Food prices, processing, and shocks: Evidence from rice and COVID-19

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Abstract
Rice is the staple food for about half of the world's population and mills are the essential processing link between farmers and consumers, making rice milling one of the most important agro-processing sectors globally. This paper assesses changes in rice and paddy prices, and processing margins during the COVID-19 pandemic shock through the lens of rice mills in Myanmar. Our data, collected through telephone surveys with a large number of medium- and large-scale rice millers in September 2020, reveal significant disruptions from the COVID-19 pandemic, including transportation restrictions, employee lay-offs, and reduced operations relative to normal times. However, milling margins, and paddy and rice prices were mostly stable, showing only minor increases compared to 2019. Rice prices increased most for the varieties linked to export markets, though the gains were mostly passed through to farmers as higher paddy prices. Similarly, higher rice prices achieved by modern mills—due to extra processing—were mostly transmitted to producers. Our results also highlight the major importance of byproducts—broken rice and rice bran—sales to overall milling margins as byproduct sales allowed mill operators to sustain negative paddy-to-rice margins.

Keywords
agribusiness, agro-processing, COVID-19, margins, mills, Myanmar, prices, rice
1 | INTRODUCTION

The COVID-19 pandemic has stressed global agri-food systems at a critical time. Global gross domestic product shrunk by 4.4% in 2020 (IMF, 2020), pushing an estimated 88 to 115 million people into extreme poverty, the first increase in 20 years (Laborde et al., 2020; World Bank, 2020b). This raises tremendous food security concerns and places heightened importance on agri-food systems, which are responsible not only for food supplies but also for the incomes and livelihoods for a large share of the global population. There are multiple demand and supply pathways through which COVID-19 could impact agri-food systems. Lower household incomes from lost jobs could shock demand. Supply disruptions could manifest through restrictions on imports, exports and transportation restrictions, as well as through exchange rate shocks, reduced access to credit, and higher energy costs (Laborde et al., 2020; Swinnen & McDermott, 2020).

Research on the impact of COVID-19 on agri-food systems shows that agricultural supply was not largely affected in the short term (Torero, 2020), partly due to the time lags in agricultural production. Yet, in the medium term, shocks to factor markets—labour and inputs—and to transportation—international trade and logistics—all increase costs (Laborde et al., 2020), and may lead to higher prices for some foods (Hirvonen et al., 2021; Narayanan & Saha, 2021; Ruan et al., 2021). There have also been widespread impacts of COVID-19 on small and medium enterprises in the agri-food system (Boughton et al., 2021; Nordhagen et al., 2021). Yet, one sector that has received little empirical attention is agro-processing (Bene et al., 2021), which accounts for 80% of global food sales and is increasingly important in lower income countries (World Bank, 2008).1

This paper documents the changes in rice milling during the COVID-19 pandemic. Rice is the staple of half of the world’s population (Mutthaya et al., 2014), and rice mills are the essential node in the value chain, converting paddy into head rice—the final consumer product—as well as important and marketable byproducts—broken rice and rice bran. We use data collected through telephone surveys with medium- and large-scale rice millers in Myanmar to assess the impact of COVID-19 on milling margins by comparing paddy, rice, and milling byproduct prices in September 2020 (during the pandemic) to September 2019 (well before the pandemic began).

The research described in this paper makes three main contributions. First, we analyse the effect of the COVID-19 shock on the processing sector and describe the influence of demand changes and local processing margins on rice and paddy prices using modelling and empirical assessments. Second, there are very few studies based on surveys of rice mills, a crucial node in the value chain. Moreover, when surveys have been done, few authors have tried to analyse mill processing margins, despite their importance for producers and consumers alike. We directly analyse milling margins using detailed survey data from rice millers. Third, we propose a more complete method of looking at milling margins by incorporating rice quality and the value of byproducts into our analysis, which are often ignored in other studies.

Our paper proceeds as follows. In the next section, we provide important background information and context around processed food consumption, the rice sector and COVID-19 in Myanmar. Section 3 outlines the conceptual framework describing how rice and paddy prices

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1A notable exception is Lusk et al. (2020) who illustrate the large impacts of COVID 19 on the beef and the pork sectors in the United States.
might respond to COVID-19 shocks. The econometric specification used to empirically test price changes in Myanmar during the crisis is discussed in Section 4 along with our phone survey methods. Section 5 presents our results including detail on the rice milling process, graphical analyses of price and margin changes, as well as price regressions. Section 6 concludes by summarising the key results and by discussing the main policy implications derived from the analysis.

2 | BACKGROUND

2.1 | Processed food consumption

The agro-processing sector is increasingly important as processed foods account for a large and increasing share of calories consumed globally. In Asia alone, case studies conducted in Bangladesh, Nepal, Indonesia and Vietnam showed that the average share of processed foods in consumption was 59% in rural areas and 73% in urban areas (Reardon et al., 2014). To assess the importance of the consumption of processed foods in Myanmar, we used data from the consumption module of the nationally representative Myanmar Poverty and Living Conditions Survey conducted in 2015 (MoPF & World Bank, 2017) and relied on the classification proposed by Monteiro et al. (2019). Unprocessed foods account for only 10% of calories consumed on average. Minimally processed foods—which include rice, as rice is produced when mills process paddy—make up almost two-thirds of calories consumed. In terms of food expenditures, the order is switched, unprocessed foods account for nearly 40% of expenditures, while minimally processed foods represent about one-quarter of expenditures. This reflects the relatively lower value of rice and other staples compared to fresh, unprocessed foods. The two other food categories are processed and culinary processed foods (e.g., packaged snacks, drinks, and prepared meals), representing 28% and 6% of food expenditures respectively.

