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Conflict, Inclusivity, and Transformation of the Rice Value Chain in Myanmar

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Abstract

In numerous low- and middle-income countries, agricultural value chains (AVC) are undergoing rapid transformation, yet scant evidence exists regarding such changes in fragile and conflict-affected settings, and little is known about inclusivity in this transformation. This study focuses on changes in Myanmar's rice value chain - using unique large-scale primary data - from 2013 to 2022, during an economic boom and subsequent political upheaval and conflict. We document remarkable shifts, including a fourfold increase in rice exports, propelling Myanmar to the world's fifth-largest rice exporter. Concurrently, domestic market conditions improved, and there was modernization in the 'hidden middle' of the value chain including increased investments in modern milling equipment and drying methods. At the farm level we note greater adoption of modern inputs (e.g., improved seed) and harvest/post-harvest technologies and increased reliance on modern specialized service providers. The transformation was not everywhere inclusive, and modernization in some areas decelerated due to conflict. Mills and farms in insecure and conflict-affected areas, as well as remote millers and smallholders, participated to a lesser extent, and the gaps widened during the crisis years. The rapid modernization in Myanmar's rice value chain from 2013 to 2019 highlights the positive impacts of stable governance, infrastructure investment, and liberalization on AVC transformation while the observed variations in modernization inclusivity across different segments of the value chain underscore the complex interplay between governance, conflict, and AVC transformation.

JEL Codes: Q13, Q17, Q18

1. Introduction

Agricultural value chains (AVC) are rapidly transforming in low- and middle-income countries (LMIC) driven by income increases, urbanization, market-oriented reforms, globalization, and innovations in practices, standards, and technologies (Barrett et al. 2022). This transformation often includes an increasing importance of supermarkets, a food service revolution, large changes in value chain intermediation, increased vertical coordination, outsourcing of agricultural services to specialized service providers, and increasing uptake of modern inputs by farmers (Barrett et al. 2022; Reardon 2015; Swinnen and Maertens 2007; Reardon et al. 2023; Diao et al. 2020). However, there are widespread concerns on nutritional, health, and environmental impacts of this transformation, leading to urgent demands for the repurposing of agricultural policies and support (Gautam et al. 2022). Moreover, the impact of these changes on the participation of - often poor - smallholders is not clear and is widely debated (Barrett 2008; Barrett et al. 2012; Davis et al. 2022).

Further, there is limited evidence on AVC performance in fragile and conflict-affected states (Bellemare et al., 2022), and even less research is conducted on how conflict affects AVC transformation. This is an important research gap as global conflicts have increased dramatically in recent years (Lay, 2023), with important implications on global food security. It is estimated that the number of undernourished people increased by almost 150 million between 2015 and 2022 (FAO et al. 2023) and people that needed emergency aid almost tripled between 2016 and 2023 (de Waal, 2024), mostly driven by an escalation of conflicts in the world.[1] While humanitarian aid has typically been used to alleviate famine situations, global aid budgets are dwindling - while annual appeals for emergency aid were funded at 60 percent a decade ago, just 35 percent were funded in 2023 (de Waal 2024) – implying that an increasing share of the food insecure in fragile and conflict-affected countries are not receiving needed assistance. It is therefore important to understand how AVCs function in these fragile environments and how AVC modernization processes are affected as well-functioning, modern, and transformed value chains will often contribute to enhanced availability of

[1] 70 percent of the hungry in the world were estimated to reside in areas affected by war and violence (WFP 2023).

food, potentially contributing to alleviate food insecurity in these fragile and conflict-affected environments.

This study explores the modernization of Myanmar's rice value chain (VC) over a period of liberalization, reform, and infrastructure expansion from 2013 to 2019, and over a period of multiple crises from 2019 to 2022 including a military coup and widespread conflict. We analyze modernization over these periods at different levels of the VC, including upstream (farms), midstream, often called the 'hidden middle' (mills), and downstream (rice vendors). The diffusion of modern practices in AVCs is well studied going back to Grilliches (1957) highlighting the roles of relative profitability in diffusion rates. However, the inclusivity in modernization, particularly in conflict-affected areas, is less explored. Conflict and unrest could disrupt modernization trends and alter patterns of inclusivity in adoption of modern practices or provision of modern services. Though the extent and directions of these potential changes are empirical questions. Using fixed effects difference-in-differences regressions, we test for inclusivity in several modernization outcome variables at the farm and mill levels for more remote locations, and smaller firms. We also analyze the relationships between local conflict and patterns in modernization.

We focus on the value chain of rice, a crop which half of the global population considers their main staple (Mutthaya et al. 2014) and therefore enormously important for food security, which has seen rapid AVC modernization in other contexts. Input use by rice farmers (seeds, fertilizer, irrigation) has seen enormous - and well-researched - changes during the Green Revolution with large transforming effects on productivity, as well as welfare (e.g. Gollin et al. 2021, Dawe et al. 2014, Otsuka et al. 2023). Relatively few studies have analyzed transformation processes in harvest and post-harvest technologies. Some authors highlight the rapidly increasing mechanization use (e.g. Otsuka et al. 2023, Diao et al. 2020). In a detailed study of the rice value chains in Asia, Reardon et al. (2014) document a quiet revolution with increasing market participation by farmers upstream; increasing investment, diversification into higher quality, and consolidation seen mid-stream; and the rapid spread of supermarkets downstream.[2]

[2] However, their study was focused on rice supplies to three mega-cities (Beijing, New Delhi, and Dhaka) and did not consider inclusiveness or conflict issues in this transformation.

While changes in AVCs in general - and rice VCs in particular – have been studied, the literature is limited by a focus on a small number of LMIC (usually countries with good research infrastructure). There is relatively little evidence from fragile and conflict-affected countries – where most of the global poor and food insecure reside (World Bank 2021, WFP 2023) – and a lack of data in the post-farmgate AVC, particularly the 'hidden middle' of AVCs (Barrett et al. 2022, Bellemare et al. 2022). In our study, we address this gap by looking at the case of Myanmar. Myanmar's economy has witnessed large volatility and fragility over the last decade and is considered a late agricultural transforming economy in South-East Asia (Boughton et al. 2022). Its economy grew rapidly after economic reform started in the 2010s, but that growth slowed after the COVID-19 pandemic and reversed after the upheaval and widespread conflicts following the arrest of Myanmar's civilian leaders in a military coup.[3] Myanmar was categorized in 2022 as one of only seven countries in the world with extreme levels of conflict severity (ACLED 2023) and as the highest level of organized criminality in the world in 2023 (Globalized Initiative against Transnational Globalized Crime 2023). In 2023, the United Nations estimated that almost 19 million people were in need of humanitarian assistance but only 37 percent of these needs were funded (UN 2023).

In this setting, we rely upon unique data from large-scale phone surveys collected at different segments of the VC – including farm and post-farmgate – complemented with insights from key informant interviews, and secondary data. We observe rapid changes over the last decade. Local rice market conditions improved with better-quality rice sold locally, and rice exports quadrupled, with Myanmar becoming globally the 5th biggest exporter of rice by the end of 2019, despite more stringent, and costly, non-tariff measures such as phyto-sanitary requirements. Moreover, the rice value chain in aggregate has proven to be resilient during the crisis years. We see shifting challenges over time – due to banking, electricity, and mobility problems that millers and traders adjusted to, at an increasing cost – but national exports mostly stabilized compared to the period before.

[3] From 2012 to 2019, after partial liberalization of its economy, its economy showed rapid growth and was in 2019, 50 percent bigger than in 2011. However, the COVID-19 pandemic and a military coup in the beginning of 2021, followed by widespread conflicts, led to economic contraction with its economy in 2022, 30 percent below the expected GDP without a pandemic and military takeover (World Bank 2023).

We find large changes and rapid modernization within the value chain. Downstream, rice is export channels have changed, moving away from low-quality rice trucked to China, to relatively better-quality and often certified rice being shipped on large vessels to a more diverse set of countries. In domestic rice distribution, modern retail is (yet) negligible at the national level, but rice quality has improved significantly. Midstream, we see a rapid rise in investments in modern drying machines - especially mechanized dryers - and modern milling machinery in the form of new mill starts and upgrading from traditional mills. This modernization has been driven, almost exclusively, by increased investments by local firm investments as Foreign Direct Investment (FDI) has been limited. Upstream, we note a substantial expansion of modern input use. The sale of branded rice seeds doubled over the last decade. We also see increased use of modern harvest and post-harvest technologies and more outsourcing of harvest and post-harvest activities, mostly linked to these modern technologies and practices.[4]

However, the majority of this transformation occurred during the period of relative stability from 2013 to 2019. We show that although modernization continued during the crisis years that followed, including an improvement in rice quality and an expansion of modern mills, many modernization processes slowed. Further, we find significant negative relationships between severe conflict and many modernization outcomes. At the farm-level, severe conflict has negative associations with the adoption of combine harvesting and drying services and use of modern dryers. In the midstream, we see negative relationships between conflict and the local share of modern mills and investments in modern drying equipment.

