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Farm productivity and efficiency in rural Bangladesh:

The role of education revisited

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Farm productivity and efficiency in rural Bangladesh: The role of education revisited

Abstract

This paper reassesses the debate over the role of education in farm production in Bangladesh using a large dataset on rice producing households from 141 villages. Average and stochastic production frontier functions are estimated to ascertain the effect of education on productivity and efficiency. A full set of proxies for farm education stock variables are incorporated to investigate the 'internal' as well as 'external' returns to education. The external effect is investigated in the context of rural neighbourhoods. Our analysis reveals that in addition to raising rice productivity and boosting potential output, household education significantly reduces production inefficiencies. However, we are unable to find any evidence of the externality benefit of schooling – neighbour's education does not matter in farm production. We discuss the implication of these findings for rural education programmes in Bangladesh.

Key words: Agriculture, returns to education, stochastic production frontier, Bangladesh.

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1. Introduction

Acknowledging the importance of education in the labour market success of individuals, governments all around the world routinely advocate further investment in education. However, the majority of the population in developing countries depend on agriculture for their livelihood. Knowledge of market returns to education is less useful as a guide to increase educational investment in such agrarian societies. In theory, education is expected to improve productivity in all spheres of activities including agriculture. A positive return to

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education arises, for example, because educated farmers are better managers, adopt more modern farm inputs and prefer risky (high-return) production technologies. Despite such common beliefs regarding the benefits of schooling in farm activities, there is weak empirical evidence to advocate educational investment in agrarian societies.

The existing studies on the determinants of farm productivity and efficiency are largely inconclusive on the question of a positive return to education. For instance, Ali and Flinn (1989), Young and Deng (1999), and Seyoum et al., (1998) demonstrate the significant role of farmers' education in raising farming efficiency in Pakistan Punjab, China and Ethiopia respectively. On the other hand, Battese and Coelli (1995) and Llewellyn and Williams (1996) fail to identify any significant impact of farmers' education on farming efficiency in India and Java-Indonesia respectively. Hasnah et al. (2004) rather report a significantly negative impact of education on technical efficiency in West Sumatra-Indonesia. Nevertheless, there is some agreement in the literature that education significantly influences the adoption of technological innovations in agriculture (for example, Hossain et al., 1990; Weir and Knight, 2004; Asfaw and Admassie, 2004).

One reason for the differences in findings across studies lies in the cross-country variation in the nature of technology underlying agricultural production. An education effect is more likely to prevail in economies where farm production is modernizing as opposed to being traditional (Lockheed et al., 1980). Partly for this reason, studies using data from Asian countries tend to find a positive return to education in farm work while such effect is often lacking for Latin America and Africa (Philips, 1994). Similar to other countries in Asia, Bangladesh agriculture has undergone significant modernization following the 'green revolution' so that a positive return is also more likely for the Bangladesh data.

Surprisingly, the majority of studies on returns to education in farm production in Bangladesh fail to find any significant impact. For instance Deb (1995), Wadud and White

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(2000), Coelli et al. (2002) and Rahman (2004) did not find any significant effect of education on production efficiency. The authors attributed this finding to the fact that the education system in Bangladesh was not agriculturally orientated. The only study that reports a positive education effect on farm efficiency is Sharif and Dar (1996). However, findings of this study are difficult to generalise. The authors use a highly purposive sample which comprises of only 100 households selected from only one village in Bangladesh, and therefore, limit scope for generalisation.

In stark contrast to the current controversy surrounding the returns to education in Bangladesh's agricultural sector, there exists a burgeoning literature documenting the positive impact of education on the welfare of individuals and households in rural areas. An additional year of schooling increases labour market earnings by 5.7% in rural areas (Asadullah, forthcoming). Education also affects household consumption in rural areas. Using household data for the year 1995-96, Wodon (2000) finds that a household with both the head and the spouse having completed secondary school have an expected per capita consumption 60% higher than that of a similar household with an illiterate head and spouse. Most importantly, educated heads in rural areas are less likely to experience intergenerational poverty traps (Asadullah, 2006). In sum, education matters for economic success in rural Bangladesh. With the majority of rural households relying on farm activities for their livelihoods, one would *a priori* expect a positive impact of education on farm production.

A potential explanation for the failure of earlier research on the farm production function using Bangladeshi data to detect an 'education effect' lies in the methodology. Most of the earlier literature employed empirical models that were underspecified in two ways. First, almost all the studies focusing on internal returns to education preclude the possibility of centralized decision making in farm work (Yang, 1998). Consequently, the farm education stock is modelled as either the level of education of the household head or that of an average

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householder. Given that much of the farm work in agrarian societies is household (instead of individual) specific, such proxies may contain little information and, therefore, undermine the actual returns to education. Earlier research on Bangladesh by Deb (1995), Wadud and White (2000) and Rahman (2004) used farmer education as the sole measure of farm human capital. Second, the existing studies of farm production in Bangladesh and other developing countries exclusively centre on internal returns to schooling, ruling out the presence of any externality effect of education in improving productivity and efficiency. Three exceptions are Appleton and Balihuta (1996), Knight et al. (2003) and Weir and Knight (forthcoming).

Educational externalities arise as uneducated farmers learn from the superior production choices of other educated farmers in the neighbourhood. A similar externality arises when educated farmers are early innovators and are copied by those with less schooling (Knight et al., 2003). Apart from such social learning, an externality effect could also capture the possibility that uneducated farmers simply access the basic literacy and numeracy skills of their educated neighbours. Partly motivated by such arguments, Appleton and Balihuta (1996) examine the effect of mean level of education of other farmers in the same enumeration area on agricultural productivity in Uganda. They conclude that the externality benefit of education is sizable: the level of primary schooling of neighbouring farmers enhances productivity of the sample farmer. Weir and Knight (forthcoming), on the other hand, explore the external effect on productivity and efficiency using Ethiopian data. Their analysis reveals the significant externality benefit of education on productivity, but no such benefit is found in improving technical efficiency. They conclude that education externalities affect adoption and spread of innovations, thereby, raising productivity in farming.

Similar education externalities could prevail in farm production in Bangladesh. In the dense and closely-knit society of rural Bangladesh characterized by an extremely low level of literacy, the educational externality could serve as an important non-market determinant of

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farm-level productivity and efficiency. The scope for social interactions is widened by the way the agricultural production system in Bangladesh is organized, particularly, rice production in irrigated areas. Although farmers commonly possess small parcels of land in various locations, each irrigated block of land used for rice production (known as the command area) hosts a large number of farmers who are effectively neighbours and have to grow rice at the same time, if not using the same varieties. Such social proximity could improve knowledge-sharing and generate positive externalities of education of individuals.

