** is a Senior Research Fellow and Myanmar Program Leader at the International Food Policy Research Institute, based in Laos PDR. **Thomas Reardon** is a University Distinguished Professor at the Department of Agricultural, Food, and Resource Economics at Michigan State University and a Nonresident Fellow at the International Food Policy Research Institute, based in California, USA. **A Myint Zu** is a Research Analyst at the International Food Policy Research Institute, based in Myanmar. **May Thet Htar** is a Research Analyst at the International Food Policy Research Institute, based in Myanmar.

ACKNOWLEGEMENTS

This work was undertaken as part of the Strengthening Resilience through Evidence: Demand-Driven Agrifood Research in Myanmar project led by the International Food Policy Research Institute (IFPRI). Funding support for this study was provided by the Australian Centre for International Agricultural Research (ACIAR). This publication has not gone through IFPRI's standard peer-review procedure. The opinions expressed here belong to the authors, and do not necessarily reflect those of IFPRI, CGIAR, or ACIAR.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
1201 Eye St, NW | Washington, DC 20005 USA
T. +1-202-862-5600 | F. +1-202-862-5606 | ifpri@cgiar.org | www.ifpri.org | www.ifpri.info

The Myanmar Strategy Support Program (Myanmar SSP) is managed by the International Food Policy Research Institute (IFPRI). The program is financially supported by the Australian Government, the Livelihoods and Food Security Fund, and the United Kingdom Government. This publication has been prepared as an output of Myanmar SSP. It has not been independently peer reviewed. Any opinions expressed here belong to the author(s) and do not necessarily reflect those of IFPRI, CGIAR, the Australian Government, LIFT, or the United Kingdom Government.