2.2 | Myanmar's rice sector

Rice, as a commodity in agricultural production and food consumption, is central to Myanmar's agriculture and policy-making. In 2017–2018, paddy accounted for 35% of all land cultivated in Myanmar—17.9 million out of 50.5 million total acres (CSO, 2019). Average annual rice consumption is estimated to be 170 kg per person per year, which is one of the highest rates in the world (USDA, 2020a). In 2015, rice made up 20% and 14% of total food expenditures in rural and urban households, respectively, and contributed to even higher shares of calories consumed—52% and 61%, respectively (Boughton et al., 2020).

Total paddy production in 2017–2018 was estimated to be 25.6 million tons. Most was used for domestic consumption, though rice is also an important source of foreign exchange for Myanmar. While official statistics put rice exports at 2.2 million tons in 2019, it is generally acknowledged that export levels are higher. USDA (2020a) estimated rice exports in 2018–2019 to be 2.7 million tons, making rice one of Myanmar's most important agricultural export products. Most exported rice goes to China, though there is increasing diversification in recent years with more exports going to Europe, Africa and other countries in Southeast Asia (Diao et al., 2020; Dorosh et al., 2019). The vast majority of exported rice is the Emata variety, a long-grain, slender and translucent rice (World Bank, 2014b). Myanmar consumers consider Emata

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2We thank Kristi Mahrt for these calculations.

3Myanmar uses the Beale classification system to group rice varieties based on paddy length and ratio of length and breadth. The categories are Emata, Ngasein, Letywezin, Meedon and Byat (World Bank 2004b). Pawsan varieties fall under the Meedon classification.
to be lower quality than the locally preferred Pawsan variety, which is a fine-quality aromatic variety with lower yields (Dorosh et al., 2019; Proximity Designs, 2016). Pawsan is not in demand outside of Myanmar, so exports of the variety are negligible.

The key link between the paddy fields and consumption or export is the mill. Rice mills convert paddy to head rice—the final consumer product—using several machines to remove the unwanted parts of the raw paddy and to make the milled rice more attractive for consumers. While head rice is the main output, the milling process produces multiple byproducts including broken rice and rice bran, which are often also sold. Myanmar’s rice milling sector has undergone dramatic change and modernisation since the industry was liberalised in 2003, particularly under the civilian government from 2010 to 2020 (Okamoto, 2005). However, medium- and large-scale mills, which are classified as having a daily throughput capacity greater than 15 tons, accounted for just 12% of all rice mills in Myanmar in 2018 (USDA, 2020a). Yet, in terms of total rice produced, these medium- and large-scale mills are becoming increasingly important, as the number of small-scale mills declines (USDA, 2020a).

2.3 COVID-19 in Myanmar

Myanmar has been severely impacted by the COVID-19 crisis. Though the officially reported case load was low early in the pandemic, the government implemented widespread movement restrictions from March 2020 through September 2020 and beyond, which had meaningful effects on movement (Goeb et al. forthcoming). A major impact has been the decline in remittance incomes, which had been important for a significant—but relatively wealthier—share of the population (World Bank, 2020a). Poor households also were affected by the pandemic through job insecurity and low savings (World Bank, 2020a). Headey et al. (2020) found that both quantitative and qualitative measures show severe and widespread income losses due to COVID-19: 35% of respondents in their surveys stated that their household failed to earn any income in September 2020. The authors estimate that the prevalence of income-based poverty at the US$1.90 per day poverty line increased from 16% in January to 63% in September 2020. In a national phone survey in June 2020, the World Bank (2020c) further found that 18% of households were facing difficulties in securing an adequate diet.

Headey et al. (2020) modelled the impact of COVID-19 related disruptions on Myanmar’s economy from both international—for example, lower agricultural exports and workers’ remittances—and domestic sources—for example, COVID-19 prevention measures, such as stay-at-home orders and temporary business closures. They find that the strict lockdowns combined with much-reduced levels of international remittances and agricultural exports resulted in a sharp increase in severe poverty, from 9.8% pre-COVID-19 to 31.6% in the period of most extreme disruptions. Similarly, Boughton et al. (2021) documented the impact of COVID-19 in different parts of Myanmar’s agri-food system and show persistent financial stress for a high proportion of households and agri-food system businesses.

The COVID-19 pandemic also affected the rice sector in different ways between March and September 2020. First, after the COVID-19 pandemic, a food reserve scheme was set up by the government where exporters were required to provide 10% of their planned exports at a low price to these food reserves (USDA, 2020b; World Bank, 2020a). Second, rice exports were affected as borders were temporarily closed at multiple locations and export quotas were established (USDA, 2020b). However, international rice trade restarted after only a short discontinuity (Htoon, 2020; Ko, 2020) and there was only a small decline in aggregate export volumes for 2020 (USDA, 2021). Finally, transport between regions became more difficult during lockdowns, leading to less rice trade through the Yangon rice wholesale market—which served as a clearing center of rice for the country—and more direct trade from rice producing regions to border crossings (Htoon, 2020).
3 | CONCEPTUAL FRAMEWORK

To explore the potential impact of the COVID-19 pandemic on rice markets, we rely on frameworks developed by Gardner (1975) and Tomek and Robinson (1990). We present two scenarios, each of which could reflect the market changes during COVID-19 in Myanmar (Figure 1). In the graphs below, $S_0$ (supply), $D_0$ (demand), $P_0$ (prices), and $Q_0$ (quantity) refer to the situation before the COVID-19 pandemic. Superscripts P and R refer to the situation for paddy and milled rice, respectively. Paddy and rice markets are connected via rice mills, and the paddy-to-rice milling margin in any scenario is the difference between the equilibrium prices for paddy and milled rice.