Given the perceived importance of education in raising productivity and efficiency in agriculture, the present study is set out to examine two important issues in Bangladesh. First, we test for the internal effect of education. That is, whether the education level of a household raises farm productivity and efficiency. Second, we test for the presence of any external effect of education. We examine whether, in addition to household's own level of education, farm production is positively influenced by education of others in the residential neighbourhood. We do so by estimating the average production function as well as stochastic production frontier for rice cultivation in Bangladesh with controls for a host of farm inputs, education stock measures and villages-level determinants.

There are three major findings of our study. First, we find a positive effect of the education level of a household on farm production. Such internal returns to education arise through raising productivity, boosting potential output and reducing technical inefficiency. On the other hand, there is no evidence of an external effect of education on agricultural productivity. Neighbour's education does not matter in reducing production inefficiency either. Lastly, farm production is centralized so that even if the household head is uneducated, productivity and potential output are augmented so long as an educated adult co-resides in the same household. The remainder of the paper is organized as follows: section 2 describes the study area, the methodology, the empirical specifications of the production

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functions and the data; section 3 discusses the results; and section 4 concludes and draws policy implications.

2. Methodology

2.1 The study area

The farm households in this study belong to the Matlab thana[1] of the Chandpur district in Bangladesh. The Matlab thana comprises of a total of 141 villages. Being criss-crossed by rivers, these villages remain sufficiently remote and well outside urban influence. Actual travel time between the capital city (Dhaka) and the Matlab thana is 5 hours. Therefore, villagers primarily rely on the local economy for their livelihoods. Agriculture constitutes the key source of earnings. Although in recent years, the study area has experienced some expansion of non-farm activities, the farm sector remains the single largest employer of the rural workforce; primary economic activities are agriculture and fishing. Rice is the principal crop in Matlab villages, in terms of its share in total cereal production. Being located in a low-lying area, the study villages are frequently flooded, particularly during the monsoon season. Hence, although unsuitable for homestead use, the flood-plain land of Matlab villages is ideal for rice cultivation. The distribution of land, however, is not homogenous. About 50 per cent of the households are landless. Increases in population growth and density have also led to a reduction in average farm size, as well as increased fragmentation of landholdings. Therefore, most of the farmers in the study area now operate as either smallholders (typically owning less than 1 ha of land) or as sharecroppers.

Similar to other regions of Bangladesh, the majority of adults in the study villages never went to school. This is despite a substantial labour market return to education in the Matlab villages – one year of additional schooling leads to a 7 per cent gain in average earnings for wage workers (Berman and Stepanyan, 2003). This is similar to the overall wage

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returns to education in Bangladesh (Asadullah, forthcoming). However, no information on returns to farm work is available. Therefore, it remains to be seen, whether similar positive returns to education prevail in farm work in the Matlab villages.

Lastly, a key aspect of social organization in rural Bangladesh is the clustering of households in a unique residential neighbourhood commonly known as 'bari'. Households belonging to the same neighbourhood maintain significant social ties, which may have implications for farm production activities. Farmers might learn by observing the (superior) input choices of their educated neighbours who are engaged in farm work. Alternatively, educated neighbours could simply share their literacy knowledge with uneducated farmers. Evidence of the economic returns enjoyed by illiterate yet proximate (to literate householder) individuals is well-documented for Bangladeshi households (Basu et al., 2002). Our study extends these ideas in the context of farm production.

2.2 Modelling internal and external benefits of education on productivity and efficiency

Application of an average production function as well as the stochastic production frontier framework is appropriate to analyze the internal and external benefits of education on productivity and efficiency. In this study, productivity is defined as the ratio of observed output to observed input use with respect to a given level of production technology. On the other hand, the term efficiency refers to technical efficiency in farm production, defined as the ratio of the observed to maximum feasible output, with respect to a given level of production technology and the observed input use (an output oriented measure).

Two basic hypotheses are tested (distinguishing between internal and external effects): whether education affects (a) productivity as well as placement of the frontier (that is, influences production as well as increases potential output), and (b) deviations from the frontier (that is, affects production efficiency). The internal benefit of education on

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productivity and placement of the frontier is captured by specifying level of education at the household as an independent variable in the average production function and in the stochastic production frontier function respectively. The external benefit of education on productivity and placement of the frontier is captured by specifying neighbourhood level of education as an independent variable in these models.

In this study, the degree of inefficiency in production is measured by the deviation from the frontier. Therefore, the internal and external effects of education on efficiency are examined by placing household-level and neighbourhood-level education in the 'inefficiency effects model' in addition to variables representing farm and village characteristics to explain the underlying causes of deviation from the frontier.

A stochastic production frontier approach, developed by Aigner et al. (1977), is utilized in this study. In this framework, the output (rice production) is treated as a stochastic production process and is defined as:

$$Q_i = f(x_i; A).\exp(\varepsilon_i) \qquad (1)$$

where $x \in R_+$ is a (*NxJ*) matrix of the inputs, $Q \in R_+$ is the (*Nx1*) vector of output, f(.) is the best practice production frontier, *A* is the technology parameter vector, and *i* subscripts individual farm households, respectively.

The error term ε_i is composed of two components:

$$\varepsilon_i = v_i - u_i \qquad (1a)$$

where the component v_is are assumed to be identically and independently distributed $\{N(0, \sigma_v^2)\}$ two sided random errors, independent of the u_is, representing random shocks, such as exogenous factors, measurement errors, omitted explanatory variables, and statistical noise. The u_is are non-negative random variables, associated with inefficiency in production, which are assumed to be independently distributed as truncations at 0 of the normal

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distribution with mean $\mu_i = \delta_0 + \sum_d \delta_d W_{di}$ and variance $\sigma_u^2 (| N(\mu_i, \sigma_u^2) |)$, where W_{di} is the dth explanatory variable associated with inefficiencies of farm i and δ_0 and δ_d are the unknown parameters.

