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Capacity Utilization of the Rice Milling Industry and Interlinkage in the Rice Market in Ghana

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Most large-scale millers in the Kumasi area, central Ghana, provide interest-free or low interest loans to farmers under the agreement that the farmers will bring their paddy to the millers. This paper examines the effect of this interlinkage on the efficiency of rice milling. A quadratic short-run cost function was estimated by controlling for self-selection bias using the results of first-stage Probit regression, and capacity utilization was calculated in relation to money lending. The results show that if a miller provides a loan to farmers, the operating rate will increase by 24% and the total cost will decrease by 17%.

Key words : inter linkage, rice milling, capacity utilization, money lending, Ghana.

1. Introduction

The improvement of local agricultural markets is a crucial part of agricultural development in developing countries. Its importance has been enhanced as a result of recent trade liberalization because local products need to compete with imports. In the process of market development, various informal institutions, such as interlinkage transactions, merchant guilds, and credit, may emerge (for example, Aoki [1] ; Grief [8] ; Hayami and Kawagoe [9]). While such informal institutions could increase efficiency under the imperfect market, their emergence itself is a sign of market imperfection. Hence by studying the nature of informal institutions in a particular market system, we will be able to identify the constraints to market development and to determine meaningful policy implications. With this idea in mind, the present paper takes an example from the rice market in Ghana and investigates interlinkage between rice millers and rice farmers.

As is the case in other West African countries (WARDA [19]), Ghana has recently seen a dramatic increase in rice consumption per capita due to urbanization ; average yearly consumption of milled rice per capita increased from 7.7 kg in the 1980s to 13.6 kg in the 1990s (FAO [6]). During the same period, while domestic rice production increased from 46,500 tons to 110,600 tons in milled rice equivalent, milled rice imports also increased from 50,400 tons to 122,400 tons (FAO [6]). This indicates that both import and domestic production equally increased during the past twenty years, but also implies that domestic production could not sufficiently meet the increasing demand for rice. Furthermore, rice imports had grown rapidly since 1999 and reached 297,000 tons in

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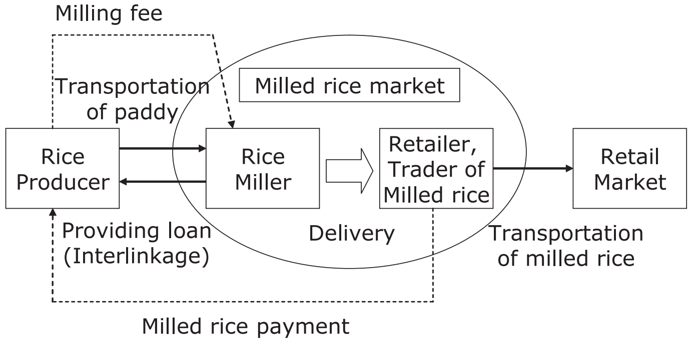

Figure 1. Distribution of local rice in the Kumasi area, Ghana

2002, while the increase of domestic rice production was moderate (FAO [6]). Because of the significant devaluation of the Ghanaian currency since the commencement of the structural adjustment program in 1983, the increasing import has become a heavy burden on the country's trade balance. And the recent surge in rice imports has caused an expansion of the country's trade deficit, which has become a serious macro economic problem (ISSER [10] ; Seini [14]). Therefore, enhancing the domestic rice supply has become an urgent policy issue in Ghana.

The question is why Ghanaian farmers do not increase rice production to benefit from the high demand for rice. A general answer is that their productivity is so low that their product cannot compete with cheap imported rice from Asian countries as well as the US : only 10% of total rice field is irrigated in Ghana, and most of the remaining is in rain-fed lowland ecology (Dalton and Guei [5]) ; the yields in irrigated field range from 4.0 to 6.0 t/ha, while those in rain-fed lowland fall between 1.5 and 2.0 t/ha (Kranjac-Berisavljevic' [11]). Hence, it is obvious that rice supply cannot be increased due to the limitation of irrigated field.

However, looking at the forest zone where the rainfall level is high, rice productivity in rain-fed lowland is not so low : according to the authors' own survey, average yield is 2.8 t/ha with modern varieties and 1.7 t/ha with traditional varieties in the Kumasi area, central Ghana (unpublished preliminary data). Not only because this relatively high yield, but also other factors make the Kumasi area potentially advantageous to produce rice in rain-fed lowland. First, Kumasi is the second largest city in Ghana with a population of more than one million according to the 2000 census (Ghana Statistical Service [7]). Hence rice demand should be growing fast due to urbanization as noted above. Second, Kumasi is an inland city located 250 km away from the coastal capital, Accra. This location could provide an advantage to locally produced rice over the imports because of the transportation cost. Third, based on our own observation as well as farmers' estimation, there are huge areas of lowlands that are not currently used for cultivation in the Kumasi area. Therefore, a significant expansion of lowland rice area is possible.