We also find that modernization has not been everywhere inclusive, with more remote and smaller firms participating less in modern practices. More remote farmers show smaller growth in adoption of combine harvesters, modern dryers, and modern mills, while smaller farmers have smaller growth in the use of combine harvesters and drying service providers. In the midstream, mills in remote areas show smaller changes in the share of modern mills in their localities, while smaller mills have significantly slower growth in modern service provision and lower investment rates in value-added

[4] Similar patterns have been illustrated in modernizing value chains in other settings (e.g. Reardon et al. 2023).

machinery. For many of these modernization outcomes, the gaps across firm size and remoteness widened during the crisis years.

Our findings point to three main implications for the modernization of Myanmar's rice VC, with relevance to other LMICs and conflict-affected countries. First, private-market oriented reform might lead to rapid modernization in AVC, while heavy intervention – e.g., low reference prices for rice; limits on internal trade in the country; control of imports and exports through an export licensing system; and currency manipulation through a dual exchange rate system – may jeopardize AVC modernization and increase uncertainty throughout AVCs. Second, local severe conflict negatively affects modernization at the farm and in the VC midstream. Third, modernization in the rice VC in this context was not everywhere inclusive, leading to concerns about livelihood improvements for the excluded farms, while conflict may further increase disparities in modernization.

2. Background

2.1 Rice in Myanmar

Paddy rice is immensely important for farmers' livelihoods and for food security in Myanmar. Rice is the main staple, accounting for 51 percent of urban calories and 62 percent of rural calories consumed, making it crucial for food security.[5] On the production side, paddy accounted for 36 percent of all (gross) land sown in the country in 2019/2020 (MoALI 2020).[6] Paddy production varies by region with the Delta – composed of Ayeyarwady, Bago, and Yangon regions - and Sagaing region in the Dry Zone the main producers.[7] The regional concentration of rice production means that trading and transporting over long distances by trucks and boats is important to ensure that rice is available country-wide (Minten et al. 2023).

Rice production and trade in Myanmar is characterized by substantial seasonal variation. Most of the paddy is produced during the rain-fed monsoon season. A second or third crop cycle can be produced in some areas during the dry season - the *winter* or *summer* season - with irrigation or residual soil moisture. This seasonality in rice production and trade has important implications. First and foremost, to ensure that rice is available for consumption throughout the year, storage of sufficient quantities over the year is required. Such storage is traditionally done at the farm level but is increasingly taken over by other agents midstream. Drying paddy rice is important to reduce the moisture levels that are high immediately after harvest to levels that are suitable for either storage or milling. This is traditionally done using sun-drying. Modern drying methods expose paddy to hot air and dry paddy faster – making them especially important in more humid regions – and ultimately produce better, more uniform quality rice. The two main types of advanced dryers are tub or batch dryers that are loaded once with a quantity of paddy that is dried and then removed, and mechanized dryers

[5] Estimated in 2015 (based on the Myanmar Poverty, Livelihood, and Consumption Survey).

[6] 52% in terms of net sown area.

[7] Combined they typically make up two-thirds of the total rice production in the country (the shares based on official MoALI data were in the season 2020/2021 31, 18, 8, and 10 percent respectively).

that mechanically move paddy through a dryer continuously. Mechanized dryers generally have higher daily capacities.

Milling processes have also shown rapid transformation over the years with significant advances in the use of improved milling machines, color sorters, polishers, and mist polishers, dramatically improving milling efficiency and quality of rice that is produced (Goeb et al. 2022). Milling machinery in Myanmar can be classified in two main types: traditional mills that use older technologies and have lower throughput capacities, and modern mills that use these newer technologies and have greater throughput capacities. More sophisticated mills allow also for the possibility to produce rice products at the demand of the client, e.g. double polishing is required for rice destined for some export markets, while domestic markets mostly prefer non-polished or single-polished rice. Traditional mills produce rice in fewer steps with fewer machines and produce mostly for local consumption, often on commission for farmers in their communities, while modern mills are more commercially oriented and use multiple steps and machines.

2.2 Economic reform and conflict

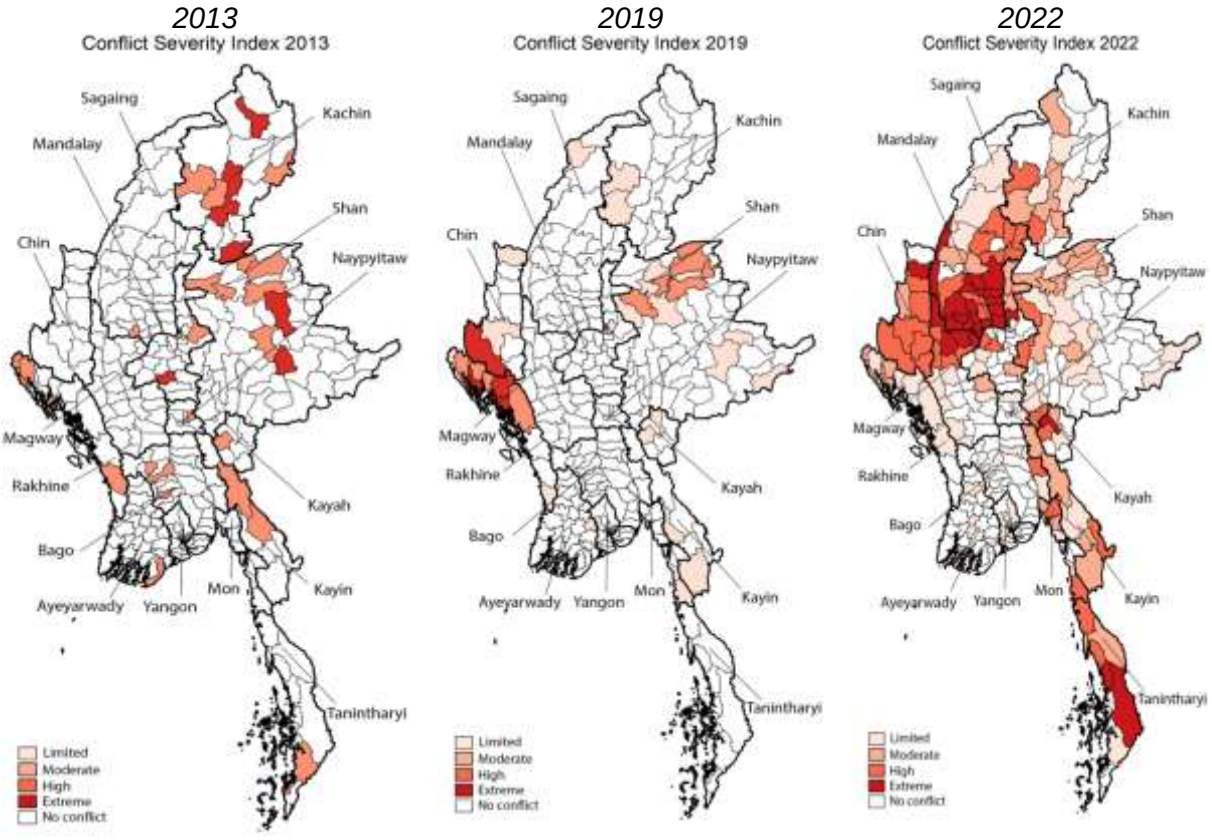
While Myanmar was the world's leading rice exporter in the beginning of the 20th century, it has suffered from economic mismanagement over time (Dorosh et al. 2019).[8] In the beginning of the 2010s, an ambitious economic policy reform program, moving away from a socialist legacy, was implemented, including new agricultural policies such as the relaxation of cropping controls. The country also became more open to international trade, with its neighbors (e.g., Thailand and China) and beyond. This gradual liberalization of Myanmar's economy in the decade to 2020 led to an overall economic expansion by 50 percent of its overall GDP and to rapid poverty alleviation (CSO, UNDP, and WB 2020, Ferreira et al. 2021). However, the

[8] In the early years of independence, all land was nationalized and throughout the military socialist era, from 1962 to 1988, compulsory cropping plans, production quotas, and mandatory sales to government marketing agencies, often at below market prices, led to long-term stagnation of rice productivity and competitiveness. Following a change to a non-socialist military government in 1988, stringent control by the state gradually loosened since, but there was still insufficient investment in rice production technology and irrigation infrastructure (Okamoto 2008, Dorosh et al. 2019).

COVID-19 pandemic and stringent mobility controls from the beginning of 2020 onwards followed by a military coup in 2021 have reversed these trends. The World Bank estimated that Myanmar's economy in 2022 was approximately 13 percent smaller than it had been three years prior (World Bank 2023). Moreover, food insecurity increased dramatically: an estimated 16 percent of the population had inadequate food consumption – borderline or poor – mid-2023, as measured by a widely-used Food Consumption Score (MAPSA 2023c).

There have also been widespread conflicts in the country since the military coup in the beginning of 2021. Figure 1 illustrates changes in conflict severity over time at the township level, categorizing townships in one of five categories (using the ACLED (2023) methodology): no, limited, moderate, high, and extreme conflict. Conflict severity clearly worsened over time. While 280 townships (85 percent of all townships) were in the no conflict category in 2013, this number fell to 153 townships in 2022 (46 percent of all townships). Conflicts are more severe in specific geographic areas with the location of most severe conflicts shifting over time. In 2019, the most severe conflicts were in northern Rakhine and Shan state but in 2022, they were relatively more concentrated in the North-West (South of Sagaing and Chin state) and the South-East of the country (Kayah, Kayin, and Tanintharyi regions) (Figure 1). Notably, most of the townships in Sagaing – representing 10 percent of rice production in 2020/21– were categorized in the high or extreme conflict severity category in 2022. On the other hand, the South-West of the country – where the Delta is located, considered the rice bowl of the country – has been relatively less affected by conflict.