The production efficiency of the farm i is defined as:

$$EFF_i = E[\exp(-u_i) \mid \varepsilon_i] = E\left[\exp(-\delta_0 - \sum_{d=1}^{D} \delta_d W_{di}) \mid \varepsilon_i\right] \qquad (2)$$

where E is the expectation operator. This is achieved by obtaining the expressions for the conditional expectation u_i upon the observed value of ε_i. The method of maximum likelihood is used to estimate the unknown parameters, with the stochastic production frontier and the inefficiency effects functions estimated simultaneously. The likelihood function is expressed in terms of the variance parameters, $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma^2$ (Battese and Coelli, 1995).

2.3 The empirical model

The production structure of rice farmers in Bangladesh is specified using a single-output, multi-input Cobb-Douglas production function and a stochastic production frontier, respectively. The general form of the production function and the stochastic production frontier for the ith farm is expressed, respectively as:

$$\ln Q_i = \beta_0 + \sum_{j=1}^{J} \beta_j \ln X_{ji} + \sum_{k=1}^{K} \alpha_k \ln E_{ki} + \sum_{m=1}^{M} \phi_m D_{mi} + \varepsilon_i \qquad (3)$$

$$\ln Q_i = \beta_0 + \sum_{j=1}^{J} \beta_j \ln X_{ji} + \sum_{k=1}^{K} \alpha_k \ln E_{ki} + \sum_{m=1}^{M} \phi_m D_{mi} + v_i - u_i \qquad (4)$$

where

$$u_i = \delta_0 + \sum_{d=1}^{D} \delta_d W_{di} + \sum_{g=1}^{G} \tau_g E_{gi} + \omega_i \qquad (4a)$$

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where the dependent variable Q is the aggregate of rice output[2] produced (kg per farm) in all three seasons, 'Aus' (pre-monsoon), 'Aman' (monsoon) and 'Boro' (dry-winter); *Xs* are the inputs of land cultivated (ha), total value of all purchased inputs[3] (taka), total imputed value of all home supplied inputs[4] (taka), and value of farm-capital assets used in rice production (taka); *Es* are the variables representing the internal and external benefits of education; and *Ds* are the village dummies; ε is the standard two-sided random error in eq (3); v is the two-sided random error and u is the one-sided half-normal error in eq (4); and ln is the natural logarithm; *Ws* in eq. (4a) are the variables representing farm-specific characteristics to explain inefficiency and includes age of the farmer (years), tenurial status (1 if owner operator, 0 otherwise), irrigation facilities of the village (1 if have facility in the village, 0 otherwise), level of infrastructural development at the village[5] (number), non-agricultural income share[6] (proportion of total household income obtained from non-agricultural sources), and *Es* are variables representing internal and external effects of education; ω is the truncated random variable; α_k, β_0, β_j, φ_m, δ_0, δ_d and τ_g are the parameters to be estimated.

The internal benefit of education is measured by two variables: (a) the education level of the household head (completed years of schooling), and (b) the maximum level of education (completed years of schooling) of adult householders (aged 19 years and over)[7]. The external benefit of education is measured by the maximum years of schooling of adult neighbours[8]. Eight specifications were adopted using three types of education variables to examine the internal and external effects of education on farm productivity and efficiency. The productivity effects were analyzed by placing these variables in the production function as well as the stochastic production frontier, while the efficiency effects were analyzed by placing them in the inefficiency effects model.

Identification of neighbourhood externality as a causal effect is dubious if there are other determinants of farm productivity and efficiency that operate at the village level. If the

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omitted village determinants positively affect farm productivity and are positively correlated with our neighbourhood education measures, the estimate of the education externality is likely to be biased upwards. We rule out this possibility of upwardly biased estimate of education externality by fully controlling for village fixed effects. This strategy ensures that our estimates of external returns to education are at least not driven by unaccounted village level determinants (both observed and unobserved) of farm productivity. Nonetheless, we cannot rule out the possibility that a similar bias may prevail due to the omission of neighbourhood level unobserved correlates of farm productivity, so that our estimates of externalities are likely to be upwardly biased[9].

Lastly, exploring externality effects at bari (instead of village) level is appropriate as baris define the relevant social space in rural Bangladesh. The extant studies (for instance, Appleton and Balihuta, 1996) investigate the neighbourhood effect at the lowest administrative level which, in most cases, remains much broader than the social space relevant for farmers in rural areas. Appleton and Balihuta (1996) use the enumeration area to define a neighbourhood in Uganda, which on an average comprises of as many as 1000 households. It is not clear, a priori, how such administrative boundaries could capture the relevant social space for farmers. Geographical remoteness is likely to inhibit any economically meaningful social interaction. Weir and Knight (forthcoming) is the only study that overcomes this problem by focusing on lower-level neighbourhoods (defined in terms of household clusters instead of some arbitrary administrative boundary) within each survey site in their Ethiopian study. Baris in our study resembles these rural neighbourhoods in Ethiopia. Therefore, throughout this study, we compare and contrast our estimates of externalities with that reported in Weir and Knight (forthcoming).

2.4 Data

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Data for this study comes from the Matlab Health and Socio-economic Survey (MHSS). The survey was conducted in all the villages of the Matlab thana in the year 1996. The dataset provides a rich description of the agricultural and non-agricultural profiles of the sample households and their asset portfolios along with complete information on the personal characteristics of the householders. The sample households were selected in two steps. First, a random sample of 2678 residential neighbourhoods – baris – was selected from the entire Matlab thana. Second, households were sampled. If a bari had just one household, it was always selected. In the case of multi-household baris, two households were selected at random from each of the sample baris. This led to a total sample of 4368 households[10]. Since for each household, we know the identity of its bari and village of location, we can account for non-household (that is, external) determinants of agricultural productivity and efficiency using this dataset.

While all the households completed the section on farm production, only 56.5 per cent (2469 households) of them were engaged in agricultural production. After purging this sample of potential outliers[11], the final sample contained a total of 2357 rice producing households. Of these, the majority (85%) came from multiple-household neighbourhoods where the mean number of households is six. For these households, the externality variable is a measure of education in the other (sampled) household in the neighbourhood. The remaining 352 households (15% of the sample), however, belong to single-household baris so that neighbourhood education is set to zero for these households.

3. Results

The summary statistics of the variables used appear in Table 1. A number of points can be noted from this Table. Farms in our sample are small, with an average size of 0.51 ha. Forty-six per cent of the household heads in our working sample never attended school so that the

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average level of the household head's education is only 3 years. The maximum average level of adult education in the household is 5.8 years, and the maximum average level of neighbour's education is 6.7 years[12]. The average age of the farmer is 49.2 years, 48 per cent of farmers are owner operators, and 97 per cent of the villages have irrigation facilities[13]. Lastly, 50 per cent of household-income is derived from non-agricultural sources.

