

Adoption of Quality-Improving Rice Milling Technologies and Its Impacts on Millers' Performance in Morogoro Region, Tanzania

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The objectives of this study are to identify the determinants of rice millers' adoption of quality-improving milling technologies and to evaluate the impacts of such technologies on millers' performance in Morogoro region, Tanzania. It is found that experience in rice trading is an important determinant of the adoption of such technologies. As for the impact, this study shows that the adoption of such technologies has a significant positive impact on millers' profit probably because the quality-improving technologies attract more customers. However, they do not influence the share of market-oriented varieties in the total milled rice produced.

Key words: rice milling, technology adoption, rice quality

1. Introduction

Rice is the second most important crop in terms of the area planted as well as the amount of output produced in Tanzania (FAOSTAT, 2019). It is also the third most consumed food crop after maize and cassava, but it becomes the second after maize in urban area (Cochrane and D'Souza, 2015). It means that rice is primarily consumed by the relatively affluent urban population of Tanzania. Rather, in rural area rice serves as the major employment and income source for many households. Thus, the increasing demand for domestically produced rice is due to urbanization, increased income, and population growth, and it generates the increase in employment in rice cultivation in rural area.

Due to the rise in rice demand, to avoid the foreign exchange loss and the influence of unstable global market on rice prices, Tanzanian government encourages the efforts toward attaining rice self-sufficiency and is motivating farmers to produce better paddy by ensuring they plant good seed and follow proper way of cultivation. We expect better paddy to be produced by farmers and this results into good quality rice. However, if the paddy is not processed well by the local rice millers, local rice will not be accepted by the affluent modern consumers and consequently cannot compete with the imported rice and will not meet the increasing demand for rice.

In fact, Tanzania witnesses high levels of qualitative and quantitative losses in rice grain during the milling process. Hence, this study focuses on local rice milling industry in Tanzania and explores how rice quality can be controlled by

considering the miller's decision to invest in new technology. The goal of this paper is to clarify whether this rather positive development is financially worthwhile.

Thus, this study will belong to the growing body of empirical literature on the impact of technology adoption in sub-Saharan Africa (e.g. Pan *et al.*, 2018 and Alem *et al.*, 2018). However, to the best of authors' knowledge, rice milling technology has never been studied in the field of economics although the improvement of local rice quality is an urgent issue in sub-Saharan Africa (e.g. Demont and Rizotto, 2012 and Futakuchi *et al.*, 2013). Even the efficiency of rice millers has seldom been analyzed except for Furuya and Sakurai (2000). Therefore, this paper will be the first one that investigates the adoption of rice milling technologies and its impact on rice millers' performance in sub-Saharan Africa.

2. Data and Methods

1) Data

The study area is the Morogoro Region of Tanzania; it is situated in the eastern agroecological zone, one of the three leading zones for rice cultivation in Tanzania. Morogoro Region is one of the five rice producing regions in Tanzania. Among the five regions, it is the closest to and lies between the country's business city, Dar es Salaam (about 184.8 km) and the national capital, Dodoma (about 262.6 km).

Morogoro Region has seven administrative units (districts), which are Ulanga, Kilombero, Morogoro rural, Morogoro urban, Mvomero, Gairo, and Kilosa. Out of the

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seven districts, Kilombero, Mvomero, and Morogoro urban are selected because rice millers are concentrated in those districts. We tried to cover all the millers in the above mentioned three districts, and finally identified 112 millers. Then, we interviewed all of them in two phases, first from February to March 2018 and second phase from May to June 2018.

Through the interview, we have recognized that the following quality-improving milling technologies are becoming popular among the millers, but only some of the millers have adopted them.

i. Paddy cleaner machine: This machine is used to clean the paddy before the milling process. It helps to remove all the foreign materials like glasses and stones that come along with the paddy after harvesting.

ii. Destoner: This machine is used to remove all the stones and other large particles that remain in milled rice.

iii. Rice grading machine: This is a new technology in Morogoro Region, in particular, and in Tanzania, in general. It mechanically separates milled rice into several categories based on the content of broken rice. The first, second, third, and fourth categories, respectively, yield grade 1 rice (no broken rice at all), grade 2 rice (a mix of broken rice (40 percent) and unbroken rice (60 percent)), grade 3 rice (completely broken rice), and grade 4 rice (small particles of broken rice). The grade 4 is not meant for direct human consumption but is used as animal feeds or as materials for processed food items.

iv. Integrated machine: This machine is integrated with all the functions used by millers during the milling process, including paddy cleaner, destoner, and grader. With the integrated machine, the miller can avail all the milling functions on a single platform.