Figure 1. Conflict severity by township in Myanmar, 2013–2022



Source: Authors' calculation based on ACLED data.

The impact of the growth and crisis period on the functioning of the rice value chain is not well understood. In the decade before the crisis, Myanmar's rice sector was lagging peers, with lower and less efficient modern input use, and therefore much lower productivity (World Bank 2014). Myanmar's value chain further suffered from inadequate infrastructure – access to electricity, roads, and ports – limiting improved performance (Basu and Sharma 2019). Moreover, it has faced unpredictable trade policies, most often because of ad hoc changes by China.[9] Most of the exported rice from Myanmar was low-quality, used for industrial purposes – for noodles, animal feed, and alcohol (processed in distilleries) in China – making exported quality in terms of broken rice often not an important consideration (Dorosh et al. 2019).

[9] Dorosh et al. (2019) show how important policies by China in the beginning of 2010s allowed rice exports to China to take off, but then it was significant constrained by China's sudden policy changes in mid-2016, reducing export demand.

Few studies have looked at the performance of the rice value chain during the crisis period. On the production side, MAPSA (2023a, b) illustrate that a typical inverse productivity - plot size relationship exists in Myanmar, with small rice plots having higher productivity levels but that the rising mechanization fees – more so in conflict-affected townships – attenuated this inverse relation and that increases in fatal violent events reduced rice Total Factor Productivity (TFP) by about four percent on average in the short-run. Minten et al. (2023) further illustrate that an increased distribution margin - due to conflict and increased transportation costs - led to 11 percent higher average retail prices after the coup, implying welfare losses of almost USD 0.5 billion for the country

3. Data and methods

3.1 Data

We use multiple primary data sources from different levels of the rice value chain in our analysis. First, we use farm data from the Myanmar Agricultural Performance Survey (MAPS), a phone survey started in the beginning of 2021. The MAPS sample is a subset of farm households from the broader Myanmar Household Welfare Survey (MHWS).[10] In combination with the development of household and population weights, the novel sampling strategy allows for estimates that are nationally, regionally, and urban/rural representative (Lambrecht et al. 2023). The MAPS focuses on the agricultural activities of crop farmers, during the monsoon and the dry season, and is fielded twice a year. In the July 2023 survey round, approximately five thousand farmers were interviewed including 3,141 rice farmers (Table 1). The questionnaire added questions to analyze modernization at the farm level including input use and technology choices in cultivation, harvest, and post-harvest activities over the previous year, as well as recall questions for three years earlier (2019, before the crisis), and ten years earlier (2013, at the beginning of the reform period).

Second, we use data from a phone survey of food vendors, with a sub-sample also collected through the MHWS. In this survey, vendors were asked to report prices of a number of foods as well as on the business environment they were operating in. In the February 2023 round of that survey

[10] The MHWS monitors household and individual welfare through a range of different indicators including wealth, livelihoods, and food insecurity.

234 rice vendors were interviewed, and we added recall questions on the evolution of rice marketing practices over the 3 and 10 years before the survey.

Table 1. Sample sizes and descriptive by survey

	Survey		
	Farmers (upstream)	Millers (midstream)	Food vendors (downstream
Sample size in 2023 survey	3141	553	234
Number of states/regions covered (of 15 in Myanmar)	15	13	15
Share defined as small	38%	22%	-
Share defined as remote	25%	20%	-
Shares in Conflict Severity Index groups			
Minimal conflict (CSI = 0)	43%	62%	-
Less severe conflict (CSI = 1)	33%	29%	-
Most severe conflict (CSI = 2)	23%	8%	-

Rice sector actors only. Small, remote, and CSI definitions for each survey defined in section 3.2. Calculations shown are for the 2023 survey rounds.

Third, we use data from a panel survey of rice millers also conducted via cellphone. The sample of rice mills is a combination of contacts from an in-person survey conducted in 2019 by the International Growth Center and contacts provided through the MHWS. While not nationally representative, it covers all of Myanmar's states and regions and includes both larger modern mills and smaller traditional mills. The miller survey captures detailed data on milling operations, including paddy purchases and rice sales, and on investments in milling machinery and equipment. In the 2022 survey round we again added recall questions to 3 and 10 years before the survey to better understand evolution and modernization in the rice value chain.

As a complement to the primary data, we conducted a number of interviews with key informants – policy makers, rice retailers, millers, exporters, traders, farmers, and input retailers – throughout 2023 which allowed us to ground truth and triangulate some of the findings presented in this analysis. We also use two secondary data sources in our analysis. The first are databases from the United Nations' Comtrade[11], UNCTAD, and the World Bank used for the evaluation of international rice trade. The second is conflict and violence data from the Armed Conflict and Event Data project (ACLED; Raleigh et al., 2010). We use ACLED data to construct a Conflict Severity Index (CSI) following Steinheubel & Minten (2023) at the township level using events occurring in the year prior

[11] http://comtrade.un.org/

to interview. This CSI has a close relationship to respondent-level reports of insecurity (MAPSA 2023d).

3.2 Methods

The first method in our analysis is descriptive. We document the patterns and trends in Myanmar's rice VC modernization over the past decade using recall data looking back over a 10-year period for multiple segments of the VC. We calculate the shares of farmers, millers, and vendors adopting several modern methods or offering/using modern services at three points in time: 10 years earlier, 3 years earlier, and at time of the survey.[12] These provide simple patterns to describe changes in the VC.

The second method is to test for inclusivity in the modernization of Myanmar's rice value chain. To do this we estimate several regressions for mills and farmers, separately, for different outcome variables, using the following fixed effects difference-in-differences (DiD) model:

$$M_{irt} = \gamma_i + \sum_{t=1}^{n} \beta_t\, t + \sum_{t=1}^{n} \delta_t [t * S_i] + \sum_{t=1}^{n} \mu_t [t * R_r] + \rho CSI_{rt} + \varepsilon_{irt}$$

where M_{irt} is the modernization outcome variable for firm i in location r at time period t. On the righthand side, γ_i are firm fixed effects which control for time-invariant firm characteristics and contexts. t are indicator variables for n time periods. We use three variables to test for inclusivity. The first is an indicator for smaller firm size S_i. For farms, we define S_i equal to 1 if the farm area owned is less than 5 acres and 0 otherwise. For millers, we define S_i equal to 1 if the mill is a traditional mill with throughput capacity below 15MT and 0 if it is modern mill.[13] The second is an indicator of remoteness of the firms R_r. For both farms and mills we define R_r as equal to 1 if the travel time to the nearest town is in the top tercile of each sample. The third is the conflict severity index CSI_{rt} discussed above and defined at the township and time period level.

[12] While we recognize the problems with the use of recall data (e.g. De Nicola and Giné 2012), we focus on important changes in technologies used by these agents and recall errors should therefore be minimal.

[13] Traditional mills are locally called "hallar sat" or "nga pone sat" and modern mills are mostly comprised of "QR sat" types.

β_t will show the average changes in modernization outcomes over time for firm size (S_i=0), not remote (R_r=0) and with no conflict (CSI_{rt}= 0). The coefficients of interest are δ_t and μ_t, showing the differences in time effects on modernization across firm size and remoteness, respectively, and ρ, showing the relationships between conflict events and modernization.

We use multiple outcome variables of modernization in the rice value chain for both farms and mills, utilizing the recall data for 2013 and 2019, and the contemporaneous data from 2022. For farms, we look at use of modern services with outcomes for (i) using a hired tractor for land preparation, (ii) using a combine harvester to harvest paddy, and (iii) outsourcing paddy drying to a service provider. We also look at whether the farms used a modern (i.e., mechanized) dryer and if they milled their paddy in a modern mill. For mills, we analyze changes in modern mill competition by looking at the share of other mills in each mill's village tract that are modern, as well as the level number of traditional and modern mills within each mill's village tract over time. We also analyze changes in modern paddy drying service provision at the mill-level using outcome variables for drying services provided by tub and mechanized drying machines.

4. Modernization in the rice value chain

This section documents the modernization in Myanmar's rice value chain from 2013 to 2022. We present descriptive results of changes at different VC levels, starting at the downstream endpoints of domestic markets and exports, going back upstream to rice millers, and finally reaching the farm level.

4.1 Downstream

4.1.1 Domestic markets

To understand domestic rice market evolution, we first analyze rice vendors sales practices at the time of the survey, the situation before the crisis (in 2019), and at the beginning of the reform period (2013). Most practices appear to have changed little over this period, as shown by mostly insignificant tests of differences over time, though there are patterns of positive changes between

2013 and 2019, followed by some declines to 2022 (Table 2).[14] Most vendors sell a relatively low number of rice varieties (less than 5), with near zero change between 2013 and 2019, but an increase of 3.4 percentage points (pp) to 2022. More than 70 percent sell rice in branded bags in 2022, most often branded by the mills (around 60 percent), similar to observations in other Asian countries (Reardon et al. 2014). But this share has declined by about three pp since 2019. Vendors mostly have good access to multiple rice suppliers. Sixty-one percent reported a lot of choice between suppliers in 2022 and while that choice did not change significantly over time, there is a decline of 5.8 pp since 2019.