Now, a more specific question is why farmers in the Kumasi area do not increase the rice supply to the Kumasi market in spite of such favorable conditions. There should be multiple problems in local rice production. Among them, this paper focuses on technical efficiency of rice milling because a high milling cost is considered to be one of the factors that discourage local rice production under the competition with imported rice.1) For example, according to our own survey in the Kumasi area, the milling fee that a producer pays to a miller, on average, accounts for 6.8% of the milled rice price at which the producer sells the milled rice to traders. But it is about 3.8% in Japan.2)

Millers are one of the key players in the Ghana's rice market. Figure 1 shows the distribution system of local rice in the Kumasi area.3) After hand threshing, rice producers transport the paddy to millers.4) The millers mill the paddy and charge a milling fee to the producers, depending on the amount (i.e. volume) of milled rice produced. Then, the producers sell the milled rice to traders who come to the millers to purchase it. Unlike other places where rice millers are also rice traders, the role of millers in the Kumasi area is only as an intermediary : each miller announces prices of milled rice that is traded at his/her mill, and based on the announced prices, transactions between producers and traders take place. Frequently producers leave milled rice at the miller when the rice is not sold immediately after milling, and the miller sells it to traders in place of the producers. Even in this case, millers do not take direct ownership of the rice.

Not only acting as an intermediary, some millers provide rice producers with funds on a loan basis under the agreement that they will bring their paddy to the millers after harvest, and surprisingly, in most cases millers charge no interest. In our preliminary survey, we focused on this issue and tried to identify hidden costs imposed on the farmers in lieu of interest, for example, fixed purchase price agreement or obliged purchase of inputs at higher prices than the market prices (e. g. Boucher [2] in Peru and Crow and Murshid [4] in Bangladesh), but in the case of Ghana, we could not find anything except for the paddy-delivery agreement. Also note that since this agreement does not specify the timing of the delivery, farmers are not obliged to mill their paddy when the milled rice price is not favorable to them. Moreover, there is no kinship or friendship between the millers who lend and the farmers who borrow. Nevertheless, there seems to be no mechanism for millers to enforce the paddy-delivery agreement, and hence the millers' bargaining position is considered to be weak in this interlinkage transaction.

From the producers' point of view, interest-free loans or loans with low interest are obviously the benefit from this transaction, but there is no conceivable cost incurred from the transaction insofar as all the millers are equal since farmers will mill their paddy at a miller anyway. In this case, millers are considered to be using the subsidized loan to attract producers at the cost of the opportunity of their funds. Hence, we hypothesize that the millers who lend money to farmers increase the operating rate of their milling machines and hence are more efficient than those who do not lend money.[5] This tendency will be more significant if the capacity of milling machine is large and/or if the competition for getting producers is high. On the other hand, however, the transportation cost incurred to the producers should differ depending on the location of the miller, and therefore each producer will choose the closest miller if all the millers are the same except for the location. A farmer will select a miller whose location is not the closest only if the benefit is more than the additional transportation cost. Hence, millers who are located in unfavorable places may be more likely to use interest-free loans to increase the number of customers. That is, the hypothesis postulated above is valid even if millers are heterogeneous. This paper is devoted to test these hypotheses so that we will identify the constraints in the local rice system. To this end, we estimate a short-run cost function for the millers and evaluate the impact of money-lending on the operating rate as well as on profitability.[6]

The remainder of this paper is organized as follows : Section 2 describes the survey of millers in the Kumasi area and provides descriptive statistics. Section 3 presents theoretical and empirical models for efficiency analysis of rice millers. Then, in section 4, data used for the estimation of a Probit model and a cost function are explained. And section 5 is for the results of the analyses and discussion. Finally, section 6 concludes this paper.

2. Rice Miller Survey

1) Study site

We identify 61 millers within a 60 km radius of the Kumasi area, in the center of which the city of Kumasi is situated. They are the millers to whom rice producers in our 19 sample villages bring their paddy for milling (see Tachibana, Shinagawa, and Sakurai [16] for the selection of the 19 villages). Out of the 61 millers, 23 millers are located within the urban area of the city of Kumasi and the remaining 38 millers are scattered over 25 satellite towns or villages around the city. Through the interview of mill owners and mill operators, information on mill and milling activity in 2001 as well as characteristics of the owners and the operators were ob-

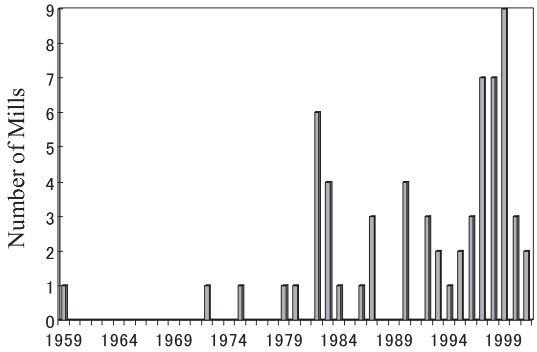

Figure 2. Establishment of mills by year

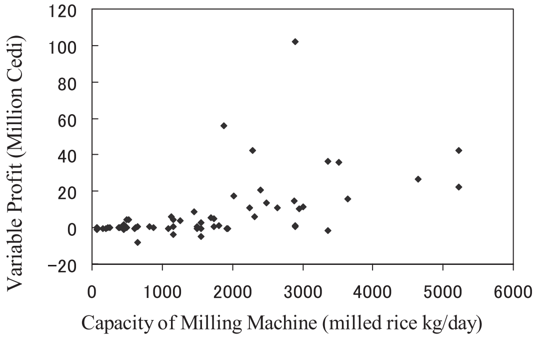

Figure 3. Relationship between variable profit and capacity of milling machine

tained.