The first scenario (Figure 1.1) looks at the case of increased processing and marketing margins. Such changes could arise during COVID-19 from higher labour costs, as milling is labour-intensive and labourers may be less willing or able to work at the mill during the pandemic; higher transportation costs, due to fewer trucks being available for paddy procurement due to increased health risks and mobility restrictions; higher interest costs (Htoon, 2020); and lower values for byproducts due to reduced demand for livestock feed. In this scenario, we would see reduced supply of rice (an upward shift of the supply curve), a higher rice price ($P^1_R$), and a lower paddy price ($P^1_P$) than in the situation before the COVID-19 pandemic ($P^0_R$, $P^0_P$).

In the second scenario (Figure 1.2), we consider a case of COVID-19 related disruptions in rice demand. First, if there is a downward shift in demand from $D_0^R$ to $D^1_R$ caused by a decline in the purchasing power of consumers (e.g., see Headey et al., 2020), rice prices would decline to $P^1_R$ and paddy prices would consequently decline to $P^1_P$. Second, if demand shifts upward due to increased demand for the government’s COVID-19 food reserve stock (Htoon, 2020; World Bank, 2020a) or due to a shift away from high value to staple products (Laborde et al., 2020)—or also due to increased international demand—rice and paddy prices would be pushed up to $P^2_R$ and $P^2_P$, respectively.

These frameworks indicate the heterogeneous effects on prices that can be found for paddy (at the producer level) and rice (at the consumer level), depending on the type and magnitude of shifts in supply or demand. Multiple forces act upon supply and demand at the same time, so the impact of COVID-19 is ultimately an empirical question. Moreover, the simple models in Figure 1 provide only a glimpse into the complex changes rice markets could face during
the COVID-19 pandemic (for more sophisticated models see, e.g., Wohlgenant, 2001; Gardner & Rausser, 2001).

4 | METHODS AND DATA

4.1 | Empirical methods

We use a simple empirical model to evaluate how milling margins, as well as paddy and rice prices, have changed during the COVID-19 crisis. This analysis is descriptive and does not isolate the causal impact of any specific policy or shock. Even in normal years there would be some year-to-year variations in prices. Still, if there were large-scale disruptions in the sector, they would show themselves in price changes. Our econometric specification pools price data for the milling input (paddy) and outputs (head rice, broken rice, and rice bran) and two time periods (before and during the pandemic) to compare the prices of the outputs to those of the input both before and during the pandemic. By framing the estimation of price changes of each output relative to paddy, we provide empirical evidence of how short-term equilibrium changes in milling margins have changed. Specifically, we employ the following fixed effect model:

\[ P_{ijt} = M_i + \beta_1 C19_t + \beta_2 HeadRice_j + \beta_3 (C19_t \times HeadRice_j) + \beta_4 BrokenRice_j + \beta_5 (C19_t \times BrokenRice_j) + \beta_6 Bran_j + \beta_7 (C19_t \times Bran_j) + \beta_8 PctBroken_{ijt} + \epsilon_{ijt} \]  

(1)

The dependent variable \( P_{ijt} \) is the price in MMK/lb for mill \( i \), time period \( t \), and type of rice product \( j \) which is either paddy (the reference product), milled rice, bran, or broken rice. \( M_i \) is the mill fixed effect which captures all time invariant characteristics for each mill. The fixed effects control for important determinants of prices and margins that do not vary over time, including mill region and location which determine proximity to paddy production zones and to rice sales locations; machinery and equipment used to mill rice, which determine rice quality and production efficiency; and management. Importantly, we hold the rice variety fixed for all \( i, j, \) and \( t \). Thus, the variety effects will also be absorbed into the mill fixed effect and average changes for different rice varieties during COVID-19 will be removed from the estimates. Other explanatory variables include three indicator variables for each main output produced by milling processes: HeadRice\(_j\) for milled rice, BrokenRice\(_j\) for broken rice, and Bran\(_j\) for rice bran. C19\(_t\) is an indicator variable equal to one if the price observation is from September 2020, after the COVID-19 policies had been put in place in Myanmar, and equal to zero for September 2019, prior to the pandemic. PctBroken\(_{ijt}\) is the percentage of broken rice in head rice sold, which is an important determinant of the milled rice price, but is not relevant to paddy, broken rice or bran and, therefore, takes a value of zero for regressions with those prices as dependent variables.

