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The influence of share tenancy contracts on the cost efficiency of rice production during the Bangladeshi wet season

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Abstract

This study investigated how crop-share tenancy affects the efficiency of rice production during the wet season in Bangladesh. In doing so, we estimated a stochastic frontier cost function to assess cost inefficiency, and test the hypothesis that share tenancy has a negative effect on cost efficiency of rice production. Through applying the "maximum likelihood-based methodology, the endogeneity problem in stochastic frontier model," was properly handled, which is the substantial contribution of the present study. This study also contributes not only toward determining the inefficiency of share tenancy contracts during the wet season for rice, also to the development of controversial debates on the efficiency of share tenancy in Bangladesh. The analysis implied that if the land tenure system is other than crop-share tenancy, cost efficiency of wet season rice production could be improved by 19 percent. This surprising result suggests that a policy to induce a tenurial system other than crop-share tenancy in changing tenancy practices would produce comparative advantage of rice production during the wet season in Bangladesh.

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1. Introduction

Bangladesh is almost self-sufficient in the domestic production of rice to achieve food security. However, foreign donors and international aid agencies have criticized certain Bangladeshi policies, including fertilizer subsidies and the price support program, owing to their ineffectiveness in achieving target levels of sustainable food security (Ahmed *et al.* 2009).

Islam (2016) estimated the domestic resource cost and cost inefficiency of rice production during the wet season. He found that the wet-season rice production of Bangladesh has no comparative advantage at import substitution, but improvements in cost efficiency could re-establish comparative advantage using a domestic resource cost (DRC) indicator. As such, exploring and redressing problems associated with the cost efficiency of rice production during the wet season represent important policy challenges.

According to the Bangladesh Integrated Household Survey (BIHS) administered by the International Food Policy Research Institute (IFPRI), roughly one-third of farmers who grow wet-season rice are tenant farmers, 90% of whom participate in crop-share tenancy contracts. Until the mid-1980s, the predominant tenancy arrangement was sharecropping, under which the harvest and certain input costs were shared by the landowner and tenants. This was the prominent tenancy arrangement in Bangladesh (Hossain, 1977). Over the last two decades, the terms and conditions of tenancy have undergone significant change (Hossain *et al.* 2014). Over time, fixed-rent tenancy has gained prominence due to the spread of cultivation of modern varieties (MVs) (Hossain *et al.* 2003). The Agricultural Census of 2008 indicates a substantial decline/change in the importance of share tenancy in favor of fixed-rent arrangement contracts (Hossain *et al.* 2014). Although the crop-share tenancy system has been changing and declining in use, it still dominates (Hossain *et al.* 2014). Most existing hypotheses on crop-share tenancy stipulate that the decision to engage in crop share tenancy is a rational one. Assuming that the economic (technical and allocative) inefficiency hypothesis of crop-share tenancy contracts is applicable to the Bangladeshi rice sector, the country's crop-share tenancy system might contribute to cost inefficiency in the production of rice during the wet season.

Nonetheless, there have been a number of debates regarding the efficiency of crop-share tenancy. Several empirical studies have failed to provide support for the allocative inefficiency hypothesis (Jacoby and Mansuri, 2009; Kassie and Holden, 2007; Otsuka *et al.* 1992; Sadoulet *et al.* 1997). By contrast, other studies have found evidence to support it (Bell, 1977; Laffont and Matoussi, 1995; Otsuka *et al.* 1992; Shaban, 1987). Empirical evidence concerning the allocative efficiency of crop-share tenancy specifically in Bangladesh is also mixed (Ahmed, 2012; Hossain, 2001; Otsuka *et al.* 1992; Taslim, 1992; Taslim and Ahmed, 1992).

With regard to the technical efficiency of crop-share tenancy, there are only a few analytical studies. Ahmed *et al.* (2002) estimated the economic efficiency and determinants of inefficiency of an alternative land-tenure system in Ethiopia using a stochastic frontier production function. The authors found that sharecropping and borrowing are less technically efficient than owner cultivation or a fixed rental market with an imperfect or absent input market. Laha and Kuri (2013) attempted to measure the level of technical efficiency under an alternative tenurial contract and its possible determinants in the agricultural sector in West Bengal, India, using a stochastic frontier production function. This study found that crop-share tenancy was less technically efficient than owner cultivation.