2) Methods

This study chooses the above-mentioned new milling technologies, namely paddy cleaner, destoner, grading machine, and integrated machine, and analyzes their impact on rice millers' performance. The performance is assessed by three indicators: (1) the utilization rate of milling capacity, (2) the profit from the milling business, and (3) the millers' ability to attract market-oriented rice varieties.

From the interview, we understand that urban consumers prefer local rice varieties to improved, high-yielding varieties (e.g. Saro) because of their texture and taste. It means that local varieties are more urban market-oriented, and hence require better milling quality to meet urban

consumers' preference. On the other hand, milling quality of improved high-yielding varieties is relatively low and sold in rural market and/or for urban poor people. In this situation, customers with local rice varieties (i.e. urban market-oriented varieties) are more likely to choose millers producing better quality rice. Therefore, we use the share of local variety processed as an indicator of millers' performance outcome and hypothesize that millers with quality-improving milling technologies will have a higher share of local varieties in total milled rice.

As for the profit, profit per kg of milled rice per month is used as an indicator of millers' performance. It is calculated in the following way:

$$P = TR - TC \quad (1)$$

where P is monthly profit per kg of milled rice, TR is monthly revenue per kg of milled rice, and TC is monthly cost per kg of milled rice. Because majority of millers are engaged only in milling, their revenue is milling fee only. Therefore, TR is the same as the milling fee per kg. It is important to give several remarks here. First, some millers provide rice grading service, where customers bring milled rice that is milled by a miller without a grading machine. Second, some millers are engaged in rice trading (i.e. purchasing paddy from farmers and selling milled rice to buyers). Although such activities should be profitable as well, we do not include profit from such activities because we focus on the performance of rice milling itself.

The total cost per kg of milled rice (TC) is calculated by considering all the costs incurred by the miller in a month. It is given by the following:

$$TC = (w_L L + w_V V + w_K K)/Q \quad (2)$$

where L is labor input, V is other variable input for machine operation like electricity, phone bill, maintenance costs, and taxes, K is the capital input, and Q is the quantity (kg) of milled rice produced in a month. Input prices for L , V , and K are given by w_L , w_V , and w_K . $w_K K$ is the depreciation cost of milling machine. Applying the straight-line method, monthly depreciation cost is obtained as the market value of the machine divided by total depreciation time expressed in months.

By defining the profit in this way, P will increase as Q increases because TR (milling fee) does not depend on Q but TC negatively depends on Q due to the fixed nature of the depreciation. Therefore, our hypothesis is that millers with

quality-improving milling technologies will have a higher utilization rate of milling capacity¹⁾ because such millers attract more customers, and as a result will have a higher profit per kg of milled rice

Since the adoption of those technologies is millers' self-selection and we have only cross-section data, we employ propensity score matching (PSM) to evaluate their impact on millers' performance (Khandker *et al.*, 2009).

3. Results

1) Descriptive statistics

Table 1 shows the characteristics of sample millers. It shows that most millers are educated and started milling business recently. About 63% of sample millers have experience in rice trading, but it does not necessarily mean that they are still involved in rice trading since some of them had stopped rice trading when they started rice milling.

Table 2 summarize adoption status of quality-improving technologies. It shows, for example in the first row, that the number of millers who do not have a paddy cleaner is 77, the number of millers who have only paddy cleaner (no other technologies) is 1, the number of millers who have a paddy cleaner plus one technology (either destoner or rice grader, but not both) is 11, and millers who have all the three technologies (i.e. an integrated milling machine) is 23. Almost two thirds of millers do not have none of the four technologies, while about 20% of millers have adopted an integrated milling machine. Based on this observation, we will assess the impact of the adoption of integrated milling machine (relative to non-adopters and partial adopters) and that of at least one quality-improving technology (relative to non-adopters).²⁾

Milling capacity utilization rate is summarized by season in Table 3. As expected, the utilization rates significantly depend on season. In average and high seasons, mean utilization rates are more than 100%, which implies that millers work more than normal working hours per day. As explained above, milling profit depends on the utilization rate of fixed capital, and hence the higher utilization rate should generate more profit. It is confirmed in Table 4.

The share of local rice varieties in total milled rice produced is provided in Table 5 by season. The share is slightly lower in high paddy supply season, but the

difference is not statistically significant. Thus, there is not seasonality in terms of rice varieties.