["Table 1" about here]

Ordinary Least Squares (OLS) regression is used to estimate the parameters of the average production function models. The Maximum Likelihood Estimation (MLE) procedure is used to estimate the parameters of the stochastic production frontier and inefficiency effects models jointly in a single stage[14] using STATA Version 8 (Stata Corp, 2003). All model specifications include four basic farm variables – land, purchased inputs, home supplied inputs and farm capital assets used directly for rice production. Also, all model specifications control for village fixed-effects (to purge the data of the village-level unobserved determinants of farm output) unless mentioned otherwise. A test for the joint significance of fixed-effects in all specifications rejected the null hypothesis of 'no influence' (H_0: $\varphi_m = 0$ for all m) at the 1 per cent level of significance (see Appendix Table A). This confirms that studies dealing with farmers' decision making process at farm-level must dissociate the effects of village-level correlates, which has not been seen in studies using Bangladesh data.

3.1 Productivity effects of education

Table 2 presents OLS estimates (with fixed effects) of the extended Cobb-Douglas[15] production functions incorporating alternative specifications of the education variables to

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account for the internal and external benefits of education in rice production. The OLS model implicitly assumes fully efficient rice farmers, an assumption that will be relaxed subsequently when we proceed to examine the stochastic frontier production function for rice farming. Overall, these six specifications are able to explain 63-65 per cent of the variation in rice production, which is much higher than the explanatory power of the OLS models of the average production functions (with/without fixed-effects) reported in other studies[16].

["Table 2" about here]

All basic farm variables significantly influence rice production and the estimates are robust irrespective of model specifications. The effect of land is dominant as expected. Output elasticity of land varies from 0.65 to 0.71, implying that a 1 per cent increase in land area will increase rice production by 0.65 to 0.71 per cent. Since, a Cobb-Douglas model is used, the sum of the coefficients of all the basic farm variables provides a direct estimate of the 'returns to scale' in rice production. This sum varies from 0.83 to 0.87 indicating decreasing returns to scale. Appleton and Balihuta (1996) and Weir and Knight (2004) also reported decreasing returns to scale in cereal production for Ugandan and Ethiopian farmers respectively. Given widespread reporting of scale inefficiency among farmers in developing countries, estimates of 'decreasing returns to scale' seem consistent with expectation.

The internal (household-level) benefits of education in rice production are first explored in the neighbourhood fixed-effects models (1) and (2) in Table 2. The motivation underlying joint control for schooling of the household head and that of other household members (Model 2) is that production decisions are likely to be made collectively when farm size is small. The distinction between farm managers and workers is marginal in such a setting. While contributions of all may matter, the highest educated member in the household is likely to play the lead role. We find that the effect of household education is 6.4%,

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comparable to the labour market returns to education in the study villages. The household head's education, however, has no effect.

To explore the external (neighbourhood-level) benefits, we re-estimate the production functions with village fixed effects and an additional control for neighbour's education (Models 3-6, Table 2). Model (3) proxies for farm education using head's schooling only. Model (4) additionally controls for maximum level of education of other household members. Model (5) jointly controls for schooling of the head and maximum level of education in the neighbourhood. Lastly, Model (6) includes all three measures of education.

We find that an additional year of the household head's education increases rice production by 4 per cent (Model 3). But controlling for maximum adult education in the household, education of the head has no impact (Models 4 and 6). This finding confirms our earlier conjecture that farm production within the household is a centralized activity so that the most educated household member plays the key role in decision making[17]. The external benefit of education, measured by neighbour's education level is weak (Models 3 and 4). When specified jointly with the household head's education, one year of additional schooling at the neighbourhood level increases rice production by 3 per cent ($p<0.10$), and is similar to the estimate of Weir and Knight (2004) for Ethiopian cereal farmers. However, when we additionally control for maximum schooling among other householders, the neighbourhood effect disappears. We also re-estimated the regressions with alternative measures of neighbour's education (e.g. mean education of adults or education of the head in the neighbouring household). However, our results remained unchanged.

In the next stage we relax the assumption of fully efficient rice farmers and estimate stochastic production frontier models to allow for farm-specific inefficiencies. The test of significance of the inefficiencies in the model rejects the null hypothesis of 'no influence' (H_0: $\mu = \gamma = 0$) at the 1 per cent level, indicating that it is a significant improvement over the

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OLS specification and inefficiencies do exist (Appendix Table A). The predicted farm specific inefficiencies are then modelled as a function of selected farm and village level characteristics. In all specifications, both the stochastic production frontier and inefficiency effects models are estimated simultaneously. These results are summarized in Table 3.

["Table 3" about here]

The influence of basic farm variables on potential rice output is robust and mirrors those obtained from the average production function models. The first four models in Table 3 provide alternative specifications to account for internal and external benefits of education on the placement of the rice production frontier. A positive significant coefficient on the relevant variable will establish the evidence of its influence on outward shift of the rice production frontier. A test of joint significance of the effect of education in shifting the production frontier outward strongly rejected the null hypothesis of 'no influence' (H_0: $\alpha_k = 0$ for all k) at the 1 per cent level, indicating that education does have an influence on increasing potential output (Appendix Table A). Once again, we find strong evidence of the internal benefits of education in shifting the rice production frontier outward. The estimates of the level and magnitude of influence mirror those obtained in the average production function estimation results reported in Table 2. An additional year of schooling of the household head or adult members within the household will shift the rice production frontier by 3–7 per cent. However, when the education of the head and that of other adult householders are controlled simultaneously, the coefficient on the former becomes insignificant. This is consistent with the argument of centralized planning. To sum up, the most educated member raises farm output not only through boosting average output, but also by shifting the production frontier. The finding of a positive effect of formal education on potential output is at contrast with Weir and Knight (forthcoming), who using Ethiopian data found no such effects.

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Turning to the external benefit of education in shifting the rice production frontier, however, evidence is still weak. When included alongside head's education, an additional year of schooling in the neighbourhood seems to shift the rice production frontier by 3 per cent ($p<0.10$). But with additional control for maximum education of the adult householder, neighbourhood education has no impact.