Each of the aforementioned studies considered only technical efficiency and not the endogeneity problem in their production frontier model. Endogeneity problems can arise in stochastic frontier models for two major reasons. First, the determinants of the cost frontier and the two-sided error term can be correlated. Second, the inefficiency term and two-sided error term can be correlated, or in particular, the determinants of the inefficiency can cause this correlation. Endogeneity in a stochastic frontier model would lead to inconsistent parameter estimates, and hence, it would need to be addressed properly (Karakaplan and Kutlu 2013, 2017a). However, the current study considers both technical and allocative efficiency, as well as endogeneity problems in the stochastic cost frontier model developed by Kutlu (2010).

In the empirical literature, there is growing concern about the endogeneity issue in stochastic frontier models but dealing with this issue is relatively more complicated in the stochastic frontier analysis than in standard regression models. For example, considering that maximum likelihood estimation is probably the most widely used method in the stochastic frontier literature, conventional maximum likelihood estimation of an endogenous stochastic frontier model would yield inconsistent parameter estimates. This would necessitate a proper instrumental variable (IV) approach in order to deal with the endogeneity issue. In the maximum likelihood framework, a standard way to deal with this problem is to model the joint distribution of the dependent variable and endogenous variables and then, to maximize the corresponding log-likelihood of this distribution. However, due to the special nature of the error term in stochastic frontier models, this is a relatively more difficult task compared to the standard maximum likelihood models involving only two-sided error terms.

Only a few studies have attempted to solve endogeneity problems in stochastic frontier models. Millimet and Collier (2008), for example, used economic modeling to investigate the endogeneity of the education market structure. They used a two-stage approach to examine the spillover effects of neighboring district efficiencies. Their first stage is a distribution-free stochastic frontier model in the style of Schmidt and Sickles (1984). In their second stage, they modeled the efficiency of a public school district with a spatial reaction function in which efficiency is assumed to be a linear function of the weighted average of neighboring school districts, exogenous district characteristics, and an error term. The coefficient of the weighted average of efficiencies captures the spillover effect, which turns out to be positive. This study concluded that the public school districts became more efficient as the neighboring school districts became more efficient. Note that their first stage requires panel data and is not applicable to a cross-sectional dataset. If instead a maximum likelihood-based stochastic frontier model were used in the first stage, the parameter estimates would be inconsistent. Therefore, the type of application by Millimet and Collier (2008) is not suitable to address the endogeneity in our study properly.

Guan *et al.* (2009) followed a two-step estimation methodology to handle the endogenous frontier regressors. In the first step of their methodology, they obtained consistent estimates of the frontier parameters using generalized method of moments (GMM), and in the second step, they used the residuals from the first stage as the dependent variable to obtain the maximum likelihood-stochastic frontier estimates. Since the second step of this procedure used standard stochastic frontier estimators, the efficiency estimates would not be consistent when the two-sided and one-sided error terms were correlated. Kutlu (2010) attempted to address the endogeneity problem in the maximum likelihood estimation context. He described a model that aimed to solve the endogeneity problem due to the correlation between the regressors and two-sided error term. Mutter *et al.* (2013) explained why omitting the variable causing the endogeneity is not a viable solution. Tran and Tsionas (2013) proposed a GMM version of

Kutlu (2010). The assumptions of these models are not sufficient to handle the endogeneity due to one-sided and two-sided error terms. Shee and Stefanou (2014) extended the methodological approach in Levinsohn and Petrin (2003) to overcome the problem of endogenous input choice due to production shocks that can be predicted by the productive unit but unknown to the econometrician. Unlike our study, however, Shee and Stefanou (2014) did not consider the endogeneity problem due to the correlation of a one-sided error term and a two-sided error term. Finally, Gronberg *et al.* (2015) attempted to solve the problem using pseudo-IV methodologies.

Karakaplan and Kutlu (2013, 2017a) introduced a maximum likelihood-based methodology to handle the endogeneity problems in stochastic frontier models (we discuss this in more detail in the methodology section). They carried out Monte Carlo simulations to analyze the small sample performance of their estimator in a variety of endogeneity scenarios and found that when there is endogeneity in the model, their estimator outperforms the model that assumes exogeneity. In addition, they presented a way to test endogeneity with their methodology (Karakaplan, 2017).