2) Determinants of technology adoption

The determinants of the adoption of milling technology are identified by using a probit model for the integrated machine and at least one technology respectively. The regression results are given in Table 1. Unlike typical cases of agricultural technology adoption, education has no effect on the adoption. Experience in rice trading has a positive effect, which implies that those who know market demand tend to invest in quality-improving milling technologies. On the other hand, years in rice milling business (experience) has a negative effect. This is interpreted that those who have entered milling business recently may be more market-oriented and as a result tend to use quality-improving technologies compared with those who started rice milling earlier. Those who were wealthy people are more likely to invest in new milling technologies, which is captured by "land owner of milling facility."

The results are used to calculate the propensity of each technology adoption for PSM analyses.

Table 2. Adoption of milling technologies (N=112)¹

Tech. Type \ Adoption status	No ²	Only this one	With another	Integrated
Paddy Cleaner	77	1	11	23
Destoner	83	0	6	23
Rice Grader	80	4	5	23
Integrated	89	-	-	23

Note:1) Unit is number of millers.

2) Number of millers adopting none of the technologies is 73 out of 112 millers surveyed. Thus, 39 millers have adopted at least one technology, including 23 millers adopting integrated milling machine.

Source: Authors' field survey 2018.

Table 3. Capacity utilization rate by season (N=112)¹

Season ²	Mean	S.D.	Min	Max
Low supply	67.4	40.4	14.4	200
Average supply	147	100	40.0	625
High supply	296	213	75.0	1500

Note:1) Unit is % of milling capacity.

2) Low paddy supply season is January – April, average paddy supply season is September – December, and high paddy supply season is May – August.

Source: Authors' field survey 2018.

1) Capacity utilization rate is obtained as the ratio of average production of milled rice per day against maximum amount (on the specification) of milled rice production per day
 2) Considering the complementarity of the quality-improving

technologies, it will be interesting to analyze the impact of each combination of the technologies. However, due to the small sample size, the number of each combination is too few to do meaningful analyses.

Table 1. General characteristics of sample millers and determinants of technology adoption (N=112)¹

Variable name	Description	Mean	S.D.	Integrated milling machine	At least one technology
<i>AGE</i>	Miller's age in years	48	10.44	0.04 (0.02)**	0.00 (0.01)
<i>EDUC</i>	Miller's number of years in formal education	10	4.20	0.03 (0.05)	0.02 (0.04)
<i>EXP</i>	Miller's experience in the milling business (years)	9	7.41	-0.08 (0.03)**	-0.05 (0.02)**
<i>RiceTrade</i>	Miller's experience in rice trading (1=yes, 0=no)	0.63	NA	1.12 (0.50)**	0.74 (0.32)**
<i>LandOwner</i>	Ownership of the land of milling facility (1=yes, 0=no)	0.54	NA	1.47 (0.45)***	0.84 (0.34)**
<i>Livingplace</i>	Location of residence (1=near milling area, 0=otherwise)	0.63	0.48	-0.44 (0.43)	-0.40 (0.32)
<i>MillFee</i>	Prevailing milling fee (TZS/kg) in the village ²	61.78	8.67	0.19 (0.07)***	0.07 (0.05)
<i>GradFee</i>	Prevailing grading fee (TZS/kg) in the village ²	11.14	1.5	0.20 (0.15)	0.15 (0.12)
<i>KILO</i>	Kilombero District dummy (1=yes, 0=no)	0.49	NA	-1.79 (0.96)*	-1.00 (0.85)
<i>MVON</i>	Mvomero District dummy (1=yes, 0=no)	0.35	NA	1.30 (0.82)	0.59 (0.48)
<i>MORO</i>	Morogoro town District dummy (1=yes, 0=no): reference	0.16	NA	NA	NA
C	Constant	1	NA	-17.8 (5.30)***	-6.88 (2.99)**

Note: 1) Probit model is used to estimate marginal effects of explanatory variables on the adoption of each technology separately. Standard errors are in parentheses and the significance level is indicated as * p < 0.1, ** p < 0.05, and *** p < 0.01.

2) Milling fee and grading fee are quite uniform within a village (a cluster of millers) regardless of the technologies adopted.

Source: Authors' field survey 2018.

Table 4. Milling profit by season (N=112)¹

Season ²	Mean	S.D.	Min	Max
Low supply	439	652	-127	5407
Average supply	1606	1798	131	12917
High supply	3757	3485	699	19477

Note:1) Unit is TZS/kg.