We find significant changes in some indicators over time. Thirty-one percent of the retailers offered home delivery of rice a decade ago. That service increased significantly to 38 percent of retailers in 2019, but we then note a small decline in 2022 to 37 percent. There are also significant increases in the number of rice retailers in the neighborhood that the rice retailer operates in, with especially a large increase seen in the last three years, reflecting an inflow of retailers possibly because of the more limited business and employment opportunities in non-food sectors during the crisis.

Most strikingly, there has been a significant increase in rice quality over the last decade. Sixty-eight percent of vendors reported that there was no foreign matter in the rice that they sold a decade ago. That share has increased by 23 pp to 91 percent in 2022. A large share of food vendors also indicated better rice quality overall at the time of survey compared to 3 and 10 years earlier. 42 and 39 percent reported an improvement over these periods, respectively. However, some also indicated a worsening (12 and 8 percent compared to 10 and 3 years earlier respectively). Finally, supermarkets, that have quickly sprung up in urban Myanmar, are still relatively less important for the distribution of rice overall - as only 0.1 percent of the purchased rice was obtained from them - in contrast to other Asian countries (Reardon et al. 2014).

[14] Note that we only use data from those food vendors that were in business over the ten-year period studied.

Table 2. Changes in rice retailing

	Year			Significance of change	
	2013	2019	2022	2019 vs 2013	2022 vs 2019
Share of retailers (%)					
Sell few (< 5) rice varieties	84.6	84.4	87.8	n.s.	n.s.
Do home delivery	30.8	38.2	36.6	*	n.s.
Sell branded bags	68.6	73.6	70.8	n.s.	n.s.
If branded, branded by:				n.s.	n.s.
Mill	67.5	67.5	69.3	n.s.	n.s.
Retailer himself	10.4	13.3	11.8	n.s.	n.s.
Number of rice retailers in neighborhood (mean)	3.65	3.84	4.38	n.s.	***
A lot of choice in rice suppliers	67	67.3	61.5	n.s.	n.s.
Quality of rice					
No foreign matter in rice	68.4	87.2	91.4	***	n.s
Rice quality in survey year compared to…					
Better now	42.4	38.9		n.s.	
Similar	45.5	53.3		n.s.	
Worse now	12.1	7.9		n.s.	
Consumers					
Share of rice purchased in supermarkets (%)			0.1		

Note: Shares only presented for those retailers that were in business over the ten-year period; n varies between 221 and 231, depending on question. Asterisks show significant differences at p-values: * < 0.10, ** < 0.05, *** < 0.01; n.s.: not significant
Source: Authors' calculations based on MAPSA's food vendor survey and MHWSs consumer survey.

4.1.2 Exports

Export markets are also important in Myanmar's rice VC[15], and we find large export changes over the last decade. In the beginning of the 2010s, Myanmar exported annually approximately 0.5 million tons (Figure 2). That quantity had more than quadrupled by the end of the 2010s, making Myanmar the fifth biggest rice exporter in the world.[16] The growth in exported volumes has slowed since the crisis, but exported quantities had not noticeably declined by the end of 2022. Moreover, there has been important diversification in trade over the last decade. While China was by far the biggest importer of Myanmar's rice in the beginning of the 2010s, Myanmar has moved largely away from rice being trucked to China through the land border in Muse, a major trading town in the North-East of Myanmar, to rice being shipped on large vessels from Yangon – carrying typically 40,000 to 50,000 tons of rice, 100 times more than typical trucks used for export to China – to a more diverse set of countries.

[15] Myanmar was estimated to export about 17 percent of its total rice production of the season 2019/2020 (USDA 2021).

[16] https://www.statista.com/statistics/255947/top-rice-exporting-countries-worldwide-2011/

In addition to quantity changes, we see significant changes in the quality of exported rice. While exports were most low-quality and uncertified rice a decade ago – e.g. 90 percent of exports were more than 25 percent broken rice, mostly destined for industrial use in China (World Bank 2014) – that is changing. China is imposing more stringent requirements on rice imports with exporting mills from Myanmar required to have been certified with respect to milling and storage conditions.[17] In the beginning of 2023, 62 mills had obtained that certificate (USDA 2023). Myanmar also exports rice to the European Union since 2017, mostly broken rice, with several phyto-sanitary conditions attached to it.[18] Head rice is increasingly exported to other Asian countries as well (USDA 2022).[19]

In order to evaluate the overall impacts of the imposition of these non-tariff measures on rice trade from Myanmar, we estimate the 'ad valorem equivalents' (AVE) such that measures are converted to equivalent tariff rates.[20] To do so, we adopt the gravity model approach developed by Kee (2006) to estimate AVEs of the four major types of NTMs, i.e. sanitary and phyto-sanitary measures, technical barriers to trade, export-related measures such as pre-export inspection requirements, and other trade measures. Figure 2 illustrates how AVEs have changed over the last decade. They increased from 7.3 percent in 2005 to 14.4 percent in 2011 to 20.4 percent in 2021, an increase of 42 percent and 6 pp in the last decade alone, highlighting the growing influence of these measures in the international trade of rice from Myanmar.

We therefore notice important changes downstream in Myanmar's value chains. Better quality rice is available in domestic markets and rice exports – with more stringent phyto-sanitary and other non-tariff measures over time – have increased rapidly in the last decade. Moreover, exports were resilient during the crisis years. That then begs the question what changes occurred midstream and

[17] Per the rules of the General Administration of Chinese Customs (GACC)

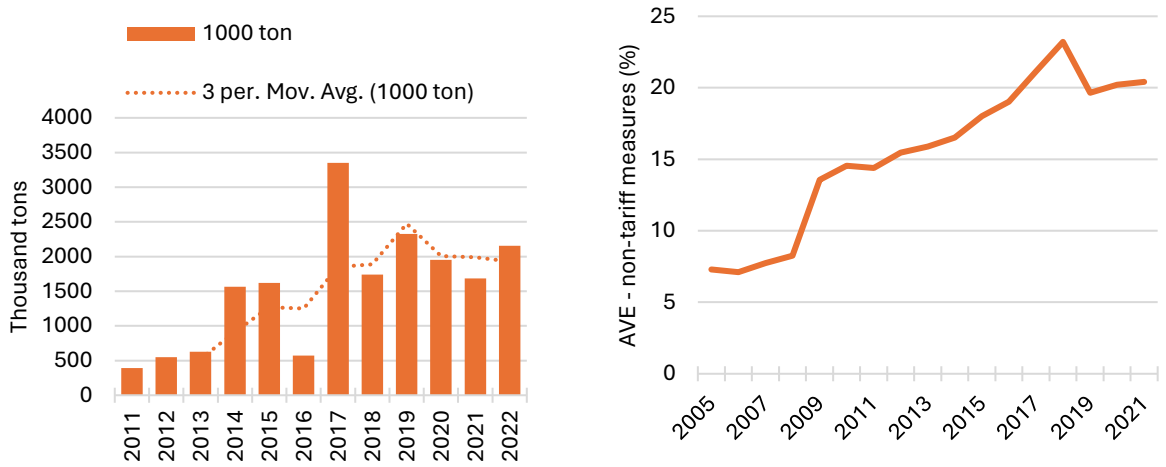
[18] Myanmar benefits from the "Everything but Arms" arrangement with the European Union since March 2017. This allows it duty-free and quota-free access for rice exports into the European Union.

[19] We also note more local requirements before exports. In 2024, exporters have to show 50 percent of ready cargo at the warehouses to be able to obtain an export license and they also need to show registration of all stocks on the MyRo platform (https://admin.myro.com.mm/export_company_list/) in their warehouses.

[20] Sources of the data are as follow: trade flow data from the CEPII-BACI database; the tariff data from the World Bank's WITS database; the different NTMs from the TRAINS database of UNCTAD; trade gravity variables from the CEPII-Gravity database.

upstream in the value chain to enable these evolutions downstream. We assess answers to this question in the next sections.

Figure 2. Changes in rice exports (quantities exported) and in ad valorem equivalents (AVE) of non-monetary measures in international trade of rice



Source: Authors' calculation based on Comtrade, UNCTAD, and World Bank.

4.2 Midstream

Recall data from both rice millers and food vendors highlight the evolution to modernized milling (Table 3). The average number of modern mills operating in the miller's same village tract/ward increased by about 60 percent from 2.4 in 2013 to 3.85 in 2019 (significantly different at the 1 percent level) and by a further 10 percent to 4.2 in 2022 (insignificant). The trend for traditional mills is the opposite: declining by 50 percent between 2013 and 2019 (significant at the 1 percent level) and a further 15 percent in 2022. Modern mills now outnumber traditional mills in our sample area as the share of modern mills increased by 27 pp from 2013 to 2019 and by 5 pp between 2019 and 2022 (both changes significant at the 5 percent level). There are two investment paths to modern mills: new entrants to milling and traditional mills upgrading to modern equipment: Both paths contributed to modernization in the midstream of the rice VC. Interestingly, the number of upgrades to modern mills is greater than the number of new modern mill investments in our sample from 2010 to 2019, but both types show parallel growth trends over this period (Appendix 1).