2) Characteristics of rice millers

Most of the rice millers surveyed started their business in recent years : 44% of the mills were established during the last five years. Figure 2 shows the number of mills established in each year. The recent sharp increase in the number of mills reflects the recent surge of demand for rice in Ghana, and also implies that the milling industry is profitable.

There is a large variation in milling capacity : maximum amount of milled rice production per day ranges from 75 to 5, 220 kg ; and the mean is 1, 637 kg/day and the standard deviation is 1, 321 kg/day. Relatively large-scale mills use one-pass type milling machines made in Japan or China, and the other mills use Engelberg type milling machines made in India or Ghana. Most of the one-pass type milling machines are driven by electric motors, while the Engelberg type milling machines are driven by diesel engines. Figure 3 shows the relationship between milling capacity and variable profit per kg of milled rice produced.[7] The correlation coefficient of the milling capacity and the variable profit is found to be 0. 445, suggesting that larger-scale mills tend to get a higher profit from milled rice production.[8, 9]

With respect to interlinkage, 27 millers provided loans to farmers in 2001 under the agreement that they would deliver their paddy to the millers. Only 6 of these millers imposed an interest and the average interest rate was 82% per year, which is close to the market interest rate in informal credit markets available to the farmers. The other 21 millers did not impose any interest on loans to farmers.

Table 1 compares average economic characteristics of the millers who lent money and those who did not. These results suggest that money-lending millers show on average higher production, lower unit variable cost, higher unit variable profit, higher labor input, and higher capital input than non-lending millers. But milling fee and wage rate are not different between the two types of millers (not shown in the table).

3. Model

The cost minimization problem of a miller is expressed as follows :

$$\text{min.} \quad C^T = w_L L + w_V V + w_K K \qquad (1)$$
$$\text{s. t.} \quad Y = f\ (L, V, K, Y_P), \qquad (2)$$

where Y is milled rice production, L is the labor input, V is the input for machine operation such as fuel, K is the capital input, and Y_P is paddy. Input prices for L, V, and K are given by w_L, w_V, and w_K. Paddy is transformed into milled rice by the production function specified in (2). Hence, technically Y_P is one of the inputs. However, as explained earlier, millers do not purchase paddy but rather sell milling service to producers, where the milling fee depends only on the volume of milled rice produced. Therefore, Y_P is considered to be exogenously given to the miller and the cost of paddy is not included in the miller's cost minimization problem.

If the capital input K is a fixed factor and the milled rice production Y is proportional to the paddy input Y_P, the variable cost function is defined as follows :

Table 1. Money lending and economic variables

Type of millers (number)	Production of milled rice*** (1,000 kg/year)	Unit variable cost** (cedi/kg/year)	Unit variable profit* (cedi/kg/year)	Labor hours** (hours/year)	Capital price index***, a) (1 : average)
Lending (27)	116.6	123.3	90.5	2,471	1.504
Non-lending (34)	32.3	229.7	6.0	1,100	0.582

Note : The means are different at the level of 1% significance (***), 5% significance (**), and 10% significance (*), respectively.
a) This is the weighted average of the user cost price of machine and the depreciation cost of workshop. The values are standardized so that the mean becomes unity.

$$C^V = C^V(Y, w_L, w_V, K) \tag{3}$$

and the short-run cost function is defined as follows :

$$C^S = C^V(Y, w_L, w_V, K) + w_K K. \tag{4}$$

The definition of capacity utilization as an index of the operating rate, the model for controlling self-selection bias, and an empirical short-run cost function are presented in the next sections.

1) Capacity utilization

This paper uses "capacity utilization," derived by Morrison [13], as the index for the operating rate.[10] Capacity utilization[11] is based on the production in the steady state of the fixed factor as explained below. If total cost is evaluated by the shadow price of the fixed factor, the cost, C^{SD}, or the shadow cost is derived from the variable cost function as follows :

$$C^{SD} = C^V - \frac{\partial C^V}{\partial K}K. \tag{5}$$

On the other hand, if total cost is evaluated by the market price of the fixed factor, the total cost, C^T, is given by the following equation :

$$C^T = C^V + w_K K. \tag{6}$$

Capacity utilization, CU, is defined as the ratio of the shadow cost and the total cost as follows :

$$CU = \frac{C^{SD}}{C^T}. \tag{7}$$

This means that capacity utilization is unity when $C^{SD}=C^T$, i.e., at the optimal where the shadow price of the fixed factor $(-\partial C^V/\partial K)$ is equalized to the market price of it (w_K), and that capacity utilization is less than unity when $C^{SD}<C^T$, i.e., the level of the fixed factor is above the optimal and hence the capacity is not fully (optimally) used. The capacity utilization defined above is used in this study as the index of the operating rate of milling machines.