There are several estimators of interest. \( \beta_1 \) will capture the change over time in prices that millers paid for paddy. \( \beta_2 \) will show the average paddy-to-rice margin—the price that millers receive for their milled rice minus what they paid for paddy—before the pandemic. Similarly, \( \beta_4 \) and \( \beta_6 \) will show the price differences before the pandemic between paddy and broken rice and bran, respectively. The change in paddy-to-rice margins after the pandemic is shown by \( \beta_3 \). If \( \beta_3 \) is positive (negative), then the change in milled rice prices was greater (less) than the change in paddy prices. \( \beta_5 \) and \( \beta_7 \) will show the same relationship but for broken rice and bran prices relative to the change in paddy prices. Lastly, \( \beta_8 \) will show the relationship of the percentage of broken rice to milled rice prices.

While the mill fixed effects control for several important determinants of price changes and produce better average estimates of the effects of COVID-19 on millers, there may be interesting differences in the observed changes in prices across some parameters absorbed into
the fixed effects. Two potentially interesting differences are rice variety and milling technology. To explore differences in changes during COVID-19 across these parameters we estimate Equation (1) for subgroups of the full sample. First, we define subgroups by varieties and estimate Equation (1) for Emata and Pawsan varieties separately. Second, we define subgroups by technology, where mills that own either a colour sorter or a mist polisher are defined as ‘modern’ while those that do not own either are classified as ‘traditional’. We estimate Equation (1) again separately for both groups in this technology dichotomy.

4.2 | Data

To learn about the effects of COVID-19 on Myanmar’s rice processing, we conducted interviews with rice mill owners or managers in September 2020. Due to the unnecessary risks of COVID-19 transmission through face-to-face interviews and the transportation restrictions that limited mobility, the interviews were conducted via telephone. The sample for analysis consists of 252 medium- and large-scale rice mills that milled paddy to rice in the 30 days prior to interview (Table 1). The sample comes from three regions—Ayeyarwady, Bago and Yangon—which collectively account for 45% of the monsoon rice (the main rice season) produced in Myanmar. The main monsoon rice paddy production region of Ayeyarwady has the most mills (146), followed by Bago (66) and townships around Yangon (40), the major urban centre in Myanmar.

The phone surveys had two primary objectives. First, to understand how rice millers had been impacted by the COVID-19 crisis, and second, to learn about milling operations and gross margins—that is, how and where rice mills make money. The questionnaire included questions on COVID-19 disruptions to business activities, such as transportation restrictions affecting paddy purchases or rice sales; business responses to those disruptions, for example, adoption of safety measures or hiring fewer employees; and prices of paddy, rice and byproducts—rice bran, bran, and broken rice.

Table 1: Sample of rice mills and price observations

| Number of active mills | All | 252 |
|------------------------|-----|-----|
| Ayeyarwady             | 146 |
| Bago                   | 66  |
| Yangon                 | 40  |

| Number of price observations | All | 2020 | 2019 |
|-------------------------------|-----|------|------|
| All                           | 1816| 914  | 902  |
| Paddy                        | 333 | 168  | 164  |
| Rice                         | 496 | 251  | 246  |
| Broken rice                  | 496 | 249  | 247  |
| Bran                          | 491 | 246  | 245  |

Note: Number of price observations varies by year and by product because not all mills sold or purchased each product in each year.

Source: Mill survey

4Defined as daily throughput greater than 15 tons.

5The sample was first used in a study conducted by the International Growth Centre in collaboration with the Ministry of Commerce in 2019.
broken rice and rice husks. We asked millers to report current (September 2020) prices and to recall prices from one year prior (September 2019). Not every mill sold or purchased each product in the time period covered by the survey. Thus, for each product and each year, the number of price observations is less than the full sample of 252 mills (Table 1). The full number or price observations is 1816, 914 in 2020 and 902 in 2019. We captured detailed price information only for the rice variety with the highest throughput in the 30 days prior to interview. Emata had the most price observations with 1407 and Pawsn had the second most with 306.

The September 2020 survey was part of a panel with the same sample of rice mills conducted during the COVID-19 pandemic. While most of the analysis in this paper relies on the data collected in the September survey, we also use data from other survey rounds. Specifically, other relevant data collected for this study include detailed information on byproduct uses (collected in the October 2020 round) and milling outputs and conversion rates of paddy into milled rice and byproducts (collected in the November 2020 round).

5  |  RESULTS

5.1  |  Rice milling in Myanmar

We begin our analysis with some descriptive data for our sample (Table 2). The average daily throughput of these mills was 27 metric tons. Daily throughputs were relatively stable over the course of the survey, suggesting that variations in total throughput—most often linked with seasonality in production—come from changes in the number of days mills were operating rather than changes in production when operational. Most medium- and large-scale mills owned important value-added machinery, including driers (63%) and whiteners (84%). Less than half of the sample owned a mist polisher (49%) or a colour sorter (46%), two key machines in modern milling processes, while 63% owned at least one of the two—we define these as ‘modern’ mills. On average, the interviewed mills employed 7 permanent and 16 temporary workers, who were predominantly male. All mills buy paddy and sell milled rice, though 53% of mills also generated revenue by milling on commission by collecting a set fee per unit milled (typically defined by bags of milled rice output).

To produce milled rice from paddy, millers feed paddy through several machines to remove undesirable portions of the paddy, which make the rice not only ready for human consumption but also more refined and attractive. The milling process inevitably produces several byproducts which themselves are often marketable, though typically not for direct human consumption.