Table 3. Changes in modern rice milling

	Year			Significance of change	
	2013	**2019**	**2022**	**2019 vs 2013**	**2022 vs 2019**
Millers (553)					
Other mills in village tract/ward					
N of traditional mills	3.27	1.62	1.37	***	n.s.
N of modern mills	2.43	3.85	4.24	***	n.s.
Modern share of mills	0.42	0.69	0.74	***	**
Rice vendors (234)					
Mill type for rice sold					
Traditional	0.6	0.43	0.35	*	n.s.
Modern	0.46	0.64	0.73	*	n.s.

Note: Asterisks show significant differences at p-values: * < 0.10, ** < 0.05, *** < 0.01; n.s.: not significant

Source: Authors' calculations based on rice miller and rice vendor surveys.

The pattern towards modern rice milling is also apparent in the mill-type used for rice sold by vendors. The share of mills selling rice from modern mills increased by 17 pp between 2013 and 2019, and a further 8 pp to 2022, while the share selling rice from traditional mills fell by similar shares in each period. In 2013, rice from traditional mills was more common (60 percent selling compared to 46 percent for modern mills), but those shares effectively flipped by 2019 and continued

the trajectory through 2022 when 73 percent of vendors sold rice from modern mills and just 35 percent sold rice from traditional mills.

By definition, and as explained above, there are differences in modern and traditional mills in their use of advanced machinery and their throughput capacities. Table 4 highlights some of these differences for the mills in our sample. Modern mills have much higher daily throughput capacity, on average at 33 MT compared to 4.5 MT for traditional types. They also mill a much lower share of their total throughput on commission for other farmers or traders and a higher share for their own paddy which they purchase. Modern mills also have much greater storage capacity. At the time of survey in 2023, modern mills had an average of 700 MT of paddy or rice in storage compared to just 52 MT for traditional mills.[21] Key informants emphasized that FDI has played a small role in the modernization of the milling sector, though there are indications that FDI will play a more important role in the near future.[22]

Table 4. Capacity, storage, and machinery use by mill type

	Traditional	Modern	Sign.
Throughput and storage one			
Throughput capacity (MT)	4.5	33	***
Share of throughput on commission	0.76	0.35	***
Share of throughput mill's purchases	0.24	0.65	***
Paddy/rice in storage (MT)	52	700	***
Machinery and equipment (% owning)			
Operational			
Stone roller	51	41	*
Bucket elevator	32	78	***
Husker	43	84	***
Warehouse	27	55	***
Drying			
Moisture meter	20	75	***
Mechanized drier	7	55	***
Drying tub	7	40	***
Value-added processing			
Whitener	18	78	***
Polisher	5	45	***
Color sorter	3	45	***
Separator	23	67	***
Transport			
Boat	1	7	***
Truck	11	25	***

Note: Asterisks show significant differences at p-values: * < 0.10, ** < 0.05, *** < 0.01; n.s.: not significant
Source: Miller survey March 2023 round.

[21] Given the high degree of seasonality in paddy production in Myanmar, the high - often improved - storage volumes of modern mills likely help smooth consumer prices throughout the year, especially of the locally consumed varieties.

[22] Most notably, Wilmar International, one of Asia's leading agribusiness groups, has invested in the construction of the biggest rice mill in the country (located in the Thilawa Special Economic Zone on the outskirts of Yangon) that became operational at the end of 2022. This mill could produce 1,200 tons of rice at day. On top of this new mill, they also started renting in other mills for their operations. Posco International, a South Korean-based company also invested in the rice milling sector, but at lower levels than Wilmar International.

To help highlight the differences in machine use across the mill types, we categorize machinery into different groups in Table 4. Traditional mills are more likely to use a stone roller process to separate rice from the husks and bran, but stone rollers are an intermediate technology in modernization. Traditional mills may use other simple technologies including pestles, while modern mills may use more advanced rubber rollers or vertical milling technologies. Every other modern machine in our surveys is more likely to be used by modern mills. There are particularly large differences in modern drying and value-added processing equipment that improved milled rice quality. Seventy-five percent of modern mills use a moisture reader to ensure paddy is sufficiently, but not overly, dried and ready for either storage or milling, compared to just 20 percent of traditional mills. Fifty-five percent of modern mills use a mechanical dryer and 40 percent use a drying tub – both are modern equipment and advances over traditional sun drying – compared to just 7 percent each for traditional mills. A majority of modern mills own a whitener and slightly less than half own polishers and color sorters, each machine refining and improving the appearance of the final head rice output. Most traditional mills do not own these machines. Finally, ownership of transport is low for both types of mills, but more common for modern types.

Our recall data also shows a significant increase in the share of modern mills that offer modern drying services to farmers or traders since 2013, but insignificant changes for traditional mills (Table 5). Just 12 percent of modern mills offered either tub or mechanized drying services in 2013, but that share increased to 29 percent in 2019 (significant change at the 1 percent level) and a more modest increase to 31 percent in 2022. Most of the modernization has been in mechanized drying which was offered as a service by just 3 percent of modern mills in 2013 and 20 percent and 25 percent in 2019 and 2022, respectively. Less than 10 percent of traditional mills offered modern drying services in 2022, which is a modest increase from 3 percent in 2013.

These advances in milling processes have led to perceived improvements in rice quality in 2022 relative to 2019 and 2013 (Table 6), similar to the patterns shown above for food vendors. 60 percent of millers report improvements in milled rice quality since 2013 and a further 37 percent report improvements since 2019. However, as seen in the food vendor data, the quality improvements are not universal as a minority of millers report a decline in either rice or paddy quality. Interestingly,

similar shares of millers also report improvements in paddy quality. This could be attributed in part to the modernization in drying processes, but improved production practices farther upstream in paddy production could also contribute to improved paddy quality as the AVC midstream often co-evolves with production at the farm (Barrett et al. 2023). The next section analyzes the modernization upstream in the VC.

Table 5. Changes in modern drying technologies by mill type

	Year			Significance of change	
	2013	**2019**	**2022**	**2019 vs 2013**	**2022 vs 2019**
Modern mills (430)					
Drying service (share providing)					
Any	0.12	0.29	0.31	***	n.s.
Tub drying	0.09	0.11	0.1	n.s.	n.s.
Mechanized drying	0.03	0.2	0.25	***	n.s.
Traditional mills (123)					
Drying service (share providing)					
Any	0.03	0.06	0.09	n.s.	n.s.
Tub drying	0.02	0.03	0.05	n.s.	n.s.
Mechanized drying	0.01	0.04	0.05	n.s.	n.s.

Note: Asterisks show significant differences at p-values: * < 0.10, ** < 0.05, *** < 0.01; n.s.: not significant

Source: Authors' calculations based on rice miller survey.

Table 6. Changes in quality in the value chain midstream

	Reference year		Sign.
	2013	**2019**	
Rice mills (553)			
Rice quality now compared to year (share)			
Better now	0.60	0.37	***
Similar	0.21	0.47	***
Worse now	0.18	0.17	n.s.
Paddy quality now compared to year (share)			
Better now	0.52	0.31	***
Similar	0.25	0.49	***
Worse now	0.23	0.20	n.s.

Note: Asterisks show significant differences at p-values: * < 0.10, ** < 0.05, *** < 0.01; n.s.: not significant

Source: Authors' calculations based on rice miller survey.

4.3 Upstream

At the farm level, we first look at levels and changes over the last decade in the adoption of modern yield-increasing technologies, and subsequently at harvesting and post-harvest technologies and practices. We find strong evidence of modernization in rice production since 2013.

In the beginning of the 2010s, the large majority of the seeds for most crops (including rice) was provided by the informal seed system, i.e. farm-saved seed or farmer-to-farmer exchanged seed (as gift or barter), with more than 90 percent of the seed planted of most crops estimated to be farm-saved seed (Van den Broek et al. 2015). Seed distribution for improved rice has been mostly in the hands of the public sector, but the improved and registered seed distributed by them was insufficient and made up less than 5 percent of the rice acreage in 2014, indicating low adoption rates of improved varieties (Van den Broek et al. 2015). Despite the lack of rice seed development by the public sector, seed markets have become more active in the 2010s. In our survey, 57 percent of the rice farmers indicated that they did not buy seed a decade ago, and if they did, it was mostly from other farmers directly (26 percent), while the formal sector (government, agri-input retailers, and NGOs) was less important (17 percent) (Table 7). By 2019, the share of the formal sector had increased substantially, by 10 percentage pp to 27 percent, but then significantly declined by 3 percentage pp during the crisis years. The share of branded rice seeds in seed acquisition in particular doubled over the last decade, to 21 percent of all farmers, and that share stayed stable over the crisis years.