2) Treatment of self-selection bias

In this paper, it will be examined if a miller operates his or her milling machine close to the optimum level by lending money to farmers. However, a miller's decision to lend money is endogenous ; that is, there is a possibility that an efficient miller is more likely to lend money to farmers rather than the money lending increasing millers' efficiency. Since we would like to examine the effect of millers' money lending on the efficiency, we need to eliminate the opposite causality, or so-called "self-selection bias," and therefore we apply the two-stage regression method presented by Carter [3].

If the short-run cost depends on money lending, a miller is assumed to behave according to the following relationship between money lending and the short-run cost :

$$C_N{}^S - C_L{}^S = d_{cs} > 0$$
$$\Rightarrow \text{The miller lends money to farmers,} \tag{8}$$
$$C_N{}^S - C_L{}^S = d_{cs} < 0$$
$$\Rightarrow \text{The miller does not lend money to farmers,} \tag{9}$$

where $C_L{}^S$ is the short-run cost when the miller lends money to farmers and $C_N{}^S$ is the short-run cost when the miller does not lend money to farmers. The difference of the costs, d_{CS}, is not observable, but instead, whether the miller lends money or not is observable. Hence, these two observable statuses of a miller are represented by a determinate variable, D, whose value is above zero when the miller lends money and equal to or less than zero when the miller does not lend money. If D can be explained by the vector of exogenous variables **X** as follows :

$$D = \mathbf{A'X} - u, \quad (10)$$

where **A** is the vector of parameters and u is unexplained residual, it leads to the following relationships :

$$u < \mathbf{A'X} \Rightarrow D > 0 :$$
The miller lends money to farmers, (11)
$$u \geq \mathbf{A'X} \Rightarrow D \leq 0 :$$
The miller does not lend money to farmers. (12)

On the other hand, since the short-run cost, C^S, is assumed to be affected by the status of money lending, the cost functions of the miller who lends money and that of the miller who does not lend money are given as follows respectively :

$$C_L{}^S = \mathbf{B}_L{}'\mathbf{Z} - v_L, \quad (13)$$
$$C_N{}^S = \mathbf{B}_N{}'\mathbf{Z} - v_N, \quad (14)$$

where **Z** is the vector of the explanatory variables of the short-run cost function given by (4), i. e., Y, w_L, w_V, and K, and $\mathbf{B}_L$ and $\mathbf{B}_N$ are the vectors of parameters of the short-run cost functions for the case of money lending and the case of non-lending respectively. If there is a self-selection bias, there will be correlations between the error terms in (10), (13), and (14), i. e., u, v_L, and v_N. Then, if there is a negative correlation between u and v_L, the short-run cost of money-lending miller is lower than the average whether the miller lends money or not. In other words, in this case, even if the short-run cost of the miller who lends money is low, it will not be the result of lending money. Therefore, in order to obtain the true effect of money lending by millers, we need to eliminate the self-selection bias in the following way.

Let us assume that the error terms, u, v_L, and v_N, follow tri-variate normal distribution. Then, the cost functions are written as follows :

$$E[C_L{}^S \mid D > 0] = \mathbf{B}_L'\mathbf{Z} - E[v_L \mid u < \mathbf{A'X}]$$
$$= \mathbf{B}_L'\mathbf{Z} + \sigma_L \frac{\phi(\mathbf{A'X})}{\Phi(\mathbf{A'X})} \quad (15)$$

$$E[C_N{}^S \mid D \leq 0] = \mathbf{B}_N'\mathbf{Z} - E[v_N \mid u \geq \mathbf{A'X}]$$
$$= \mathbf{B}_N'\mathbf{Z} - \sigma_N \frac{\phi(\mathbf{A'X})}{1-\Phi(\mathbf{A'X})} \quad (16)$$

where σ_L is the covariance of u and v_L, σ_N is the covariance of u and v_N, $\Phi(\cdot)$ is the cumulative distribution function, and $\phi(\cdot)$ is the probability density function. Now, the probability of loan provision is given by prob $(D>0)=\Phi(\mathrm{A'X})$ and that of no provision is given by prob$(D\leq 0)=1-\Phi(\mathrm{A'X})$.

Instead of estimating functions (15) and (16) separately, we estimate the following switching regression equation, which is obtained by the combination of (15) and (16) (Maddala [12]) :

$$E[C^S = E[C^S{}_L \mid D > 0]\mathrm{prob}(D > 0) + E[C^S{}_N \mid D \leq 0]\mathrm{prob}(D \leq 0)$$

$$= \left[\mathbf{B}_L'\mathbf{Z} + \sigma_L \frac{\phi(\mathbf{A'X})}{\Phi(\mathbf{A'X})}\right]\Phi(\mathbf{A'X}) + \left[\mathbf{B}_N'\mathbf{Z} - \sigma_N \frac{\phi(\mathbf{A'X})}{1-\Phi(\mathbf{A'X})}\right][1 - \Phi(\mathbf{A'X})]$$

$$= \mathbf{B}_L'\mathbf{Z}\Phi(\mathbf{A'X}) + \sigma_L\phi(\mathbf{A'X}) + \mathbf{B}_N'\mathbf{Z}[1-\Phi(\mathbf{A'X})] - \sigma_N\phi(\mathbf{A'X})$$
$$= \mathbf{B}_N'\mathbf{Z} + (\mathbf{B}_L' - \mathbf{B}_N')\mathbf{Z}\Phi(\mathbf{A'X}) + (\sigma_L - \sigma_N)\phi(\mathbf{A'X}), \quad (17)$$