In the November round of phone interviews, we asked millers how much of each product they typically produce from milling 100 baskets of paddy. Figure 2 gives an overview of the products produced during the milling process, with separate bar graphs showing detail within rice products and head rice, respectively. About 24% of the paddy weight is lost when husks are removed in the first milling stage. A further 8% is removed as rice bran. Rice products (head rice and broken rice) account for 68% of the original paddy weight. Broken rice is the recovered broken rice grain, which is sold as a byproduct. However, head rice, which is the final product sold to consumers, also contains some share of broken rice that is not separated out, typically between 5% and 25% depending on quality and the targeted market. Exact conversion ratios from paddy to rice might differ depending on rice varieties, quality of the mill, and preferences by consumers (Aung, 2017).

With nearly a 50/50 split between marketable head rice and byproducts produced by the milling processes, recovering and selling byproducts is essential to mills’ bottom lines; 71% of mills reported that byproduct sales were ‘very important’ to their business. To better understand the importance of rice byproducts and how they are used in Myanmar, we asked millers whether they sold each byproduct and what the end uses were in 2019. The various uses for each product are presented in Appendix Table A1.
| # or % share | Definition                                                                 |
|-------------|---------------------------------------------------------------------------|

**Price data sample (# of operating mills)** 252 Operating mills were those milling paddy into rice in the 30 days prior to interview in September

- Ayeyarwady: 146
- Bago: 66
- Yangon: 40

**Average daily rice throughput (MT/day)** 26.7 Average daily milled rice throughput in the days that mills operated in August

**Machinery (share of mills that own, %)**

- Drier: 63 Share of mills that own a drier
- Mist polisher: 49 Share of mills that own a mist polisher
- Colour sorter: 46 Share of mills that own a colour sorter
- Bucket lift: 89 Share of mills that own a bucket lift
- Whitener: 84 Share of mills that own whitener
- Modern mill: 63 Modern mills are those owning either a mist polisher or colour sorter
- Traditional mills: 37 Traditional mills are not modern

**Employees (mean #)**

- Permanent—Male: 6 Number of permanent male employees
- Permanent—Female: 1 Number of permanent female employees
- Temporary—Male: 15 Number of male temporary or casual workers hired by the mill in the week prior to interview
- Temporary—Female: 1 Number of female temporary or casual workers hired by the mill in the week prior to interview

**Processing on commission (%)** 53 Share of mills that processed paddy on commission, as a service

*Source: Mill survey*

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**FIGURE 2** Breakdown of rice milling outputs. *Source: Mill survey*
Nearly every mill sells bran and broken rice—91% and 92%, respectively. However, only 10% sell husks. Both bran and broken rice are most commonly sold as feed. Bran almost exclusively goes to fish and livestock feed, with other uses being reported by fewer than 10% of millers. Broken rice is mostly used to feed livestock, and much less so for fish. There is an important quality distinction within broken rice. Larger, more complete pieces of broken grain are typically sold for further processing into human foods—61% of mills reported selling broken rice for noodle production. Rice husks have a much smaller market than bran and broken rice and are used mostly as a low-cost fuel source, though have other non-market uses, including livestock feed and bedding, and fertiliser. Resourceful mills will also burn their own rice husks to operate driers or compost the husks for use as a fertiliser.

5.2 | COVID-19 impacts on rice milling

Mills reported large business disruptions due to COVID-19 and corresponding policy responses implemented to mitigate its health burden. In September 2020, 39% of the millers interviewed reported transportation disruptions to buying paddy or selling rice caused by transportation restrictions (Appendix Table A2). There were also effects on operations: 7% of mills closed for at least one week in September, 42% reduced their operating time and 25% hired fewer employees. Further, 23 mills were completely closed due to COVID-19 in the 30 days prior to the September interviews. In response to these disruptions, 16% of active mills applied for a loan and 63% adopted at least one safety precaution—mask wearing and handwashing were the most common, but social distancing was only adopted by one mill.

To begin the exploration of the impacts of COVID-19 on prices, we use simple kernel density estimations of prices in 2019 and 2020 for the two most common varieties in our data, Emata and Pawasn (Figure 3). There are five main takeaways.

First, there was considerable variation in both paddy and rice prices, indicating important sources of price variability to explore further. Next, rice prices were generally higher in 2020 compared to 2019. The price increases appear to pass through to paddy prices, which were also higher. Third, varietal differences matter tremendously. Pawasn receives significantly higher prices than Emata. Fourth, Pawasn price distributions show greater variance than the Emata price distributions. With no export market as an anchor point for Pawasn, the prices for this domestic market variety are subject to greater fluctuations (World Bank, 2014b). Lastly, despite the differences in price levels, the distributions and changes across years are largely similar for both Pawasn and Emata. Thus, although prices have increased during the COVID-19 pandemic, there is no noticeable increase in price variations at the mill level.