The key goal of the present study is to investigate whether crop-share tenancy contracts affect the economic efficiency of rice production during the wet season in Bangladesh. Hence, we use the IFPRI data to apply an endogenous Cobb–Douglas stochastic frontier cost function model and to estimate the effects by tenancy type on the cost inefficiency of wet season rice production.

To explore these issues, we organize this paper as follows. In the next Section 2, we explain the theoretical and empirical framework concerning the frontier cost function model. In Section 3, we present the results derived from the model and interpret those results. Finally, in Section 4, we offer some concluding remarks and policy recommendations.

2. Methodology

2.1. Data and analytical method

In this section, we utilized data collected from 6,500 rural households for the 2011–2012 Bangladesh Integrated Household Survey (BIHS). Although the BIHS contains data of several types, we used only plot-level data of rice farming households during the wet season in Bangladesh.

Previous research on Bangladeshi rice producers' efficiency has generally used two approaches: the frontier function approach (Alam, 2006; Rahman, 2003; Rahman *et al.,* 2013) and data envelopment analysis (Coelli *et al.,* 2002; Wadud and White, 2000). We used the Cobb–Douglas stochastic frontier cost function approach (Aigner *et al.,* 1977; Coelli *et al.,* 2005; Kumbhakar and Lovell, 2000) to calculate the cost inefficiency of rice-producing farms in Bangladesh, to address the endogeneity problem.

2.2. An Econometric Approach

Karakaplan and Kutlu (2013, 2017a) considered a stochastic frontier method with endogenous explanatory variables in the frontier and inefficiency functions.

$$y_i = x'_{1i}\beta + v_i - su_i \qquad (1)$$
$$x_i = Z_i\delta + \epsilon_i$$

$$\begin{bmatrix} \tilde{\epsilon}_i \\ v_i \end{bmatrix} \equiv \begin{bmatrix} \Omega^{-1/2} \epsilon_i \\ v_i \end{bmatrix} \sim \mathrm{N}\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} I_p & \sigma_{vi}\rho \\ \sigma_{vi}\rho' & \sigma_{vi}^2 \end{bmatrix} \right)$$

S= - 1 for cost functions

where y_i is a scalar representing cost; x_{1i} is a vector of exogenous and endogenous variables; x_i is a p × 1 vector of all endogenous variables (excluding y_i), $Z_i = I_p \otimes z_i'$ and z_i are a $q \times 1$ vector of all exogenous variables; v_i and ϵ_i are two-sided error terms; and $u_i \geq 0$ is a one-sided error term capturing inefficiency. In their framework, a variable is endogenous if it is not independent from v_i. Ω is the variance–covariance matrix if ϵ_i; σ_{vi}^2 is the variance of v_i; and ρ is a vector representing the correlation between $\tilde{\epsilon}_i$ and v_i.

Karakaplan and Kutlu (2013, 2017a) presented the following estimator, which outperforms standard estimators that ignore the endogeneity in the model:

$$\ln L(\theta) = \ln L_{y|x}\ (\theta) + \ln L_x\ (\theta) \qquad (2)$$

where

$$\ln L_{y|x}\ (\theta) = \sum_{i=1}^{n} \{ ln2 - \frac{1}{2}\ ln\sigma_i^2 + ln\emptyset \left(\frac{e_i}{\sigma_i}\right) + \ln \phi\ (\frac{-s\lambda_i e_i}{\sigma_i})\}$$

$$= \sum_{i=1}^{n} \{\frac{\ln\left(\frac{2}{\pi}\right) - ln\sigma_i^2 - (\frac{e_i^2}{\sigma_i^2})}{2} + ln\phi\ (\frac{-s\lambda_i e_i}{\sigma_i})\}$$

$$\ln L_x\ (\theta) = \sum_{i=1}^{n} (\frac{-p \times ln2\pi - \ln(|\Omega|) - \epsilon_i'\Omega^{-1}\epsilon_i}{2})$$

$$e_i = y_i - x_{1i}'\beta - \frac{\sigma_{wi}}{\sigma_{cw}}\eta'(x_i - Z_i\delta)$$