To estimate equation (17), first, parameter **A** is obtained by estimating equation (10) in the Probit model, and $\Phi(\mathbf{A'X})$ and $\phi(\mathbf{A'X})$ of each miller are calculated by using the estimated parameters. Then, parameters $\mathbf{B'}_N$, $\mathbf{B'}_L-\mathbf{B'}_N$, and $\sigma_L-\sigma_N$ are obtained by estimating equation (17). $(\mathbf{B'}_L-\mathbf{B'}_N)\bar{\mathbf{Z}}$ is the average effect that shows the changes in the short-run cost when an average miller provides a loan to farmers, where $\bar{\mathbf{Z}}$ is the sample mean of **Z**. The differential effect, $\sigma_L-\sigma_N$, indicates a difference in the short-run cost by factors other than observable variables.

3) Empirical model

If the short-run cost function (4) is specified in a normalized quadratic function, the switching regression equation (17) can be written as follows :

$$E\left[\frac{C^S}{w^L}\right] = \alpha_{0N} + \alpha_{YN}Y + \alpha_{VN}\frac{w_V}{w_L} + \alpha_{KN}K + \frac{1}{2}\beta_{YYN}Y^2 + \frac{1}{2}\beta_{VVN}\left(\frac{w_V}{w_L}\right)^2 + \frac{1}{2}\beta_{KKN}K^2 + \beta_{YVN}Y\frac{w_V}{w_L} + \beta_{YKN}YK + \beta_{VKN}\frac{w_V}{w_L}K + \frac{w_K}{w_L}K + \Big[(\alpha_{0L} - \alpha_{0N}) + (\alpha_{YL} - \alpha_{YN})Y$$

$$+ (\alpha_{VL} - \alpha_{VN})\frac{w_V}{w_L} + (\alpha_{KL} - \alpha_{KN})K$$
$$+ \frac{1}{2}(\beta_{YYL} - \beta_{YYN})Y^2$$
$$+ \frac{1}{2}(\beta_{VVL} - \beta_{VVN})\left(\frac{w_V}{w_L}\right)^2$$
$$+ \frac{1}{2}(\beta_{KKL} - \beta_{KKN})K^2$$
$$+ (\beta_{YVL} - \beta_{YVN})Y\frac{w_V}{w_L}$$
$$+ (\beta_{YKL} - \beta_{YKN})YK$$
$$+ (\beta_{VKL} - \beta_{VKN})\frac{w_V}{w_L}K\Big]\Phi(\mathbf{A'X})$$
$$+ (\sigma_L - \sigma_N)\phi(\mathbf{A'X}). \quad (18)$$

Applying Shephard ' s lemma to equation (18), the following conditional input demand function of machine operation can be derived :

$$E[V] = E\left[\frac{\partial C^S}{\partial w^V}\right] = E\left[\frac{\partial(C^S/w_L)}{\partial(w^V/w_L)}\right] = \alpha_{VN} + \beta_{VVN}\frac{w_V}{w_L}$$
$$+ \beta_{YVN}Y + \beta_{VKN}K$$
$$+ \Big[(\alpha_{VL} - \alpha_{VN}) + (\beta_{VVL} - \beta_{VVN})\frac{w_V}{w_L}$$
$$+ (\beta_{YVL} - \beta_{YVN})Y + (\beta_{VKL} - \beta_{VKN})K\Big]$$
$$\Phi(\mathbf{A'X}). \quad (19)$$

From the linear homogeneous condition of the prices and the short-run cost, the following conditional input demand function of labor is obtained :

$$E[L] = E\left[\frac{\partial C^S}{\partial w_L}\right] = E\left[\frac{C^S}{w_L}\right]$$
$$- E\left[\frac{\partial C^S}{\partial w_V}\frac{w_V}{w_L}\right] - E\left[\frac{\partial C^S}{\partial w_K}\frac{w_K}{w_L}\right]$$
$$= \alpha_{0N} + \alpha_{YN}Y + \alpha_{KN}K + \frac{1}{2}\beta_{YYN}Y^2$$
$$- \frac{1}{2}\beta_{VVN}\left(\frac{w_V}{w_L}\right)^2 + \frac{1}{2}\beta_{KKN}K^2 + \beta_{YKN}YK$$
$$+ [(\alpha_{0L} - \alpha_{0N}) + (\alpha_{YL} - \alpha_{YN})Y$$
$$+ (\alpha_{KL} - \alpha_{KN})K + \frac{1}{2}(\beta_{YYL} - \beta_{YYN})Y^2$$
$$- \frac{1}{2}(\beta_{VVL} - \beta_{VVN})\left(\frac{w_V}{w_L}\right)^2$$
$$+ \frac{1}{2}(\beta_{KKL} - \beta_{KKN})K^2$$
$$+ (\beta_{YKL} - \beta_{YKN})YK\Big]\Phi(\mathbf{A'X})$$
$$+ (\sigma_L - \sigma_N)\phi(\mathbf{A'X}). \quad (20)$$

Parameters of the short-run cost function (18) are obtained by the system estimation of equations (18), (19), and (20).