To provide a more complete picture of COVID-19’s impact on rice mills, we calculate gross milling margins for 2020 and 2019 and compare the changes for Emata and Pawasn varieties. Our calculations account for the values of paddy input, rice output and each marketed byproduct using the following equation:

\[
\text{Margin}_{ikt} = \left( \frac{P_{\text{rice}}}{C_{\text{rice}}^k} + \frac{P_{\text{broken}}}{C_{\text{broken}}} \right) + \left( \frac{P_{\text{bran}}}{C_{\text{bran}}} \right) + \left( \frac{P_{\text{husk}}}{C_{\text{husk}}} \right) - \left( \frac{P_{\text{paddy}}}{4600} \right)
\]

(2)

with the margin for mill \( i \), variety \( k \) and year \( t \). Each price (\( P \)) is from reported data at the mill level and is set to zero for mills that did not sell. Each conversion rate (\( C \)) represents the average amount of each product produced from 100 baskets of paddy at the variety level.\(^6\) We assume the same

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\(^6\) We use the average conversion rates for two reasons. First, the conversion rate data were collected in a different survey round (November) than our price data (September) and the samples do not align perfectly. Second, there were several unrealistic responses that suggested some millers did not understand the question properly or that there was an error in conversion rates among units during data collection.
conversion rates between 2019 and 2020. Milling equipment is typically used for many years without much decline in efficiency, and mills were presumably less likely to have invested in new equipment during the pandemic. The value of paddy input is the mill-variety-year price multiplied by 100 baskets, which we assume to have a dry input weight of 46 pounds—the official Myanmar conversion rate.

**FIGURE 3** Paddy price (top), rice price (middle), and gross milling margin distributions for Pawsan and Emata varieties, 2020 and 2019. *Note:* Kernel density estimations. *Source:* Mill survey
There are three key results in our analysis of gross milling margins (Figure 3). First, gross margins for both Emata and Pawsan are slightly higher in 2020 than 2019. This suggests that on a per-unit-milled basis at the mill level, challenges presented by the COVID-19 crisis have not had substantial negative effects on milling margins. Second, gross margins for Pawsan show a much wider variance than Emata. The wider paddy and rice price variations for Pawsan pass through to total margins, while byproduct sales do little to reduce and may increase variance. Third, margins for the more expensive Pawsan variety are higher, as noted in other settings for higher quality rice (Minten et al., 2013).

Figure 4 presents the average output revenues and paddy costs for Emata and Pawsan by year. The importance of byproduct sales is immediately evident. The revenue from rice sales alone is less than the paddy cost in each case. Thus, without the ability to market byproducts, milling paddy-to-rice margins would need to increase, putting downward pressure on paddy prices paid to farmers and upward pressure on milled rice prices to consumers.

After rice, broken rice is the main contributor to margins. Pawsan revenues from broken rice are slightly higher than those for Emata. This is not because prices are higher—they are statistically similar. Rather, it is because more broken rice is recovered from Pawsan varieties as the final consumer head rice is sold with a lower percentage of broken rice in it than is the case for Emata varieties. Bran is the third leading contributor to milling margins, but with total values of about one-third of broken rice for Emata and one-quarter of broken rice for Pawsan. The value of husks is negligible. Confirming the results in Figure 3, milling margins increased in 2020 from 2019 for both varieties. Pawsan margins were higher than those for Emata by about 45%.

While the graphs give an idea of overall changes in prices and margins, we explore further variations using the regression framework presented in Section 3. We begin by presenting the full pooled estimation in column 1 of Table 3.

The constant is the average of fixed effects and reflects the average paddy price in 2019, which is estimated to be 150 MMK per pound. The C19 coefficient reveals change in paddy prices in 2020 and shows a significant increase of about 7 MMK per pound paid to farmers. In 2019, the paddy-to-rice price margin was 130 MMK per pound, that is, rice prices were 130 MMK per pound higher than paddy prices (89%), as shown by the head rice dummy coefficient. The paddy-to-rice margins increased significantly by 5.5 MMK per pound during the pandemic, shown by the C19 × Head rice coefficient in column 1. Thus, per pound of paddy milled, millers were making slightly more money in 2020 compared to 2019. To rephrase these results, rice

![Figure 4](image-url) Average milling paddy costs, revenues, and margins in MMK per 100 baskets of paddy, Pawsan and Emata varieties for 2020 and 2019. Source: Mill survey
prices increased by 5.5 MMK per pound more than paddy prices in September 2020 compared to September 2019. However, it is important to note that the paddy-to-rice margin increase is small relative to rice prices, only 2% of the average head rice price. Thus, processing margin increases did not drive large price changes for consumers. Also, overall head rice prices increased by an average of 13 MMK per pound during the pandemic, but most of that change (7 MMK per pound) was passed through to farmers in the form of higher paddy prices. It must be noted that most paddy purchases in our data occurred at the farmgate and only about 30% happened at the mill. Thus, rising transportation costs from COVID-19 restrictions were not likely to be driving the increase in paddy prices, and farmers were receiving higher farmgate prices.

Column 1 of Table 3 also shows interesting effects on byproduct prices. Intuitively, head rice is the most valuable product from rice milling and receives the highest price per pound of all the outputs, demonstrated by the head rice coefficient being much greater than those for broken rice and bran. Moreover, the differences between paddy and broken rice price did not significantly change during the COVID-19 pandemic. The broken rice price also increased in similar magnitude to head rice and both differences are insignificant. The small and insignificant price changes for broken rice relative to paddy indicate that demand from the noodle