Our earlier finding that the maximum education of the householder, instead of that of the household head, matters most in farm production suggests that educated householders are substitutes for one another. In order to formally test for this possibility, we also estimated an average production function and stochastic frontier production functions for a sub-sample of households where the household heads are uneducated[18]. Reassuringly, we find robust internal benefits of education (adult household education) on rice productivity and placement of the rice production frontier. The externality effect of neighbourhood education remains absent. Therefore, households where uneducated heads co-reside with educated adult members still experience significant gains in rice production. This finding has important policy implications which we discuss later in the paper.

Next, to detect any non-linearity in returns to the household head's education on rice productivity and placement of the frontier, we categorized his/her education into three levels: up to primary level, up to secondary level, above secondary level (details are given in Table 1). The results are presented in Appendix Table B, Models 1-4. We find that the influence of education on rice productivity and placement of the frontier kicks in only when the head's education level lies between primary and secondary level[19]. Tertiary level of education, perhaps, drives the household head away from rice production allowing him/her to engage in off-farm and non-agricultural activities, which presumably provides higher income when compared with rice farming. However, controlling for maximum schooling in the household, head's education once again has no impact.

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3.2 Efficiency effects of education

Given robust internal benefits of education in rice productivity and the placement of the production frontier and the missing external benefits of education in the same, we next investigate the influence of education on technical efficiency. Prior to the discussion of these effects, we want to briefly highlight the farm-specific efficiency scores presented in Table 4. The mean efficiency level varies between 71–73 per cent across specifications, indicating that rice production can be increased up to 27–29 per cent by improving technical efficiency alone with no additional use of resources. The minimum efficiency level is 12 per cent, whilst the maximum is 94 per cent. The results are similar to those reported by Wadud and White (2000) and Coelli et al. (2002) for Bangladesh.

["Table 4" about here]

Models 5, 6, 7 and 8 in Table 3 present the results of 4 alternative specifications of the internal and external effects of education on technical efficiency. Five variables representing farm characteristics and selected village-level characteristics are used to explain farm-specific technical inefficiency, in addition to variables representing the internal and external effects of education (for details, see lower panel of Table 1). A test of joint significance of all variables including education rejects the null hypothesis of 'no effect' (H_0: $\delta_d = 0$ for all d) at the 10 per cent level in all cases (see Appendix Table A). Non-agricultural income share seems to be the dominant variable in explaining technical efficiency. The significant positive sign on this coefficient points towards a situation where households with a higher opportunity to engage in non-agricultural activities fail to pay adequate attention to their rice production activities and are, therefore, highly inefficient. The result is similar and consistent with the findings of Ali and Flinn (1989), Wang et al. (1996) and Rahman (2003). Rice producers also benefit significantly from better infrastructure[20]. Underdeveloped infrastructure has negative effects

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on technical efficiency, as farmers may not have the required inputs to use at the correct time, or not at all. This result corroborates the findings of Ali and Flinn (1989), Coelli et al. (2002) and Rahman (2003), indicating that farmers in remote villages are less efficient after accounting for other correlates of efficiency. Weak evidence that owner operators are relatively efficient compared with tenants is also found.

Turning to our variables of interest, we find weak evidence of the external benefits of education in improving technical efficiency (Models 7 and 8). The coefficient on the neighbour's education variable is significant in Model 7 only. Once we additionally control for adult education within the household, neighbourhood education becomes insignificant (Model 8). Nevertheless the test of joint significance of the inefficiency effect of all education variables strongly rejected the null hypothesis of 'no effect' (H_0: $\tau_g = 0$ for all g) at the 5 per cent level (Appendix Table A).

Similar results follow when the household head's education is categorized into levels (see Models 5, 6, 7 and 8, Appendix Table B). Beyond secondary schooling, head's education does not matter in reducing production inefficiencies (Model 5). Once, again, the external returns to education are absent net of level of education of adult householders.

4. Conclusions and policy implications

Like other developing countries, Bangladesh is characterized by low human capital investment. Returns to additional investment are high; schooling is vital to labour productivity. Yet earlier studies eschewed the positive role of education in farm work arguing that formal schooling in Bangladesh is not agriculture-oriented, and hence makes little contribution to improving farm productivity and efficiency. To the extent that schooling raises literacy and numeracy skills and the ability to process agricultural information, an education effect can exist independent of school curriculum design. Returns to such skills are

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particularly magnified in a modernizing agricultural sector, where access to advanced technology complements human capital stock (Rosenzweig, 1995). This study therefore reassessed the puzzle over low returns to schooling in farm work in Bangladesh using a large dataset of rural rice producing households spread over 141 villages.

Three sets of results follow from our empirical analysis. First, the results espouse the existence of the internal benefits of education in rice production: education matters in raising productivity, boosting potential output and improving efficiency. This is consistent with the fact that farm work in Bangladesh involves modern varieties of seeds and inputs. There are several implications of such a positive education effect. First, similar to labour market returns to education, schooling is relevant even in an agrarian setting where wage work opportunities may be limited. This, therefore, questions the commonly held view that household investment in children's schooling in agrarian societies is discouraged by a lack of a return to education in farm work. Second, the finding that proximity to an educated adult in the household boosts farm productivity implies that not all farmers who are uneducated are worse-off in farm work. Earlier studies (for example, Sharif and Dar, 1996a, b) on the effect of education on rice production inefficiency in Bangladesh probably overstate the efficiency loss suffered by less educated farmers in rural Bangladesh. Given the evidence of a centralized production regime, public policy should therefore aim at targeting farm households where all members are uneducated. How this can be achieved, nevertheless, remains unclear. If the education effect merely reflects the effect of basic literacy and numeracy skills, then a well-designed adult literacy programmes could serve as a potential policy intervention. Providing literacy training to one adult householder would suffice. On the other hand, if education captures the effect of farm-specific lessons acquired during one's school years, then adult literacy programmes may not be sufficient.

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Our data supports the relative importance of basic education over higher education in agriculture. When household head's education is decomposed by levels of education, the results show that head's primary and/or secondary level of education has a significant impact on productivity (Appendix Table B, Model 1). Farmers who complete secondary schooling also enjoy significant efficiency gains (Appendix Table B, Model 5), suggesting that basic literacy skills, usually attained during primary and secondary schooling, are more relevant in farm production than tertiary education.