Table 7. Changes in input markets

	Year			Significance of change	
	2013	**2019**	**2022**	**2019 vs 2013**	**2022 vs 2019**
Seeds					
Purchased from whom: (share)					
Other farmers	26	24	21	*	**
Agri-input retailer/private sector	12	19	18	***	n.s.
Government	5	7	6	***	**
NGO	0	0	0	n.s.	n.s.
Do not buy	57	50	56	***	***
Share of farmers using formal market	17	27	24	***	**
Share of branded in purchased seeds	26	41	46	***	**
Share of farmers using branded seeds	11	21	21	***	n.s.
Fertilizer					
Use urea on rice plots (share)	70	80	73	***	***
Use compound fertilizer on rice plots	32	44	37	***	***

Asterisks show significant differences at p-values: * p < 0.10, ** p < 0.05, *** p < 0.01; n.s.: not significant.
Source: Authors' calculations based on MAPS.

The increasing role of the private sector is noted in the registration of new rice seed varieties in the country. Based on data from the National Seed Committee, the total number of new rice seed varieties registered over the period 2013-2022 was 137 (Figure 4). All the newly registered varieties were from the public sector in 2013.[23] That share gradually declined over the decade and by 2022, 44 percent of all the registered seeds in the previous decade were released by the private sector. We see especially rapid growth in the total number of new varieties registered since 2018, possibly linked to the approval of the Plant Variety Protection Law in 2016.[24]

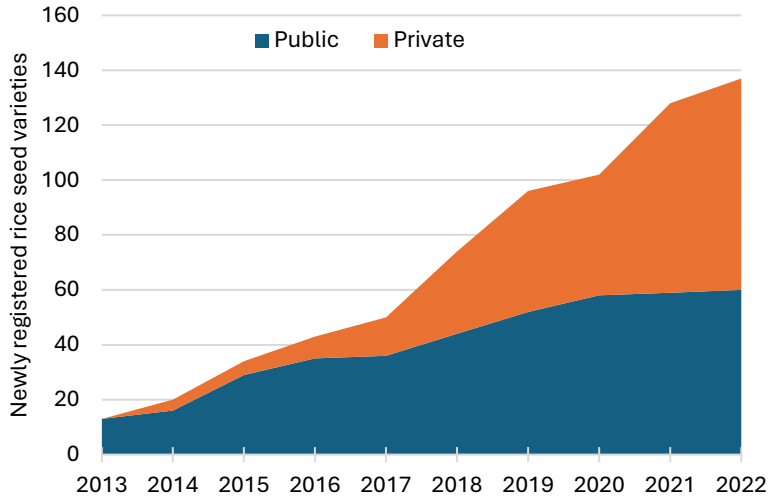
Chemical fertilizer use also increased over the last decade (Table 7). The share of farmers that reported using urea and compound fertilizer on rice plots increased significantly by 9 and 11 pp between 2013 and 2019. Quantities applied likely grew more than simple adoption.[25] Conflicts since 2021 as well as the increases in international fertilizer prices, due to the war in Ukraine, have interrupted that growth in fertilizer imports and use. Based on Comtrade data, it is estimated that imports in 2021 fell to half of the level of 2020, back to the levels of 2015. Similar reversals are seen in the share of farmers using fertilizer in the farm survey (Table 8). Levels were lower in 2022 than before the crisis but they were still at a higher level than in 2013.

[23] Between 1974 and 2013, 104 seed varieties were registered in Myanmar, all by the public sector.

[24] The law was designed to protect the rights of breeders of new plant varieties, to encourage investments and development of the breeding of new plant varieties in both public and private sectors, and to promote the production and cultivation of new improved varieties. While Myanmar has made progress for a more active involvement of the private sector in the seed sector through the establishment of national seed policies and improved regulatory frameworks as detailed in a seed road map by the government, a large number of hurdles still need to be addressed (Subedi et al. 2017).

[25] Comtrade data show an approximate quadrupling of fertilizer imports in the country between 2011 and 2020. While these import figures reflect use on all crops, it seems that rice cultivation has been characterized by substantially more fertilizer use in the 2010s given that rice is so important in the country.

Figure 3. Newly registered rice seed varieties in Myanmar, 2013-22



Source: Authors' calculations based on data from the National Seed Committee.

Changes in practices related to modernization of harvesting and post-harvest technologies and outsourcing practices are presented in Table 8 (maps are available at the township level in Figure A.2). As documented in other studies (MAPSA 2023d, Belton et al. 2021), we find that the use of combine-harvesters – most often done by service providers – has rapidly taken off since the beginning of the 2010s. During the most recent year, 54 percent of the farmers reported to have used a combine-harvester on most rice plots. While we have no data on the evolution of the use of commercial mechanization service providers of combine-harvesters over time, they were however almost exclusively rented in for cultivation harvesting activities at the time of the survey.[26] Farmers hiring in tractors increased by 33 pp over the last decade. Outsourcing drying services has also increased, but the growth has been more modest: 22 percent of the farmers indicated that they outsourced the drying of paddy. This compares to 14 percent ten years earlier, an increase of 8 pp (Table 8).

We also see substantial modernization in the use of post-harvest technologies. There are only small changes in drying practices over time: sun-drying is the most applied method and modern dryer use is still limited. However, we see a significant decline in the share of farmers doing sun-drying, by 7 pp, from 96 percent in 2013 to 91 percent in 2019, and a further decline to 89 percent during the crisis years (significant at the 10 percent level). Modern dryer use increased accordingly.

[26] During the last post-monsoon season, 97 percent of the combine-harvest users on their main rice plot reported that they were hiring them.

On the other hand, a much larger change is noted in the use of modern mills by farmers, confirming trends seen in the previous section. Twenty-one percent of the farmers reported using them in 2013 but that share doubled since and 47 percent of the rice farmers reported their use in 2022.

Table 8. Changes in the use of service providers and modern equipment by farmers

	Year			Significance of change	
	2013	**2019**	**2022**	**2019 vs 2013**	**2022 vs 2019**
Use of service providers (share)					
Plowing services					
Hired tractor use for plowing	26.7	55.8	59.9	***	***
Combine-harvester use					
Combine-harvester used on most rice plots	12.9	50.2	54	***	**
Drying methods					
The person that takes care of drying					
Farmers	86	79.4	77.9	***	n.s
Trader/miller	13	19	20.5	***	n.s
Somebody else	1.1	1.6	1.6	n.s.	n.s
Use of modern equipment (share)					
Method mostly used for the drying of paddy					
Sundried	96.1	90.7	89	***	*
Modern dryer	3.9	9.3	11	***	*
Modern mills					
Modern mills mostly used for milling paddy	22.2	45.2	51.2	***	***

Asterisks show significant differences at p-values: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; n.s.: not significant.
Source: Authors' calculations based on MAPS.

5. Conflict, inclusivity, and value chain modernization

Having described the rapid modernization in Myanmar's rice VC between 2013 and 2019 and a general slowdown, but with continued growth in some areas since 2019, we now turn to our econometric tests of inclusivity in that modernization, starting in the mid-stream with rice millers before moving upstream to the farm-level. These tests control for time invariant factors at the firm (mill or farm) level and better isolate the relationships between modernization and remoteness, firm size, and conflict.

At the mill level, we find evidence of heterogeneous modernization patterns across these variables (Table 9). The transition to modern milling technology is significantly slower in more remote locations. The change in the share of modern mills in millers' village tracts since 2013 was 12 pp lower in 2019 and 8 pp lower in 2022 for remote areas. This relationship is driven by both a slower increase in modern mills and a slower decline in the number of traditional mills. The expansion of modern paddy drying service provision appears to be driven almost exclusively by larger mills (estimates of remoteness are insignificant). Relative to 2013, smaller mills were less likely to begin

tub-drying services by 2.8 pp in 2019 (significant at the 5 percent level) and 2.1 pp in 2023. The growth in mechanized drying service provision is even more uneven, with changes since 2013 of -16 pp and -20 pp for 2019 and 2022, respectively (both significant at the 1 percent level). This highlights the complementarities in milling modernization between investments in advanced milling machines.[27]

[27] For formal tests of associations of conflict with mill investments and with quality changes in the rice milling industry, see Appendix 2.

Table 9. Associates of modernization, drying service provision, and quality changes for millers

	Modernization						Modern drying service provision			
	Modern share of mills		N of modern mills		N of traditional mills		Tub		Mechanized	
year 2019	0.278***	(13.05)	1.762***	(7.41)	-1.858***	(-8.52)	0.022	(1.59)	0.181***	(8.23)
year 2022	0.329***	(14.85)	2.146***	(9.35)	-2.294***	(-9.32)	0.029**	(2.00)	0.214***	(9.14)
Interactions with remoteness										
2019 * remote	-0.120***	(-2.81)	-1.252***	(-4.27)	1.406***	(4.18)	0.018	(0.81)	-0.005	(-0.13)
2022 * remote	-0.082*	(-1.79)	-1.183***	(-4.03)	1.351***	(3.18)	0.022	(0.85)	-0.019	(-0.44)
Interactions with small mills										
2019 * small							-0.028**	(-1.98)	-0.159***	(-5.59)
2022 * small							-0.021	(-1.03)	-0.204***	(-6.51)
Conflict severity index										
CSI group 1	-0.018	(-0.78)	-0.138	(-0.55)	0.472	(1.50)	-0.008	(-0.48)	0.045*	(1.68)
CSI group 2	-0.076**	(-2.36)	-0.421*	(-1.71)	0.962***	(3.16)	-0.019*	(-1.83)	0.022	(0.77)
Constant	0.427***	(32.36)	2.382***	(18.80)	3.199***	(24.33)	0.030***	(4.06)	0.023*	(1.88)
Mill fixed effects	Yes		Yes		Yes		Yes		Yes	
N	1346		1474		1459		1492		1492	
R-sq	0.354		0.146		0.171		0.011		0.166	

z statistics in parentheses. * p<.1, ** p<.05, *** p<.01. Sample sizes vary by available data for dependent variables. CSI group 1 is moderately insecure. CSI group 2 is very insecure.