By differentiating the variable cost function in equation (18) with respect to capital input K and multiplying by the wage rate w_L, the shadow value of capital is given as follows :

$$E\left[-\frac{\partial C^V}{\partial K}\right] = E\left[-\frac{\partial(C^V/w_L)}{\partial K}w_L\right]$$
$$= -(\alpha_{KN}w_L + \beta_{KKN}Kw_L$$
$$+ \beta_{YKN}Yw_L + \beta_{VKN}w_V)$$
$$- [(\alpha_{KL} - \alpha_{KN})w_L$$
$$+ (\beta_{KKL} - \beta_{KKN})Kw_L$$
$$+ (\beta_{YKL} - \beta_{YKN})Yw_L$$
$$+ (\beta_{VKL} - \beta_{VKN})w_V]\Phi(\mathbf{A'X}) \quad (21)$$

$$E\left[-\frac{\partial C^V}{\partial K} \mid D > 0\right] = -(\alpha_{KL}w_L + \beta_{KKL}Kw_L + \beta_{YKL}Yw_L + \beta_{VKL}w_V) \quad (22)$$

$$E\left[-\frac{\partial C^V}{\partial K} \mid D \leq 0\right] = -(\alpha_{KN}w_L + \beta_{KKN}Kw_L + \beta_{YKN}Yw_L + \beta_{VKN}w_V) \quad (23)$$

By substituting parameters and average values of variables into equation (21), the shadow value of capital is calculated, and the shadow cost, i. e., the total cost evaluated by the shadow value, is obtained by substituting the shadow value of capital into equation (5). Then, the shadow value and the total cost give the capacity utilization as defined in equation (7). Two cases will be compared : one in which millers lend money, i. e., the value for $\Phi(\mathbf{A'X})$ is unity : and the other in which millers do not lend money, i. e., the value for $\Phi(\mathbf{A'X})$ is zero.

4. Data

1) Price and quantity of capital

In order to estimate the cost function and to obtain capacity utilization, we need to have reasonable estimates for the price of capital, w_K, as well as quantity of capital utilized, K. For the price of capital, we use a capital price index. This is the weighted average of the user cost price of milling machine and workshop. On the other hand, a capital quantity index is used as the quantity of capital, which is calculated as the total depreciation cost over the capital price index.

The user cost price of milling machine and workshop, p_{ku}, is calculated by using the straight-line method as follows :

$$p_{ku} = p_{kp}(r + D_r), \tag{24}$$

where p_{kp} is the acquisition value, r is the interest rate in the agricultural market in Ghana in 2001, i. e., 0. 44, and D_r is the depreciation rate. The straight-line depreciation rate D_r is the reciprocal number of the durable period : the durable period of a milling machine is estimated from the number of years already in operation and the expected number of years still to be in use ; and the durable period of a workshop is assumed to be 25 years uniformly.

The depreciation cost of milling machine and workshop is also calculated using the straight-line method. For the calculation, it is assumed that the salvage value, p_{ks}, of milling machine and workshop accounts for 10% of the acquisition value. Then, the depreciation cost, DC, is obtained by the following equation :

$$DC = (p_{kp} - p_{ks})D_r. \tag{25}$$

The acquisition value p_{kp} of a milling machine is deflated by the consumer price index which is year 2000 base and the only available deflator in Ghana, and that of a workshop is estimated by the miller assuming that it is constructed now.[12)]

2) Price and quantity of variable inputs

Labor input is the number of workers employed in rice milling and its price is their wage rate. The price index of machine operation input (i. e., non-labor variable input) is calculated by the weighted average of prices of fuel, electricity, oil, and replacement parts for the milling machine. Cost shares of these inputs are used as the weights. The quantity index of machine operation input is the total cost over the price index.

5. Estimated Parameters

Table 2 shows the results of the estimation of equation (10) by Probit. The results show that the millers who provide rice producers with funds on a loan basis tend to have the following characteristics : 1) having a large milling machine ; 2) located in the city of Kumasi ; 3) engaged in milling for a long period of time ; and 4) relatively young in age.

These results can be interpreted as follows. First, millers who have a large milling machine are likely to lend money to farmers, probably because such millers have more available funds, but also because such millers need to collect more paddy to increase their operation rate, which is consistent with the hypothesis. Second, the positive effect of the location in the city of Kumasi may be explained by two factors : (1) competition among millers is severe in Kumasi as there are many millers within a small area ; and (2) traffic congestion in Kumasi imposes higher transportation costs including the opportunity costs of time to producers. Both of them are consistent with the hypothesis.
Third, a longer experience in milling can be advantageous for millers to gather information about producers and markets, which enables millers to make loan agreements that may not be enforceable. Fourth, younger entrepreneurs may be more willing to expand their business by engaging in non-traditional transactions.