2) See Table 3 for the definition of seasons.

Source: Authors' field survey 2018.

Table 5. Share of local rice by season (N=112)¹

Season ²	Mean	S.D.	Min	Max
Low supply	77	30	0	100
Average supply	76	19	0	100
High supply	74	20	0	100

Note:1) Unit is % of total milled rice.

2) See Table 3 for the definition of seasons.

Source: Authors' field survey 2018.

3) Impact of technology adoption

The results of PSM are shown in Table 6. Using the three indicators explained above, the impact is assessed for each technology and each season separately.

First of all, it is revealed that the adoption of quality-improving technology, even at least one technology, increases capacity utilization rate and as result generate

more milling profit. The impact (i.e. difference between adopters and non-adopters after matching) becomes larger as the season becomes busier. Probably because millers with quality-improving technologies have higher fixed capital cost and larger milling capacity,³⁾ capacity utilization and profit become much lower in idle seasons. The result also can be attributed to the seasonality of labor demand. Since quality-improving machines are generally labor-saving technologies, they are more preferred during the post-harvest season when labor demand is high. On the other hand, in low paddy supply season some customers may prefer manual cleaning since it is cheaper.

When we compare the two types of technology, we need to note that "at least one technology" includes integrated milling machine. From the comparison, we find that the impact on rice milling profit is bigger in the case of "at least one technology" than in the case of integrated milling machine. This is because control group of the former is non-adopters (millers adopting none of the three technologies), while control group of the latter is non-adopters and millers adopting one or two of the three technologies. The result suggests that investment in one or two of the three technologies can produce a big return.⁴⁾

3) Such characteristics are not directly used for matching due to potential endogeneity.

4) Even if we exclude 23 millers adopting integrated machine from

the analyses, the results qualitatively do not change although the impacts become a little smaller. The results are not shown in this paper, but available from the authors.

As for the share of local rice, we cannot find any impact of the quality-improving milling technologies on it. Because the local varieties include many different types of rice and their share is already more than 70% on average, it is difficult to find any impact on the share. Moreover, some of the local varieties are for self-consumption, and are milled at the most convenient millers regardless of the technologies.

4. Conclusion

This study aims to identify the determinants of rice millers' adoption of quality-improving milling technologies and to evaluate the impacts of technology adoption on rice millers' performance, using data of 112 rice millers in Morogoro Region, Tanzania.

The probit regressions suggest that experience in rice trading has a significant influence on the adoption of quality-improving technologies. Those who are wealthy people (inferred by the land ownership) are more likely to invest in them, which implies the existence of financial constraint to the investment.

PSM analyses reveal that when millers improve the technology of their mills, their profits generally increase because they can attract more customers and the utilization rate of milling facility rises. However, the adoption of quality-improving technologies does not seem to have an influence on the share of local varieties (market-oriented varieties), and this can be because some farmers just use the most convenient millers and do not care about the technologies.

Given the huge impact on profit, millers who cannot invest in the quality-improving technologies will not survive in the rice value chain in Tanzania. Since our analyses indicates the existence of financial constraint to the

investment in such technologies, a policy to support medium or long-term investment should be introduced. It will benefit not only millers, but also farmers and traders.

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Table 6. Impact of quality-improving technology on miller's performances (N=112)¹

Technology	Season	Milling Profit (TZS/kg)			Capacity Utilization Rate			Share of Local Rice		
		Treated	Control	diff.	Treated	Control	diff.	Treated	Control	diff.
At least one technology ²	Low	815	223	592***	0.74	0.60	0.14	0.86	0.83	0.03
	Average	2842	854	1987***	1.72	1.23	0.49*	0.79	0.78	0.01
	High	6510	2025	4485***	3.47	2.44	1.06*	0.74	0.77	-0.03
Integrated machine ²	Low	891	419	472*	0.84	0.57	0.27*	0.88	0.89	-0.01
	Average	3209	1670	1539*	2.24	1.35	0.89**	0.81	0.83	-0.02
	High	7527	4076	3450**	4.77	3.21	1.56*	0.79	0.75	0.04

Note: 1) Propensity score matching (one-to-one, nearest neighbor matching imposing common support without specifying caliper) is used. Significance level of the impact is indicated as * p < 0.1, ** p < 0.05, and *** p < 0.01.

2) The number of treated is 32 and the number of control is 73 in the case of "At least one technology." They are 21 and 89 respectively in the case of "Integrated machine." Balancing is confirmed from kernel density plots.