The third important finding relates to education externalities. The absence of a 'neighbourhood education' effect in farm production is in contrast with other studies that have tested for similar effects using developing country data (for example, Weir and Knight, forthcoming). The precise reason for this discrepancy is not clear. One possibility is that educational spill-over effects on potential output arise through adoption of high yielding variety (HYV) technologies[21]. But the adoption rate of these HYV technologies is higher in Bangladesh (including the study villages) compared with Ethiopian villages so that returns to education in the form of 'learning-from-others' is likely to be less in Bangladesh.

In conclusion, evidence of a significant household education effect is consistent with the fact that farmers in Bangladesh operate in a modernizing environment (for example, one where there are changes in technology and infrastructure) compared with other regions such as Africa and Latin America where farm production is largely traditional. Despite such returns, the distribution of education stock is sparse in rural Bangladesh. A vast majority of the farming population remains uneducated or lives in isolation from other educated individuals (in own household or in the residential neighbourhood). Consequently, only a fraction of them succeed in appropriating returns from advanced technology in farm work. Lack of education (or access to it) then partly explains why Bangladesh agriculture has not been able to fully exploit the available technologies. In spite of modernization, total factor

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productivity growth in agriculture has declined at an annual rate of 0.23 per cent per year for the period 1961–1992 mainly owing to dramatically falling efficiency, and this is despite strong technological progress (Coelli et al., 2003). Current policy initiatives of the government to expand educational opportunities in rural areas of the country are therefore well-placed and promise significant long-run returns in terms of bolstering agricultural productivity.

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Footnotes

1. Thana is the second lowest unit of local government in Bangladesh.
2. We have aggregated the volume of rice produced over all three seasons covering a crop year. This is because our main focus is to determine the internal and external benefits of education on overall rice production (the main staple and dominant crop in Bangladeshi farming) which is unlikely to differ across seasons for the same household. The main difference one usually obtains in parameter estimates of basic production inputs is across varieties of rice produced, as the input mix as well as use rates differ to a large extent between production of traditional and modern rice varieties. Unfortunately, our data do not distinguish between the varieties of rice produced in each season. In this specification, we implicitly assume that the production function is same for both traditional and modern rice.
3. Purchased inputs include seeds/seedlings, fertilizers, pesticides, irrigation, hired labour, and hired animal power services.
4. Home supplied inputs include all family labour, animal power services, manures, and seeds.
5. The index of underdevelopment of infrastructure is constructed using a cost-of-access approach. A total of six infrastructural indicators are used. These are: local market, bank, thana (sub-district) headquarter, bus stop, boat station, and telephone office (for details of construction procedure see Ahmed and Hossain, 1990).
6. The non-agricultural income share is composed of earnings from selling labour (permanent, seasonal as well as daily labour), revenues from household assets other than farm, non-farm assets and livestock, and earnings from primary and secondary non-agricultural sources.

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7. We only focus on householder (farm) workers. Information on workers hired from outside the household is unavailable and hence not accounted for in our analysis.
8. As discussed later in the paper, we also experiment with other measures of neighbourhood education such as mean education of adults in the neighbouring household and education of the head of the neighbouring household.
9. For a comprehensive discussion of the issue of identification of neighbourhood effect, see Durlauf (2004).
10. Further details on the MHSS are available in Rahman et al. (2001).
11. Outliers in the output variable were identified by examining the ratio of rice output (kg) per decimal unit of land cultivated. Any observation with a ratio less than 2 or greater than 140 ($2<x<140$) is defined as an outlier and discarded. This is equivalent to restricting the sample to observations that fall within 3 standard deviations of the mean ratio.
12. The neighbourhood variable is constructed by excluding all members of the index household.
13. This, however, does not guarantee that all farmers within the village have full access to irrigation.
14. The single-stage approach is considered superior against the conventionally used two-stage approach wherein the first stage involves estimation of the stochastic production frontier and the prediction of inefficiency effects under the assumption that these inefficiency effects are identically distributed with one-sided error terms. The second stage involves specification of a regression model for predicted inefficiency effects, which contradicts with the assumption of an identically distributed one-sided error term in the stochastic frontier (Battese and Coelli, 1995).

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15. The rationale behind using Cobb-Douglas specification as opposed to a more flexible Translog specification lies in the fact that we control for village level correlates of productivity and efficiency using the least-square dummy variable (LSDV) approach. This entails inclusion of 139 village dummies so that our variable list ranges from 144 to 149 variables in production frontier models alone. In such a setting, Translog specification is not feasible, owing to the problem of multicollinearity (Hsing, 1993). Moreover, Kopp and Smith (1980) suggest that the choice of functional form has a limited effect on technical efficiency. Consequently, Cobb-Douglas specification is widely used in studies that use large number of independent variables (e.g., Weir and Knight, forthcoming; Rezitis et al., 2002; Xu and Jeffrey, 1998; Dawson and Lingard, 1989).
16. For example, Weir and Knight (forthcoming) report adjusted R^2 of 0.55 for the OLS models of cereal output with site level fixed effects. The better-off fit of our models perhaps owes to the use of a large number of village dummies to control for village level fixed effects.
17. The choice of maximum education could be problematic if it proxies access to non-farm cash income, rather than direct access to skills learned at school. We tested for this by additionally controlling for non-farm income of the household. However, it did not drive out the effect of maximum household education.
18. The results are not reported here but available from the authors upon request.
19. This finding is consistent with the experience from other Asian countries, wherein a positive education effect on technology adoption is documented only if farmers have more than four years of schooling (Philips, 1994).
20. The infrastructure index is defined as the level of underdevelopment of infrastructure. Hence, a positive coefficient on this variable indicates positive effect on efficiency.

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21. The differences in results, however, could also reflect the possibility that the existing evidences on the externality effects of education are exaggerated. Recent research on human capital externalities in the labour market context suggests that naïve estimates of educational externalities are upwardly biased. And when corrected for endogeneity of education, there is little evidence in support of externalities of education (Acemoglu and Angrist, 2000). Although a similar analysis is yet to be attempted for agricultural production, it is difficult to rule out the prospect of a spurious externality effect of education in farm activities.

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References

Acemoglu D. and Angrist, J., 2000, How large are human capital externalities? Evidence from compulsory schooling laws. NBER Macroeconomics Annual, 15, 9-59.

Ahmed, R. and Hossain, M., 1990, Developmental impact of rural infrastructure in Bangladesh. IFPRI Research Report 83, International Food Policy Research Institute, Washington, D.C.

Aigner, D., Lovell, C.A.K., and Schmidt, P., 1977, Formulation and estimation of stochastic frontier production function models. Journal of Econometrics, 6, 21-37.