|                  | Variety          | Modern/Traditional |
|------------------|------------------|--------------------|
|                  | Emata            | Pawsan             | Modern | Traditional |
| Constant (paddy 2019) | (1)             | (2)                | (3)    | (4)         | (5)         |
|                   | 150.19***        | 139.59***          | 199.80*** | 153.49***   | 144.57***   |
|                   | (1.69)           | (1.29)             | (5.99)  | (2.40)      | (2.19)      |
| Post (paddy 2020) | 7.34***          | 8.33***            | 3.69    | 7.15***     | 7.59***     |
|                   | (1.15)           | (1.22)             | (4.00)  | (1.53)      | (1.76)      |
| Head rice         | 130.50***        | 108.49***          | 147.81*** | 132.97***   | 123.44***   |
|                   | (5.48)           | (3.80)             | (8.39)  | (6.84)      | (9.43)      |
| Post ×Head rice   | 5.52***          | 6.39***            | 6.10    | 5.56***     | 5.59**      |
|                   | (1.50)           | (1.31)             | (4.53)  | (1.93)      | (2.42)      |
| Broken rice       | 10.99***         | 21.41***           | −40.10*** | 8.87***     | 14.59***    |
|                   | (2.49)           | (2.00)             | (6.89)  | (3.29)      | (3.82)      |
| Post ×Broken rice | 1.97             | 0.64               | 7.680*  | 1.31        | 3.22        |
|                   | (1.38)           | (1.55)             | (3.99)  | (1.78)      | (2.22)      |
| Bran              | −36.49***        | −24.17***          | −99.25*** | −38.11***   | −33.75***   |
|                   | (3.47)           | (2.92)             | (10.15) | (4.73)      | (4.95)      |
| Post ×Bran        | 9.10***          | 7.22***            | 16.45*** | 10.94***    | 5.97*       |
|                   | (1.75)           | (1.85)             | (4.57)  | (2.03)      | (3.26)      |
| pctBroken         | −3.11***         | −1.49***           | −2.58*** | −3.46***    | −2.33***    |
|                   | (0.52)           | (0.32)             | (0.96)  | (0.70)      | (0.82)      |
| Mill fixed effects| YES              | YES                | YES     | YES         | YES         |
| Observations      | 1816             | 1407               | 306     | 1143        | 673         |
| R-squared         | 0.78             | 0.81               | 0.91    | 0.77        | 0.79        |

Notes: Heteroscedasticity robust standard errors in parentheses. Constant in mill fixed effect model represents the average of the fixed effects; * p < 0.10, ** p < 0.05, *** p < 0.01. Prices are in MMK per pound.

Source: Mill survey
making and livestock feed sectors—the two major markets for broken rice (Appendix Table A1)—were not disproportionately disrupted by the COVID-19 pandemic. However, there are larger changes for bran prices. Bran receives a much lower price per pound than the other products, and even significantly lower than paddy. Yet, the bran prices significantly increased by 9 MMK per pound more than paddy prices during the pandemic. This suggests some substantial demand changes from fish farms, the main market for bran (Appendix Table A1). Conversations with industry experts suggest that there may have been feed substitution effects driving the demand increase. Fish farmers may have increased the share of low-cost bran in their feeding programmes, substituting away from higher priced pellets and mixed feeds, many of which are imported. The price increases for byproducts relative to paddy might have helped mills to keep changes in processing margins low and allow them to pay higher prices to farmers for their paddy during the COVID-19 pandemic.

The final insight from column 1 is that the share of brokenness in the head rice leads to significantly lower prices, as has been shown in numerous other settings (Minten et al., 2013; World Bank, 2014a). A 1% increase in brokenness reduces the price of head rice by approximately 3 MMK by pound.

Table 3 also explores differences in the price and margin changes by rice variety with separate estimates for Pawsan and Emata varieties in columns 2 and 3. The differences in marketing channels for these two important varieties—Emata is exported in large quantities while Pawsan is consumed only domestically—underscore some interesting differences in the estimated effects. While these varieties are, to some degree, substitutes for domestic consumption in Myanmar, we would expect any large demand shifts to at least move these prices in the same direction, though there may be different magnitudes. Confirming the observations from Figure 3, average paddy prices are much higher for Pawsan than Emata, 43% higher in 2019. Interestingly, Emata paddy prices increased significantly by 8 MMK per pound during COVID-19. Paddy-to-rice margins also significantly increased by 6 MMK per pound for Emata varieties. Thus, mills milling Emata rice enjoyed higher gross returns in 2020 than in 2019. Head rice prices increased by 13 MMK per pound overall, which is likely linked to higher global rice prices relative to 2019—the Food and Agriculture Organisation rice price index was 108.6 in November 2020 compared with 102.5 in November 2019. Again, most of this price increase was transferred back to farmers in higher paddy prices.

In contrast, for Pawsan varieties, the estimated changes in both paddy-to-rice margins and paddy prices paid to farmers were smaller and not statistically different from zero, though we note that we have less power in our Pawsan estimates due to fewer observations. One possible reason that Pawsan did not enjoy similar price increases as Emata is a decline in purchasing power from lower incomes in the local market (Headey et al., 2020; World Bank, 2020c). Local consumers may have substituted away from the higher-priced Pawsan rice varieties, offsetting any potential price increasing factors.