$$\epsilon_i = x_i - Z_i\delta$$

$$\sigma_i^2 = \sigma_{wi}^2 + \sigma_{ui}^2$$

$$\lambda_i = \frac{\sigma_{ui}}{\sigma_{wi}}$$

where $\theta = (\beta', \eta', \varphi', \delta')'$ is the vector of coefficients; y = $(y_1, y_2, \ldots\ldots\ldots, y_n)'$ is the vector of dependent variables; $x = (x_1', x_2', \ldots\ldots., x_n')'$ is the matrix of endogenous variables in the model; ∅ and ϕ denote the standard normal probability density function and the cumulative distribution function; $u_i = \sigma_u(x_{2i}; \varphi_u)u_i^*; x_{2i}$ is a vector of exogenous and endogenous variables; $u_i^* \sim N^+(0,1)$ is a producer-specific random component; $\sigma_{ui}^2 = \exp(x_{2i}'\varphi_u)$; $w_i = \sigma_{vi}\sqrt{1-\rho'\rho}\tilde{w}_i = \sigma_{wi}\tilde{w}_i$; $\sigma_{wi} = \sigma_{cw}\sigma_w(.;\ \varphi_w)$; $\sigma_{wi}^2 = \exp(x_{3i}'\varphi_w)$; $\sigma_{cw} > 0$ is a function of the constant term; $\sigma_{cw}^2 = \exp(\varphi_{cw})$, where φ_{cw} is the coefficient of the constant term for $x_{3i}'\varphi_w$; $\tilde{w}_i \sim N(0,1)$; x_{3i} is a vector of exogenous and endogenous variables that can share the same variables with x_{1i} and x_{2i}; Ω is the variance–covariance matrix if ϵ_i; σ_{vi}^2 is the variance of v_i; and ρ is a vector representing the correlation between $\tilde{\epsilon}_i$ and v_i. The control function approach is a base assumption in this model. For details about the assumptions and how the estimation is derived, refer to Karakaplan and Kutlu (2013, 2017a).

Moreover, Karakaplan and Kutlu (2013; 2017a) provide the following formula to predict the efficiency, $EFF_i = \exp(-u_i)$:

$$E\{exp(-su_i)|e_i\}^s = \{\frac{1-\Phi(s\sigma_i^* - \mu_i^*/\sigma_i^*)}{1-\Phi(-\mu_i^*/\sigma_i^*)} exp\,(-s\mu_i^* + \frac{1}{2}\sigma_i^{*2})\}^s \quad (3)$$

$$\mu_i^* = \frac{-se_i\sigma_{ui}^2}{\sigma_i^2}$$

$$\sigma_i^{*2} = \frac{\sigma_{wi}^2\sigma_{ui}^2}{\sigma_i^2}$$

Finally, Karakaplan and Kutlu (2013, 2017a) proposed a test for endogeneity. In this test, the joint significance of the components of the η term is checked. If the joint significance of the components is not rejected, then correction for endogeneity is not necessary, and the model can be fit by traditional frontier models. However, if the components of the η term are jointly significant, then there is endogeneity in the model, and a correction through (2) would be necessary (Karakaplan, 2017; Karakaplan and Kutlu, 2017a).

2.3. Empirical model

We ran a translog cost frontier model but could not obtain the expected results. Thus, we opted to use the Cobb–Douglas cost frontier model proposed by Aigner *et al.* (1977) to estimate a Cobb–Douglas stochastic frontier cost function. We specified the model using double-log form and wrote it by normalization with the urea fertilizer price as:

$$lnC_i/P_{3i} = \beta_0 + \sum_{j=1}^{10}\beta_j \ln(\frac{P_{ji}}{P_{3i}}) + \beta_{11}lnQ_i + (V_i + U_i) \quad (4)$$

where C_i is the total production cost (Tk), P_{1i} is the seed price (Tk/kg), P_{2i} is the mechanical ploughing price (Tk/ha), P_{3i} is the urea fertilizer price (Tk/kg), P_{4i} is the triple super phosphate (TSP) fertilizer price (Tk/kg), P_{5i} is the mureat of potash (MOP) fertilizer price (Tk/kg), P_{6i} is the irrigation cost (Tk/ha), P_{7i} is the pesticide and insecticide price (Tk/ha), P_{8i} is the manure price (Tk/ha), P_{9i} is the labor price (Tk/worker-days), P_{10i} is the land rent cost (Tk/ha), and Q_i is production (Kg). B_0 *to* β_{11} are the parameters to be estimated, V_i *is* a statistical disturbance term, and U_i represents farmer-specific characteristics related to cost inefficiency. In the cost frontier model, the condition of linearity of homogeneous degree 1 should be satisfied, that is, $\sum_{j=1}^{9}\beta_j = 1$.