Ali, M. and Flinn, J.C., 1989, Profit efficiency among Basmati rice producers in Pakistan Punjab. American Journal of Agricultural Economics, 71, 303-310.

Appleton, S. and Balihuta, A., 1996, Education and agricultural productivity: evidence from Uganda. Journal of International Development, 8, 415-444.

Asadullah, M. N., forthcoming, Returns to education in Bangladesh. Education Economics.

Asadullah, M. N., 2006, Intergenerational economic mobility in rural Bangladesh, Paper presented at the Royal Economic Society (RES) Annual Conference, Nottingham.

Asfaw, A. and Admassie, A., 2004, The role of education on the adoption of chemical fertilizers under different socioeconomic environments in Ethiopia. Agricultural Economics, 30, 215-228.

BBS., 2001, Statistical Yearbook of Bangladesh, 1999. Bangladesh Bureau of Statistics, Dhaka.

Basu K., Narayan, A. and Ravallion, M., 2002, Is literacy shared within households? Theory and evidence for Bangladesh. Labour Economics, 8, 649-665.

Battese, G. and Coelli, T., 1995, A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical Economics, 20, 325-332.

For Peer Review

Berman, E. and Stepanyan, A., 2003, Fertility and education in radical Islamic Sects: Evidence from Africa and Asia. NBER working paper no. 2434.

Coelli, T., Rahman, S. and Thirtle, C., 2002, Technical, allocative, cost and scale efficiencies in Bangladesh rice cultivation: a non-parametric approach. Journal of Agricultural Economics, 53, 607-626.

Coelli, T., Rahman, S. and Thirtle, C., 2003, A stochastic frontier approach to total factor productivity measurement in Bangladesh crop agriculture, 1961-92. Journal of International Development, 15, 321-333.

Dawson, P.J., and Lingard, J., 1989, Measuring farm efficiency over time on Philippine rice farms. Journal of Agricultural Economics, 40, 168-177.

Deb, U.K., 1995, Human Capital and Agricultural Growth in Bangladesh, Unpublished Ph.D. Thesis, University of the Philippines at Los Banos.

Durlauf, S., 2004, Neighbourhood Effects, In J.V. Henderson and J.-F. Thisse (eds) The Handbook of Regional and Urban Economics, Volume 4. Cities and Geography, North Holland, Amsterdam.

Hasnah, Fleming, E.M., and Coelli, T., 2004, Assessing the performance of a nucleus estate and smallholder scheme for oil palm production in West Sumatra. Agricultural Systems, 79, 17-30.

Hossain, M., Quasem, M.A., Akash, M.M. and Jabbar, M.A., 1990, Differential impact of modern rice technology: The Bangladesh case. Bangladesh Institute of Development Studies, Dhaka.

Hsing, Yu, 1993, On the choice of production functions: the case of US manufacturing industries. Applied Economics, 25, 321-324.

Knight, J., Weir, S., and Woldehanna, T., 2003, The role of education in facilitating risk-taking and innovation in agriculture. Journal of Development Studies, 39, 1-22.

For Peer Review

Kodde, D., and Palm, F. 1986, Wald criteria for jointly testing equality and inequality restrictions. Econometrica 54: 1243-1248.

Kopp, R.J. and Smith, V.K. 1980, Frontier production function estimates for steam electric generation: a competitive analysis. Southern Economic Journal, 47, 1049-1059.

Llewellyn, R. and Williams, J.R., 1996, Nonparametric analysis of technical, pure technical, and scale efficiencies for food crop production in East Java, Indonesia. Agricultural Economics, 15, 113-126.

Lockheed, M., Jamison, D. and Lau, L., 1980, Farmer Education and Farm Efficiency: A Survey. Economic Development and Cultural Change 29, 1: 37-76.

Philips, J.M., 1994, Farmer education and farm efficiency: a meta-analysis. Economic Development and Cultural Change, 43, 149-165.

Rahman, M. M. 2004, The application of frontier approaches to model the efficiency of rice producers in Bangladesh. Unpublished Ph.D. thesis. Imperial College at Wye, University of London.

Rahman, O., Menken, J., Foster, A., and Gertler, P., 2001, Matlab Health and Socio-economic Survey (MHSS), 1996, 5th ICPSR version, RAND Inter-university Consortium for Political and Social Research (ICPSR), Ann Arbour, Michigan.

Rahman, S., 2003, Profit efficiency among Bangladeshi rice farmers. Food Policy, 28, 487-503.

Rezitis, A.N., Tsiboukas, C., and Tsoukalas, S. 2002, Measuring technical efficiency in the Greek agricultural sector. Applied Economics, 34, 1345-1357.

Rosenzweig, M., 1995, Why Are There Returns to Schooling? *American Economic Review* 85 (2), 153-158.

For Peer Review

Seyoum, E.T., Battese, G.E., and Fleming, E.M., 1998, Technical efficiency and productivity of maize producers in eastern Ethiopia: a study of farmers within and outside the Sasakawa Global 2000 project. Agricultural Economics, 19, 341-348.

Sharif, N.R. and Dar, A., 1996a, An empirical study of the patterns and sources of technical inefficiency in traditional and HYV rice cultivation in Bangladesh. Journal of Development Studies, 32, 612-629.

Sharif, N.R. and Dar, A., 1996b, Stochastic frontier and technical efficiency distributions: an analysis based on rice farming data for Bangladesh. Canadian Journal of Economics, 29, 582-86.

Stata Corp, 2003, Stata Statistical Software: Release 8.0. Stata Corporation, College Station, Texas.

Wadud, A. and White, B., 2000, Farm household efficiency in Bangladesh: a comparison of stochastic frontier and DEA methods. Applied Economics, 32, 1665-1673.

Wang, J., Cramer, G.L., and Wailes, E.J., 1996, Production efficiency in Chinese agriculture: evidence from Rural Household Survey data. Agricultural Economics, 15, 17-28.

Weir, S. and Knight, J., forthcoming, Production externalities of education: evidence from rural Ethiopia. Journal of African Economies.

Weir, S. and Knight, J., 2004, Externality effects of education: dynamics of the adoption and diffusion of an innovation in rural Ethiopia. Economic Development and Cultural Change. 53, 93-113.

Wodon, Q., 2000, Microdeterminants of consumption, poverty, growth, and inequality in Bangladesh. Applied Economics, 32, 1337-1352.