Source: Authors' calculations based on miller survey.

Conflict is negatively associated with modernization in milling (Table 9). Specifically, the most severe conflict group shows negative and often significant relationships to modernization in mill types as well as modern drying service provision. The coefficients for the less severe conflict group are mostly in the same direction as the more severe conflict group, but the magnitudes are smaller, and they are largely insignificant. The share of modern mills in millers' village tracts is 7.6 pp lower for CSI group 2 relative to the CSI group 0 (significant at the 5 percent level). This is driven by both a smaller number of modern mills (-0.4, significant at the 10% level) a greater number of traditional mills (0.96, significant at the 1 percent level). Conflict also shows a negative relationship to modern drying service provision. Mills in the most conflict affected areas were 1.9 pp less likely to offer tub drying services (significant at the 10 percent level), a meaningful effect size from the excluded group average of 3 percent providing that service. An extension of this analysis looking at recent milling investments, between 2020 and 2022, that does not rely on recall data confirms the negative association between severe conflict and milling investments (Appendix 3).

We now turn to analyzing inclusivity upstream in the rice VC using similar DiD regressions at the farm. We find significant heterogenous effects in rice farmers' use of modern service providers for harvest and post-harvest technologies (Table 10). The least remote, most secure, and larger farmers see substantially larger changes in the adoption of modern practices as well as in the outsourcing to specialized service providers. Overall, farmer adoption increased by 28 pp in the use of service providers for plowing and 10 pp in outsourcing of drying practices, as well as by 51 pp in the use of combine-harvesters, 8 pp in the use of modern dryers, and 30 pp in the use of modern mills in the period between 2013 and 2019. These adoption levels further increased during the crisis years, by between four and eight pp depending on the technology and practice.

Remoteness is significantly related to smaller changes in modernization for all practices and services used in both 2019 and 2022, except for hired tractors for plowing. Further, the gaps in adoption between remote and less-remote farmers widened between 2019 and 2022 (shown by larger DiD coefficients), except for the use of combine-harvesters. Smaller farms also show smaller changes in adoption rates for four modernization outcome variables between 2013 and 2019, and between 2013 and 2022 (bigger changes are noted for the use of service providers for plowing).

There is a particularly large gap between small and large farms in the use of combine-harvesters and of modern mills, and the gap increases during the crisis years between 2019 and 2022.

Finally, all indicators of insecurity show negative relationships with the use of modern service providers and the use of modern equipment, and 6 out of 10 coefficients are significant. Higher conflict severity is generally associated with bigger effects, as shown in bigger coefficients. Severe insecurity was associated with eight, three, and four pp lower use of combine harvester service providers, drying service providers, and modern drying technologies, respectively.

Overall, the mill- and farm-level results show that modernization in Myanmar's rice VC was not everywhere inclusive. We find significantly lower modernization rates for remote areas, for smaller firms, and in conflict affected areas. We also find that the modernization gaps have widened over the crisis years since 2019 for many outcomes. Overall, the results highlight the importance of economic reform, infrastructure, security, and scale for modernization in the rice VC.

Table 10. Associates of farmer use of modern service providers and modern equipment

	Use modern service providers						Use modern equipment			
	Tractor		Combine harvester		Drying		Modern mill		Modern dryer	
year 2019	0.282***	(12.58)	0.505***	(19.91)	0.099***	(6.86)	0.299***	(14.96)	0.084***	(6.79)
year 2022	0.332***	(13.01)	0.555***	(19.73)	0.143***	(7.75)	0.382***	(17.27)	0.129***	(8.10)
Interactions with remoteness										
2019 * remote	-0.038	(-1.21)	-0.124***	(-3.10)	-0.053***	(-3.33)	-0.061**	(-2.20)	-0.044***	(-3.13)
2022 * remote	-0.036	(-0.95)	-0.094**	(-2.23)	-0.065***	(-3.39)	-0.074**	(-2.34)	-0.055***	(-3.33)
Interactions with small farms										
2019 * small	0.047**	(2.07)	-0.129***	(-6.10)	-0.027**	(-2.55)	-0.089***	(-4.80)	-0.021**	(-2.20)
2022 * small	0.065***	(2.65)	-0.137***	(-5.78)	-0.052***	(-4.13)	-0.109***	(-5.52)	-0.042***	(-3.77)
Conflict severity index										
CSI group 1	-0.044**	(-2.21)	-0.009	(-0.36)	-0.028**	(-2.35)	-0.015	(-0.79)	-0.032***	(-2.89)
CSI group 2	-0.047	(-1.54)	-0.077***	(-2.80)	-0.030**	(-2.00)	-0.026	(-1.36)	-0.044***	(-4.75)
Constant	0.264***	(23.22)	0.125***	(9.25)	0.139***	(21.92)	0.225***	(24.33)	0.039***	(7.49)
Farm FE	Yes		Yes		Yes		Yes		Yes	
N	8836		9458		9458		8773		9132	
R-sq	0.198		0.389		0.073		0.253		0.077	

z statistics in parentheses. * p<.1, ** p<.05, *** p<.01. Sample sizes vary by available data for dependent variables. CSI group 1 is moderately insecure. CSI group 2 is very insecure.

Source: Authors' calculations based on miller survey.

6. Conclusions

This study documents rapid modernization in Myanmar's rice value chain in the past decade, both at the farm and further downstream in the VC among processors and retailers. There have been large improvements in rice quality after milling and in paddy quality produced. Exports grew as Myanmar became an important exporter of rice, the fifth largest globally by the end of 2019, and exports stabilized during the crisis years following 2019, showing strong aggregate resilience in the VC to conflict following a military coup in 2021. For domestic consumption, supermarkets do not have a large market share but perceived quality in retail improved rapidly.

Rice farmers increasingly used modern inputs (e.g., purchased (often branded) seed and chemical fertilizer) and modern machinery service providers. Hired tractor plowing services increased by 30 pp between 2013 to 2019 and combine harvester service usage increased 37 pp over the same period. Farmer use of modern mills to process their paddy doubled to 41 percent in 2019. Rice vendors report an increasing share of rice sold coming from modern mills. Mills reported an increase in modern mills in their vicinity and a declining number of traditional mills, and there is an increasing trend in the number of modern mill investments to 2019, in the form of new mill starts and upgrading from older traditional mills. Postharvest drying services also expanded rapidly, particularly modern drying by modern mills.

However, despite some continued modernization during the crisis years after 2019, many modernization processes decelerated. Severe conflict is found to negatively impact various aspects of modernization, notably the adoption of tractor plowing services and modern dryers at the farm level, and the prevalence of modern mills and drying equipment in midstream operations. Additionally, modernization has been less inclusive, with remote and smaller firms lagging in adopting modern practices. This gap in modernization, particularly in the use of combine harvesters, modern dryers, and mills, as well as investment in value-added machinery, has widened during these crisis years, particularly affecting smaller and more remote operations.

The rapid modernization in Myanmar's rice VC from 2013 to 2019 highlights the positive impacts of stable governance, infrastructure investment, and liberalization on AVC modernization while the more muted growth – albeit with some remarkable resilience – following the military takeover

documents the potential threats to AVC modernization from unpredictable policy, violence, and trade restrictions. Further, the observed variations in modernization inclusivity across different segments of the value chain underscore the complex interplay between governance, conflict, and AVC development. The findings suggest that interventions aimed at promoting inclusive and sustainable modernization in conflict-affected regions must be nuanced and context-specific. Overall, this study reaffirms the crucial need for stable political and economic environments to foster effective agricultural growth and development.

This study largely relies on recall data, a limitation that points to the importance of regular, high-quality data collection at multiple points in AVCs in both times of stability and of conflict. We also document broad trends but do not identify the specific policy or investment changes that lead to modernization. This is an important area for future study, along with exploration of the enabling and driving factors that lead to AVC modernization and resilience amidst ongoing conflict. Finally, future research should further analyze inclusivity in AVC development to better identify when and where actors are lagging in modernization.