Next, the system of short-run cost function (18), conditional input demand function of machine operation (19) and labor (20) is estimated simultaneously by using the predicted values for probability density and cumulative distribution obtained from the first-stage Probit regression.[13)] Table 3 shows the result of the system estimation.

By substituting these parameters and the mean values of the variables into equations (22) and (23), the shadow value of capital is obtained and then the shadow cost, i. e., the total cost evaluated by the shadow value, is calculated. The ratio of the shadow cost to the total cost corresponds to the capacity utilization as defined by equation (7). Table 4 compares the costs and the capacity utilization between the millers who lend money and those who do not. These results indicate that if an average miller lends money to farmers, the capacity utilization will increase by 24%, and the total cost of operation will decrease 17%. Hence, the main hypothesis of this paper is supported empirically. The cost reduction by the increase of operating rate is 14. 84 cedi/kg of milled rice, which is equivalent to 1, 024*10^3 cedi for an average miller. On the other hand, a miller provides 3, 829*10^3 cedi of interest-free loan to farmers on average,

Table 2. Determinants of money lending

Variables	Estimates	t-value
Intercept	0.9169	0.8860
Location (1 : Kumasi city, 0 : outside the city)	0.9452	2.2399**
Experience in rice related job (1 : milling in other places ; 0 : otherwise)	0.9340	1.2525
Age of mill owner	−0.0353	−2.1123**
Age of operator	−0.0224	−1.1315
Number of years since establishment	0.0413	1.7380*
Capacity of milling machine (milled rice kg/day)	0.0049	2.4613**
Floor area of workshop (m²)	−0.0379	−0.9001

Note : The Probit model is used for estimation. The number of observations (i.e. millers) is 61. Fraction of correct prediction is 0.7541. ** significantce at 5% level and * significantce at 10% level.

Table 3. Results of the estimation of the sort-run cost function

Parameters	Estimates	t-value
α_{0N}	5.2696	1.699
α_{YN}	0.02016	0.454
α_{VN}	−1631.2	−0.428
α_{KN}	−0.08742	−3.601
α_{AKN}	−0.001430	−0.316
β_{YYN}	−0.0007491	−0.370
β_{VVN}	−316.78	−0.107
β_{KKN}	−0.00004642	1.823
β_{YVN}	66.350	2.241
β_{YKN}	−0.00004905	−0.255
β_{VKN}	1.1433	0.386
α_{0L}	2.1941	0.310
α_{YL}	−0.02272	−0.056
α_{VL}	3048.4	1.431
α_{KL}	−0.06022	−0.798
β_{YYL}	0.0009459	0.528
β_{VVL}	−3241.9	−1.302
β_{KKL}	0.00002586	0.380
β_{YVL}	17.116	1.624
β_{YKL}	−0.00003026	−0.143
β_{VKL}	−0.4886	−0.249
$\sigma_L - \sigma_N$	0.7385	0.266

while the interest rate for the saving at banks is 20% per year. Hence, the opportunity cost of the fund is 766*10^3 cedi. It means that a miller gains 258*10^3 cedi from the increase of the operating rate of the milling machine by lending money to farmers.

Figure 4 shows the relationship between the average variable cost and the capital input for money-lending and non-lending millers re-

Table 4. Costs and capacity utilization

	Means of estimates	
	Non-lending	Lending
Unit variable cost (cedi/kg)	66.811	51.971
Unit total cost (cedi/kg)	86.600	71.760
Capacity utilization	0.683	0.925

spectively obtained by simulations of an average miller using the estimated parameters. The figure shows that if a miller does not lend money to farmers, the average cost of operation will increase as the capital input level increases, and that if a miller lends money to farmers, the cost will decrease as the capital input level increases because the milling machine is more efficiently utilized. The two average cost curves cross at a quite small capital input level. The result suggests that ensuring sufficient supply of paddy to fully utilize existing milling machine is crucial for the management of rice mill.

6. Concluding Remarks

We examined the effect of millers' subsidized loans on milling efficiency by estimating the short-run cost function. The estimation results suggest that the operation rate of milling machine should increase by 24% by lending money to farmers with an unenforceable harvest-delivery agreement. Furthermore, in this case, the total cost of operation should decrease by 17% compared to the case where no loan is provided, and consequently the miller's efficiency is enhanced. Thus, with respect to the interlinkage transaction, we can conclude as follows : (1)

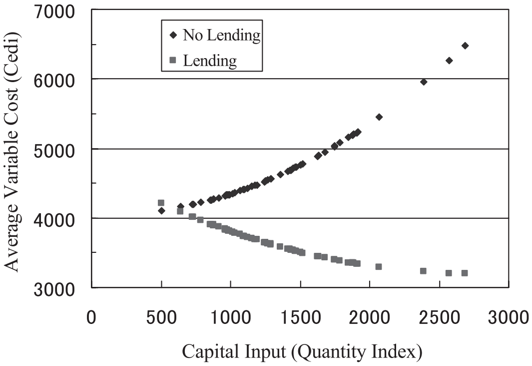

Figure 4. Simulation results for capital input and average variable cost

millers increase the operation rate by providing subsidized loans to farmers ; (2) as a result millers enhance the efficiency ; and (3) farmers can obtain loans with low or no interest. It is reasonably inferred that millers increase the amount of paddy collection by lending money to farmers to realize (1) and (2).