We chose the Cobb–Douglas specification method based on the fact that it requires the function to be self-dual, as in the case of the cost function. Thus, our analysis is based on this assumption.

To examine the determinants of cost inefficiency, we used the following regression equation:

$$U_i = U_i^* \times \sigma_u\,(S', \varphi) \quad (5)$$

where S' includes other variables that potentially explain wet season rice farmers' cost inefficiency and φ is its parameter to be estimated. This alternative specification implies a different notation.

$$U_i = \delta_0 + \delta_1 S_{1i} + \delta_2 S_{2i} + \delta_3 S_{3i} + \delta_4 S_{4i} + \delta_5 S_{5i} + \tau_i \quad (6)$$

where U_i is the cost inefficiency scores, S_{1i} is the age of the respondent (years), S_{2i} is the crop-share tenancy dummy (D = 1 if a crop-share tenant, and 0 otherwise), S_{3i} is education (years of schooling), S_{4i} is farm size (ha) and S_{5i} is a household head gender dummy (D=1 if the household head is male, and 0 otherwise). δ_0 *to* δ_5 are inefficiency parameters and τ_i is an error term. We included these socioeconomic variables in the model to determine their influence on the cost inefficiency of Bangladeshi rice farms.

Within the stochastic cost frontier model, there might be an endogeneity problem related to the crop-share tenancy dummy variable, because the crop-share tenancy variable is self-selected and might be endogenous to u_i, as well as the farm size variable, as the farm size (ha) variable is the operated land, and includes rental land. To resolve this endogeneity problem, we used the method presented by Karakaplan and Kutlu (2013; 2017a). For this purpose, we tested the joint significance of the components of η term. If the components were jointly significant, then it could be concluded that there is endogeneity in the model used in this study. If the components were not jointly significant, this would indicate that the correction term is not necessary, and that efficiency can be estimated with the traditional frontier model. The significance of the k^{th} component of η indicates that x_{ik} (the k^{th} component of x_i) and v_i are correlated. Hence, a particular variable of interest is endogenous if the corresponding component of η is significant. Essentially, this endogeneity test relies on reasoning observed in the standard Durbin–Wu–Hausman test for endogeneity. Finally, note that when $\eta = 0$, the standard errors from the second stage of the two-step estimator are valid. Moreover, asymptotically, they are as efficient as the one-step version. Hence, the F-test can be applied to test the endogeneity of relevant variables, by testing the joint significance of the components of η. This model is a particularly attractive option, as its use enables us to test the endogeneity of the inefficiency term u_i (see also Karakaplan 2015). The estimated endogeneity test result indicates that there is an endogeneity problem in the stochastic cost frontier model used in this study with respect to the farm size variable only (Table II).

To address the endogeneity problem, we used household's total asset value[1] variable as an instrument for crop-share tenancy, and an adult household size[2] variable as an instrument for endogenous farm size. Currently, there is no straightforward way to statistically test instrument exogeneity[3]. However, the prediction equations[4] are available in the Appendix. Looking at the prediction equations, all excluded instruments are statistically significant at the 1% level. Their z-values are reasonable. In particular, adult household size's z-values are 14.31 in the farm size prediction equation and 5.82 in the crop-share tenancy prediction equation. The household total asset value variable's z-values are 17.89 in the farm size prediction equation and -5.48 in the crop-share tenancy prediction equation. For a single endogenous variable, a commonly used rule of thumb to justify the strength of an instrument is to have its z-value greater than $\sqrt{10} \cong 3.16$ (or F-value > 10). In our case, all relevant z-values are in line with this rule of thumb (Karakaplan and Kutlu 2017b).