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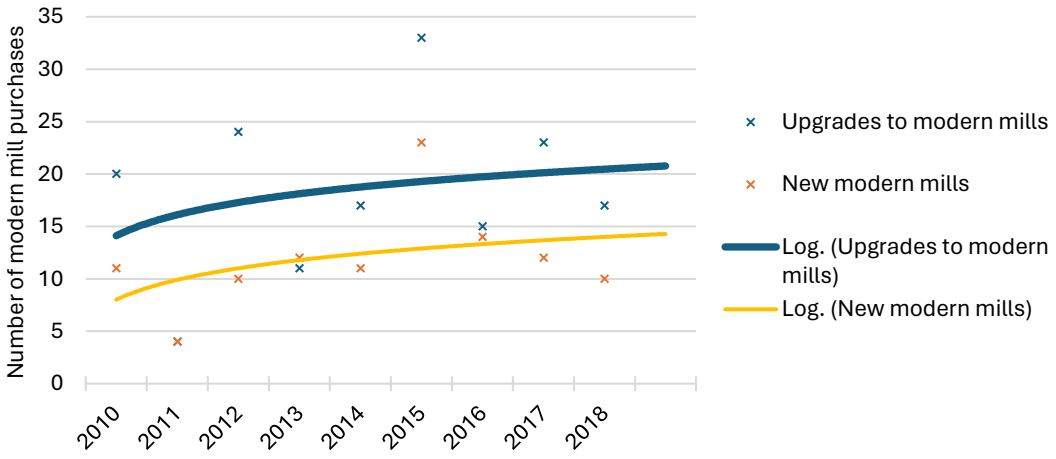
Appendix

Appendix 1: Modern mill investments

In the midstream of Myanmar's rice VC, there has been a rapid growth of modern mills with advanced machinery and higher throughput capacities. In our 2020 survey of rice millers, we asked mills when they started milling using modern machinery, either upgrading from traditional machinery or starting a new modern mill. This allows us to plot the number of modern mill investments over time (Figure A.1). There is a clear increasing trend in modern mill investments from 2010 to 2019. Interestingly, the number of upgrades to modern mills is greater than the number of new modern mill investments, but both types show parallel growth trends over this period. This suggests that both paths have contributed to modernization in the midstream of the rice VC. Traditional mills have grown and advanced to modern machinery and there has been a concurrent inflow of new investments into modern rice milling. However, our data do not allow us to track upgrades or new mill starts after 2019.

Figure A.1 Number of modern mill purchases – upgrades of existing mills and new mill starts - by year

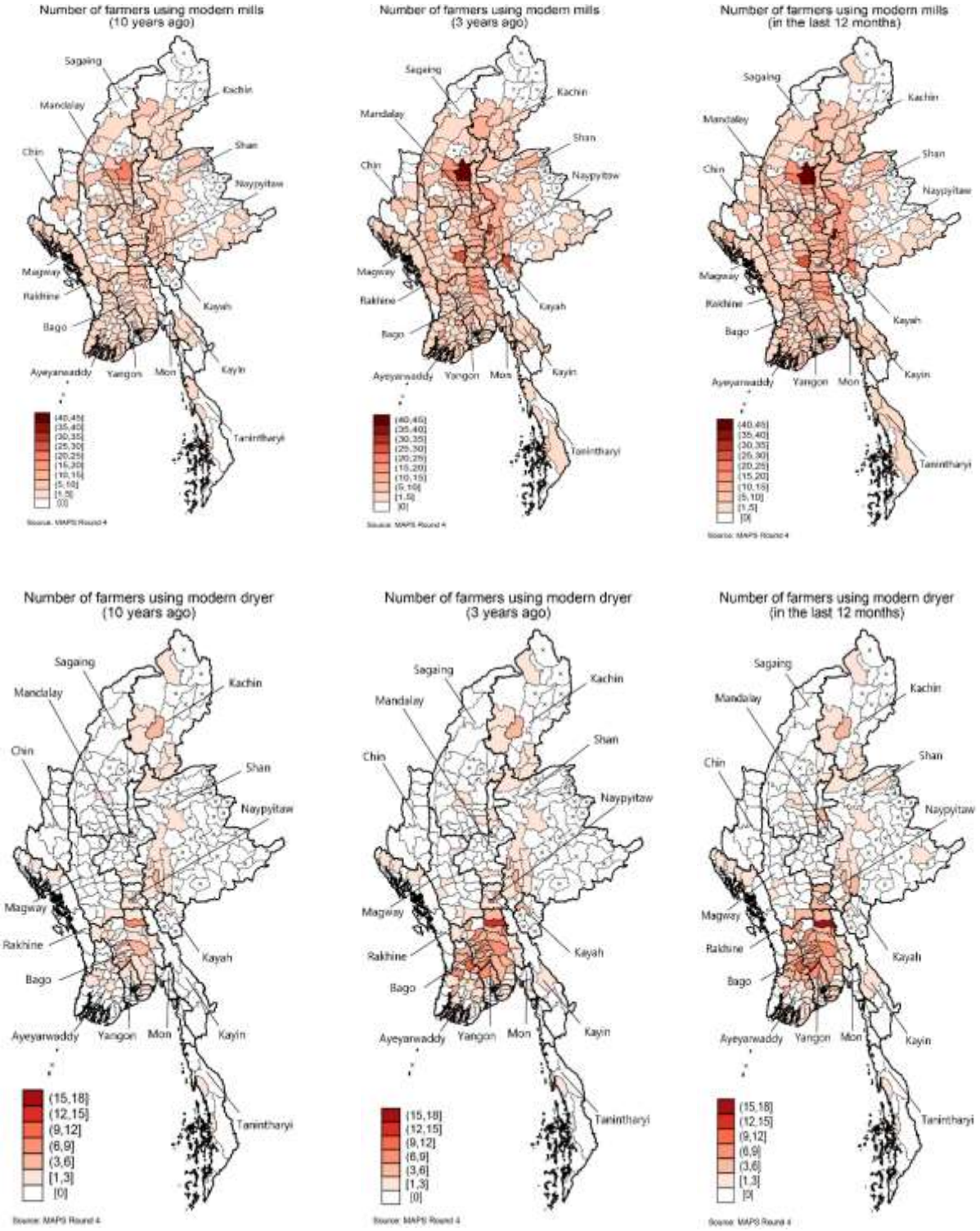


Logarithmic fit to show pattern over time. Sample restricted to modern mills active in 2019 to eliminate bias from sample construction.

Source: Authors' calculations based on rice miller survey.

Appendix 2: Changes in the adoption of harvest and post-harvest technologies

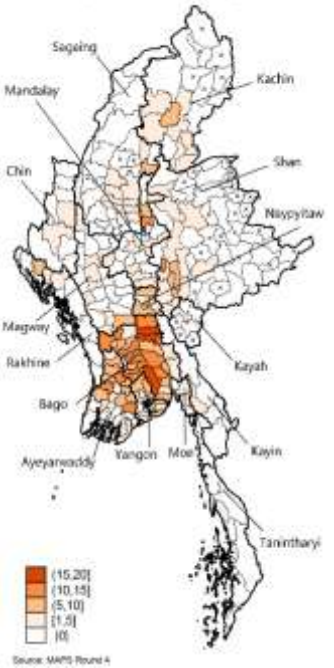
Figure A.2 Changes in the adoption of harvest and post-harvest technologies



Traders/Millers drying harvested paddy
(10 years ago)

Traders/Millers drying harvested paddy
(3 years ago)

Traders/Millers drying harvested paddy
(in the last 12 months)



Number of farmers using combine harvesters
(10 years ago)

Number of farmers using combine harvesters
(3 years ago)

Number of farmers using combine harvesters
(in the last 12 months)

Appendix 3: Associations of investments and quality changes in the rice milling industry

Our panel data for mills also allow us to look at more recent modernization patterns without relying on recall data through investments in modern machinery and equipment between 2020 and 2022. We define three indicator outcome variables for whether or not the mill made investments in (i) any new equipment or machinery, (ii) any value-added machinery including whiteners, polishers, and color sorters, and (iii) drying machinery including modern dryers and drying tubs.

With these more recent data, we estimate heterogeneity in modernization over the crisis period in milling investments. We find that mills in more remote areas are somewhat more likely to make an investment in a value-added machine in 2021 or 2022 relative to 2020 (significant at the 10 percent level for 2021) (Table A.1). The DiD estimates are smaller for smaller mills who are 6 pp less likely to invest in value-added machines in 2022 (significant at the 5 percent level). Severe conflict has a negative relationship to modernization over this period. CSI group 2 is 2.5 pp less likely to make an investment in value-added machinery (insignificant), and 5 pp less likely to invest in drying equipment (significant at the 5 percent level).

Table A1. Mill machinery investments 2020-22

	Value added machines		Drying equipment	
year 2021	-0.039*	(-1.85)	-0.021	(-1.14)
year 2022	0.074***	(3.11)	0.022	(1.10)
Interactions with remoteness				
2021 * remote	0.035*	(1.65)	0.032	(1.09)
2022 * remote	0.044	(1.09)	0.01	(0.34)
Interactions with small mill				
2021 * small	0.025	(1.13)	0.022	(1.07)
2022 * small	-0.059*	(-1.89)	-0.006	(-0.27)
Conflict severity index				
CSI group 1	-0.011	(-0.52)	0.000	(-0.02)
CSI group 2	-0.025	(-0.88)	-0.052**	(-2.20)
Constant	0.069***	(7.80)	0.054***	(6.71)

Mill fixed effects	Yes	Yes
N	1656	1656
R-sq	0.041	0.012

z statistics in parentheses. * p<.1, ** p<.05, *** p<.01. CSI group 1 is moderately insecure. CSI group 2 is very insecure. Value added machines include whitener, polisher, or color sorter. Drying equipment includes tub or mechanized drier.

Source: Authors' calculations based on miller survey.