As discussed in Introduction, millers' efficiency is considered to be one of the crucial factors to develop the local rice market system, and therefore the findings of this paper implie that the emergence of this interlinkage transaction enhances the efficiency of rice market in the Kumasi area. However, as also noted previously, the emergence of this kind of interlinkage itself indicates the imperfection in the rice market. Thus, based on the findings, the following policy implications can be drawn. First, although our data suggest that larger-scale milling machines are more technically efficient, the millers cannot fully utilize the capacity without paying the cost to ensure supplies. It means that in order to improve the milling efficiency, policies that reduce the cost of paddy collection should be considered, for example, the improvement of transportation and storage systems for paddy. Second, although we did not investigate the benefit that farmers gain from this interlinkage, we believe that they enjoy the subsidized loans as long as their crop does not fail. However, the emergence of this informal money lending implies that the credit market is not functioning well.

Large-scale milling machines should be promoted in Ghana, because they will enhance competitiveness of locally produced rice thanks to their superior technical efficiency as shown in this paper. However, the analyses of this paper imply that the efficiency will not improve the rice market system as much as expected without complementary policies to increase the operation rate.

1) Another problem in the rice milling industry is that physical quality of milled rice (such as the contamination of broken rice and foreign matter) is lower than that of imported rice. Since the quality depends on milling technology (Unnevehr, Duff, and Juliano [18]), technology innovation will be necessary in order for local rice to compete with imported rice. Please refer to Sakurai and Furuya [15] for the quality issue.
2) Producers' brown rice price is about 16,000 yen per 60 kg and the husking fee is 600 yen per 60 kg of brown rice on average in Japan, hence the husking cost accounts for 3.8%. Although this figure does not include the cost of polishing, we consider that this is an appropriate estimation to compare with the Ghanaian case because rice milling in Ghana is a single process of husking and polishing at the same time.
3) According to farmers in the Kumasi area, there used to be paddy traders who came to villages to purchase paddy and carry it to rice millers. But these days, such traders have disappeared and farmers themselves bring paddy to rice millers, paying the transportation costs.
4) Rice is not a traditional crop in the Kumasi area, and is grown in lowlands mainly as a cash crop today. Hence, farmers do not mill paddy by hand even for self-consumption but always use millers.
5) This paper focuses on the effect of the millers' money lending on milling efficiency because it is a significant observation in the study site. But it does not necessarily mean that it is the only way to enhance the efficiency. One possible way is a reduction of the milling fee to attract more customers. According to our observation, however, milling fees do not differ between money-lending millers and non-lending millers, and hence we do not think that they use the milling fee to increase the operation rate. Although we cannot show concrete evidence, our impression from the discussion with millers is that they want to keep large farmers who will bring a big amount of paddy by providing loans rather than attracting many small farmers by reducing the milling fee.
6) While it would be interesting to know if this

interlinkage between producers and millers is Pareto improving, this paper deals with only millers. But since producers are willing to be engaged in this interlinkage, we can naturally assume that the subsidized loans increase producers' welfare even though there are some additional costs from transportation. Therefore, we can infer that this interlinkage is Pareto improving, if the hypothesis concerning millers is supported.

7) Since all the millers except three millers own only one milling machine, milling capacity of each mill is equivalent to that of milling machine of the miller. As for the three millers who own two milling machines, the average capacity of the two milling machines are use in Figure 3, but the depreciation costs are the summation of the two machines.

8) Timmer [17] considers capital cost and concludes that small-scale millers are more efficient in Java. But the capacity of the small-scale millers in Java is about 1, 800 kg of milled rice per day, which is medium to large-scale in our study site.

9) Variable profit is defined as the total cost minus variable cost in this paper.

10) There are two other indices for the operating rate. One is the ratio of actual operating hours observed and maximum possible operating hours. The usage of this index is very popular, but the definition of "maximum possible" is ambiguous. For example, it is not realistic to operate a machine for 24 hours at its maximum speed. The other index is the ratio of actual operating hours observed and maximum operating hours in the past. Although this index is easy to calculate, it is quite sensitive to the addition of data, that is, the index depends on the maximum operating hours in the past which may be changing over time. Therefore, we do not use these indices in our study.

11) If the fixed factor is only capital, the number will be called capital utilization ; otherwise, it will be called capacity utilization.

12) There are some missing values for the acquisition value of milling machine and workshop. In the case of milling machines, the value of a similar one in terms of the number of years in operation and milling capacity is substituted. And in the case of workshop, the value of another one of close size is substituted.

13) The system is estimated by the full information maximum likelihood (FIML) estimation and signs of parameters of the first power term of the capital, i. e., α_{KN} and α_{KL} are restricted to be negative in functions.

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