3. Results and Discussion

The summary statistics are presented in Table I. On an average, it costs 51,804.974 Taka (Bangladeshi currency) to produce 3,507.75 kilograms of rice per hectare of land. The relatively low standard deviation associated with this mean cost indicates that most rice farmers produce similar amounts of rice during the wet season. Of the various factors that influence the production of rice, labor cost accounts for the highest variance (45.15%), followed by land rent

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[1] Household asset value influences the choice of crop-share tenancy. Thus, household asset value is correlated with crop-share tenancy.

[2] Farm size enlargement depends on the number of adult family members in the household. Thus, adult household size is correlated with farm size.

[3] At present, there is no formal statistical test for instrument exogeneity.

[4] As explained by Karakaplan and Kutlu (2017a), estimations with this model are performed in a single stage. Thus, to avoid confusion, the authors did not use the name "first-stage statistics" and, instead, called them prediction equations.

(28.86%), mechanical ploughing costs (9.50%), chemical fertilizer costs (7.26%), and seed costs (6.63%). Table I also includes the socio-economic characteristics of the survey's respondents. On average, respondents were 46.55 years old, with about 4.16 years of education. Crop-share tenancy was present in about 30% of the observations.

Rice production in the wet season is dependent on rain. Thus, rice is a crop with low-yield potential. Crop output (i.e., harvested rice) tends to be equally divided (50:50) during the wet season, despite the fact that the crop-share tenant (*bargadar*) generally provides all the inputs needed for producing rice (Bode *et al.* 2002). Furthermore, according to officers with knowledge of the realities of land tenancy, crop-share tenants tend to bear all input costs during the wet season, despite sharing the output equally.[5]

Table I. Descriptive statistics for rice production during the wet season in Bangladesh

Items	Mean	S.D.	% of total cost
Total production cost (Tk/ha)	51804.974	12805.25	
Seed cost (Tk/ha)	3430.87	1524.96	6.63
Mechanical ploughing cost (Tk/ha)	4919.62	1180.24	9.50
Urea fertilizer cost (Tk/ha)	3080.97	631.45	5.96
TSP fertilizer cost (Tk/ha)	456.62	970.02	0.88
MOP fertilizer cost (Tk/ha)	224.96	504.65	0.43
Irrigation cost (Tk/ha)	908.20	1111.29	1.75
Pesticide and insecticide cost (Tk/ha)	373.184	768.75	0.72
Manure cost (Tk/ha)	67.96	265.71	0.13
Labor cost (Tk/ha)	23391.22	11540.23	45.15
Land rent cost (Tk/ha)	14951.37	1836.434	28.86
Production (Kg/ha)	3507.75	1019.28	-
Age of respondent (years)	46.55	12.60	-
Education (years of schooling)	4.16	4.34	-
Farm size (ha)	0.605	0.463	-
Gender dummy (head male=1, 0 otherwise)	0.961	0.179	
Crop-share tenancy dummy (D=1 if crop-share tenant, and 0 otherwise)	0.3040	0.460	-
Owner operator	0.6663	-	-
Fixed rent land	0.0118	-	-
Mortgage in land	0.0179	-	-

Source: BIHS data, 2011–2012.
Note: 1) Official exchange rate: US$ 1 = 71.17 Bangladeshi taka.

The results of the Cobb–Douglas endogenous and exogenous stochastic frontier cost function estimation are presented in Table II. After eliminating the endogeneity problem, the empirical results indicate that the coefficients of production, seed price, TSP fertilizer price, MOP fertilizer price, labor price, land rent cost, mechanical plowing price, irrigation cost, pesticide and insecticide price, and manure price are positive and significant, implying that an increase in the magnitudes of these variables would result in a corresponding increase of the cost of producing wet season rice. In our study, we used mechanical plowing price, pesticide and insecticide price, and manure price per ha as a proxy for their input prices. These results are

[5] This information was provided to the authors by field-level agriculture officers and rice researchers from the Ministry of Agriculture. They include Md. Motlubur Rahman, agriculture officer, Dinajpur sadar upazila, Dinajpur, A.K.M. Monjure Maula, agriculture officer, Poba upazila, Rajshahi from the Department of Agricultural Extension, Md. Mahabubur Rahman Dewan, Head, Kushtia Regional Station, Kushtia, Dr. Md. Ibrahim, Head, Satkhira Regional Station, Satkhira, and Dr. Md. Rafiqul Islam, Head, Rajshahi Regional Station, Rajshahi from the Bangladesh Rice Research Institute, Bangladesh.

consistent with past theory and a priori expectations. After addressing the endogeneity problems, the mean cost efficiency increased slightly. The efficiency analysis indicates that the mean cost efficiency of rice-producing farms in Bangladesh was 0.8142 during the wet season. However, we tested a homogeneous of degree one condition. Our test result shows that the hypothesis is accepted and follows a homogeneous of degree one condition in the endogenous stochastic cost frontier model.