For byproducts, varietal differences are much less important. Although the coefficients for broken rice and bran as well as their interactions with C19 are different, these differences are relative to paddy. Broken rice in both varieties sold at around 160 MMK per pound in 2019. For bran, the 2019 price estimates were 115 MMK per pound of Emata and 101 MMK per pound of Pawsan. The changes in both broken rice and bran prices were similar across varieties. Again, the coefficients show differences; both byproducts show larger and significant changes for Pawsan, but these are relative to paddy prices, which did not change for Pawsan but did for Emata. Emata broken rice prices rose by 9 MMK per pound in 2020 and bran prices rose by 16 MMK. For Pawsan, the changes were 11 MMK and 20 MMK per pound, respectively. Thus, byproduct prices played an important role in millers’ financial viability during the pandemic, particularly for Pawsan, which did not show paddy-to-rice margin increases. Further, byproduct prices are not affected by the differentiated output markets for Emata and Pawsan that drive differences in paddy and rice prices.
Columns 4 and 5 in Table 3 compare modern and traditional mills with separate fixed-effects estimations. Modern mills achieve higher rice quality, controlling for variety, through use of polishers and colour sorters, which translates to higher paddy-to-rice margins by about 10 MMK per pound relative to traditional mills. A substantial portion—about 50%—of the higher prices modern mills receive for head rice is passed through to farmers in higher paddy prices. Prices per pound are about 9 MMK higher for paddy and about 10 MMK higher for rice. In terms of price changes during the pandemic, both modern and traditional mills show similar patterns. The exception is in bran prices, for which modern mills enjoyed a greater price increase above paddy price changes than did traditional mills.

6 | CONCLUSIONS AND POLICY IMPLICATIONS

The COVID-19 pandemic has led to substantial disruptions to agri-food systems around the world and, in some cases, large food price increases. In this paper, we explore price changes in Myanmar's rice sector early in the pandemic through the lens of rice millers. Rice mills play crucial roles in rice value chains as the essential agro-processing link between paddy production and rice consumption, though their operations are not well understood. Other research suggests that mill profitability in Myanmar was seriously affected by the pandemic, jeopardising their roles in the value chain (World Bank, 2020a).

We find that Myanmar's rice mills were not exempt from the general COVID-19 disruptions experienced in the country—transportation disruptions, employee lay-offs, and reduced operations at the mill level. Yet, despite these challenges, the processing sector was surprisingly resilient early in the crisis and milling margins were relatively unaffected. Through mill fixed effects regressions on prices of paddy, head rice, broken rice and rice bran, comparing prices in September 2020 (during the pandemic) to those in September 2019 (prior to the pandemic) we show that paddy-to-rice margins increased slightly. However, importantly for consumers and producers alike, the increased margins were small—only 2% of head rice prices. Both paddy and rice prices increased significantly, though about half of the rice price increases were transmitted through to producers. There were smaller and insignificant price increases for the locally preferred and more expensive Pawson rice variety, which may have experienced a drop in demand as a consequence of the pandemic. We also find that modern mills were able to achieve higher rice prices. A large share of the rice price increases was passed through to farmers as higher prices for their paddy, suggesting that modernisation in the mills may lead to developments back to the farm level in higher quality paddy. Lastly, our results further underscore the overall importance of byproducts to rice millers. Stability in byproduct markets helped millers' bottom lines and further contributed to their ability to pass any rice price changes on to producers. During the pandemic, rice bran prices increased significantly, potentially driven by a demand increase from aquaculture.

Linking these results to the model scenarios presented in Section 3 (Figure 1), we note that changes in paddy-to-rice marketing margins have been small and, in the case of the locally traded Pawson variety, insignificant. Margin changes have not been a major explanation for price changes in the paddy and rice markets. We find, however, important effects of demand changes. Increased global demand and international rice price increases have contributed to price increases during COVID-19 for Myanmar's exported rice variety, Emata.7 Local demand

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7We tried to collect data on mills selling to exporters with intentions to explore differences in price changes across buyer types, which could further provide insights into the degree of trade disruptions and impacts on prices. Unfortunately, the question proved to be problematic as most mills sell to traders who then ultimately sell to exporters further down the value chain and millers appeared to struggle with the question and many provided inconsistent answers. Thus, we did not have a high enough level of trust in those data to present them in the paper. However, we do know that only the Emata varieties of rice are exported in meaningful quantities, and our paper relies on that fact and the price analysis results to argue that export disruptions were likely minor overall.
changes also had an apparent effect. The more expensive, locally preferred rice has seen insignificant paddy and rice changes relative to 2019, which are potentially linked to the significant increase in poverty rates caused by the pandemic (Headey et al., 2020; World Bank, 2020a, 2020c).

From the above analysis of food prices and processing margins for medium- and large-scale rice mills in Myanmar during the COVID-19 pandemic, we derive two main policy implications. First, access to international markets is important during severe shocks. Links to export markets can stabilise domestic prices, an important consideration for food security in these settings (Dawe, 2001; Khadijat et al., 2021), and keep them insulated from potential demand shifts, which in the case of Myanmar early in the COVID-19 shock was a decline in purchasing power from lower incomes. Further, farmers benefit from international price increases as higher rice prices were transmitted to farmers in the form of higher paddy prices.

Second, mills with more advanced equipment, that is, modern mills, received higher prices for rice derived from extra processing and refinement, and about half of those gains were again passed to farmers in higher paddy prices. Thus, modernisation in the processing sector can pull along other segments of the value chain and have benefits for farmers and should be encouraged through further relaxation of investment restrictions, broader access to capital through freer financial sectors, and expanded access to international markets.

Our data only allow a preliminary assessment of Myanmar's rice milling sector during COVID-19. Future research should continue to monitor changes in the sector and help identify whether the benefits of modernisation and integration into global markets persist into the future. Additionally, future research should explore in greater detail the linkages between modern milling technologies and paddy production at the farm level. Further research is also needed to understand the linkages of Myanmar's domestic rice prices to international prices for exports, and to understand the domestic substitution patterns for different rice varieties.

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