Table II. Frontier cost function estimates in Bangladeshi wet season after normalization by urea fertilizer price (Tk/kg)

Variables	Exogenous model		Endogenous model	
	Estimate	S.E.	Estimate	S.E.
lnSeed price (Tk/kg)	0.050***	(0.015)	0.050***	(0.015)
lnMech. plowing price (Tk/ha)	0.149***	(0.013)	0.151***	(0.013)
lnTSP fertilizer price (Tk/kg)	0.039***	(0.014)	0.036***	(0.014)
lnMOP fertilizer price (Tk/kg)	0.043**	(0.017)	0.041**	(0.018)
lnIrrigation cost (Tk/ha)	0.012***	(0.002)	0.012***	(0.002)
lnPesticide and insecticide price (Tk/ha)	0.031***	(0.002)	0.033***	(0.002)
lnManure price (Tk/ha)	0.012***	(0.004)	0.013***	(0.004)
lnLabor price (Tk/man-days)	0.234***	(0.022)	0.241***	(0.022)
lnLand rent cost (Tk/ha)	0.461***	(0.022)	0.454***	(0.022)
lnProduction (Kg)	0.132***	(0.011)	0.131***	(0.011)
Constant	1.840***	(0.150)	2.008***	(0.150)
Mean cost efficiency	0.8113		0.8142	
Dep. Var.: (ln Sigma u-square (σ_u^2))				
Constant	−3.674***	(0.271)	−3.630***	(0.273)
Respondent age (years)	0.001^{NS}	(0.004)	−0.003^{NS}	(0.006)
Crop-share tenancy dummy	0.311***	(0.066)	0.239**	(0.098)
Education (years of schooling)	−0.006^{NS}	(0.007)	−0.024*	(0.014)
Farm size (ha)	0.071^{NS}	(0.067)	0.090***	(0.029)
Household head gender dummy (male=1)	−0.032^{NS}	(0.038)	−0.056^{NS}	(0.036)
Dep. Var.: (ln Sigma v-square (σ_v^2))				
Constant	−3.882***	(0.081)	-	-
Dep. Var.: (ln Sigma w-square (σ_w^2))				
Constant	-	-	−3.861***	(0.081)
Log likelihood	508.06		−3723.18	
Endogeneity test:				
η_1 (crop-share tenancy dummy)	-		0.024	(0.011)
η_2 (farm size)	-		−0.072***	(0.012)
η endogeneity test:	-		χ^2 (2) = 36.76 (p = 0.000)	
Homogeneity test:				
Ho : $\sum_{j=1}^{9} \beta_j = 1$	Chi2 (1) = 1.31^{NS} (p=0.2529)		Chi2 (1) = 1.69^{NS} (p=0.1930)	
N	3,740		3,740	

Source: BIHS data, 2011–2012.
Notes: ***p < 0.01, **p < 0.05, *p < 0.1. NS = Not significant. Tk = Taka (Bangladeshi currency). Ha= Hectare. kg = Kilogram.

Table II summarizes the results of the inefficiency analysis. The crop-share tenancy dummy variable coefficient is positively significant, indicating that if the crop-share tenurial arrangement for wet season rice production were to increase, then the inefficiency associated with rice production would also increase. Considered together, these findings suggest that crop-share tenancy is not an efficient means of rice production during the wet season in Bangladesh.

Several case studies report significantly lower rice yields per hectare of land under share tenancy vis-à-vis owner cultivation (Bhuiyan, 1987; Mandal, 1980; Shahid and Herdt, 1982; Talukder, 1980). The household head gender dummy is negative and insignificant. In the present context, this finding is consistent with Rahman (2010). However, education (year of schooling) has a negative and significant influence on cost inefficiency. This result is consistent with Asadullah and Rahman (2009).

4. Conclusion and policy recommendations

In this study, we have investigated how crop-share tenancy affects the efficiency of rice production during the wet season in Bangladesh. To do so, we leveraged a more advanced analytical method of endogenous Cobb–Douglas stochastic cost frontier function compared to previous studies. The current study contributes not only toward determining the inefficiency of share tenancy contracts during the wet season for rice, but also to the development of controversial debates on the efficiency of share tenancy in Bangladesh. The results of the estimation suggest that if the land tenure system is not crop-share tenancy, cost efficiency of wet season rice production is improved by 19 percent. This surprising result suggests that a policy to induce a tenurial system other than crop-share tenancy in changing tenancy practices would produce comparative advantage of rice production during the wet season in Bangladesh. However, most existing hypotheses on crop-share tenancy stipulate that the decision to engage in crop share tenancy is a rational one. Therefore, the government cannot force tenants and landowners to change the tenancy form. However, if the risk-sharing hypothesis[6] reflects the reality of the wet season in Bangladesh, then we propose the following policy recommendations: (i) to increase job opportunities for poor tenant farmers in non-farm sectors, (ii) to offer some micro insurance to the village poor, including crop-share tenancy farmers, (iii) to develop and disseminate different stress-tolerant crop varieties to address the unstable production caused by climate change, and (iv) to increase crop diversification in the dry season, so that annual income can be increased and farmers can reduce crop-share tenancy contracts.

[6] According to the risk-sharing hypothesis, a poor tenant who wants to avert production risk prefers a share-tenancy contract to a fixed-rent contract, as he or she can share risk with the landowner.

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Appendix: Prediction equation (first-stage) estimates for endogenous variables.

Dependent variable: Farm size	Coefficient	S.E.	Z values
Constant	0.0943^{NS}	0.2943520	0.32
Adult household size (Instrument)	0.0727***	0.0050771	14.31
Total asset value (Instrument)	0.000068***	0.0000038	17.89
lnSeed price	-0.0206NS	0.0297872	-0.69
lnMech. plowing price	-0.0636***	0.0245273	-2.59
lnTSP fertilizer price	-0.0333^{NS}	0.0272929	-1.22
lnMOP fertilizer price	0.0219^{NS}	0.0348487	0.63
lnIrrigation cost	-0.0018^{NS}	0.0030170	-0.59
lnPesticide and insecticide price	-0.0338***	0.0039554	-8.56
lnManure price	-0.0233***	0.0072960	-3.19
lnLabor wage	-0.0207^{NS}	0.0430666	-0.48
lnLand rent cost	0.0560^{NS}	0.0419635	1.33
lnProduction	-0.0072^{NS}	0.0228516	-0.32
Respondent age (years)	0.0015***	0.0005688	2.61
Education (years of schooling)	0.0140***	0.00161	8.70
Household head gender dummy (male=1)	0.2203***	0.0379595	5.80
Observations		3740	

Note: Asterisks indicate significance at the 1% (***) level and NS= Not significant

Dependent variable: Crop-share tenancy dummy	Coefficient	S.E.	Z values
Constant	0.5328^{NS}	0.3191582	1.67
Adult household size (Instrument)	0.03237***	0.0055593	5.82
Total asset value (Instrument)	-0.000023***	0.0000042	-5.48
lnSeed price	-0.0436^{NS}	0.0322950	-1.35
lnMech. plowing price	-0.0118^{NS}	0.0265926	-0.44
lnTSP fertilizer price	0.0310^{NS}	0.0295936	1.05
lnMOP fertilizer price	0.0392^{NS}	0.0377825	1.04
lnIrrigation cost	-0.0160***	0.0032716	-4.89
lnPesticide and insecticide price	0.0061^{NS}	0.0042888	1.42
lnManure price	0.0087^{NS}	0.0079104	1.10
lnLabor wage	0.1968***	0.0466939	4.22
lnLand rent cost	-0.0927**	0.0454964	-2.04
lnProduction	-0.0111^{NS}	0.0247758	-0.45
Respondent age (years)	-0.0025***	0.0006197	-4.06
Education (years of schooling)	-0.0166***	0.0017537	-9.45
Household head gender dummy (male=1)	0.1781***	0.0413485	4.31
Observations		3740	

Note: Asterisks indicate significance at the 1% (***) and 5% (**) levels and NS= Not significant