Yang, D., 1998, Education in production: Measuring labour quality and management. American Journal of Agricultural Economics, 79, 764-772.

For Peer Review

Young, D., and Deng, H., 1999, The effects of education in early-stage agriculture: some evidence from China. Applied Economics, 31, 1315-1323.

Xu, X., and Jeffrey, S.R., 1998, Efficiency and technical progress in traditional and modern agriculture: evidence from rice production in China. Agricultural Economics, 18, 157-165.

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Table 1: Summary statistics of variables

Variables	Description	Full Sample		Uneducated-head Sample	
		Mean	Std. Dev.	Mean	Std. Dev.
Farm variables					
Rice output	Unit of measurement: kg	1615.79	1888.73	1355.45	1448.98
Area cultivated	Unit of measurement: hectare	0.51	0.65	0.44	0.60
Purchased inputs	Unit of measurement: Taka[a]	4133.43	4315.82	3472.54	3396.45
Home supplied inputs	Unit of measurement: Taka[a]	306.40	861.29	275.85	705.09
Value of farm capital assets	Unit of measurement: Taka[a]	1001.51	5963.08	435.34	2830.56
Education variables					
Household head's education	Years of schooling completed	3.07	3.66	0	1
Primary education (grade 1 – 5)	Dummy (1 if head's education is grade 1–5, 0 otherwise)	0.31	0.36	0	1
Secondary education (grade 6 – 10)	Dummy (1 if head's education is grade 6–10, 0 otherwise)	0.18	0.38	0	1
Higher secondary and above (grade 11+)	Dummy (1 if head's education is grade >10, 0 otherwise)	0.04	0.21	0	1
Adult education in household	Maximum years of schooling completed (among adults)	5.78	4.11	3.45	3.87
Neighbour's education	Maximum years of schooling completed (among adults)	6.73	3.97	4.98	4.03
Other variables					
Age of the farmer	Years	49.17	13.13	49.67	13.27
Household head is female	Dummy (1 if head is female, 0 otherwise)	0.08	0.28	0	1
Tenurial status	Dummy (1 if owner operator, 0 otherwise)	0.48	0.50	0.39	0.49
Irrigation facilities in village	Dummy (1 if have irrigation, 0 otherwise)	0.97	0.16	0.98	0.15
Infrastructure index	Aggregate index of village-level facilities	4.20	4.70	4.22	4.70
Non-agricultural income share	Unit of measurement: Proportion	0.50	0.43	0.49	0.44
N		**2357**		**1104**	

Note: [a] = Exchange rate, 1 USD = Taka 48.06 in 1998/99 (BBS, 2001)

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Table 2: Estimates of average production function (Dependent variable: Natural log of rice produced)

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	2.832	2.815	2.91	2.879	2.885	2.876
	(21.89)**	(21.77)**	(40.42)**	(39.65)**	(39.28)**	(39.16)**
Farm variables						
ln Land	0.712	0.703	0.661	0.655	0.658	0.654
	(26.01)**	(25.44)**	(45.96)**	(45.12)**	(45.55)**	(45.07)**
ln Purchased inputs	0.122	0.118	0.134	0.134	0.135	0.134
	(6.06)**	(5.87)**	(12.13)**	(12.06)**	(12.14)**	(12.06)**
ln Home supplied inputs	0.023	0.021	0.021	0.02	0.021	0.02
	(3.25)**	(2.96)**	(4.98)**	(4.81)**	(4.95)**	(4.81)**
ln Farm assets	0.012	0.012	0.019	0.018	0.018	0.018
	(1.73)+	(1.69)+	(4.40)**	(4.25)**	(4.28)**	(4.23)**
Education variables						
ln Head's education	-0.011	-0.031	0.037	0.014	0.026	0.013
	(0.47)	(1.24)	(2.90)**	(0.92)	(1.87)+	(0.86)
ln Adult education in HH	-	0.064	-	0.054	-	0.052
	-	(2.00)*	-	(3.05)**	-	(2.51)*
ln Neighbour's education	-	-	-	-	0.027	0.005
	-	-	-	-	(1.75)+	(0.26)
Adjusted R^2	0.65	0.65	0.65	0.65	0.65	0.65
F test	321.89	270.22	1081.95	906.55	902.98	776.73
Village fixed effects	No	No	Yes	Yes	Yes	Yes
Neighbourhood fixed effects	Yes	Yes	No	No	No	No
N	2357	2357	2357	2357	2357	2357

Notes: (1) Absolute value of t statistics in parentheses (2) + significant at 10 per cent; * significant at 5 per cent; ** significant at 1 per cent.

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Table 3: Estimates of stochastic production frontier (Dependent variable: Natural log of rice produced)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Production frontier model								
Constant	3.691	3.636	3.659	3.636	3.710	3.749	3.735	3.752
	(11.00)**	(10.84)**	(10.91)**	(10.83)**	(10.92)**	(11.23)**	(10.99)**	(11.20)**
Farm variables								
ln Land	0.665	0.657	0.662	0.657	0.665	0.657	0.660	0.657
	(47.63)**	(46.75)**	(47.31)**	(46.73)**	(46.67)**	(45.27)**	(45.97)**	(45.28)**
ln Purchased inputs	0.114	0.112	0.114	0.112	0.113	0.112	0.113	0.112
	(11.52)**	(11.48)**	(11.56)**	(11.47)**	(11.36)**	(11.20)**	(11.34)**	(11.22)**
ln Home supplied inputs	0.020	0.019	0.019	0.019	0.019	0.019	0.019	0.019
	(5.11)**	(4.90)**	(5.08)**	(4.90)**	(5.07)**	(4.88)**	(5.02)**	(4.89)**
ln Farm assets	0.016	0.015	0.015	0.015	0.016	0.015	0.015	0.015
	(4.07)**	(3.89)**	(3.93)**	(3.88)**	(4.13)**	(3.95)**	(3.99)**	(3.92)**
Education variables								
ln Head's education	0.039	0.011	0.027	0.011				
	(3.20)**	(0.77)	(2.05)*	(0.75)				
ln Adult education in HH		0.063		0.063				
		(3.80)**		(3.27)**				
ln Neighbour's education			0.028	0.001				
			(1.94)+	(0.04)				
Model diagnostics								
Log Likelihood	-1695.00	-1687.83	-1693.13	-1687.83	-1696.36	-1690.08	-1692.07	-1689.52
Wald χ^2	6460.96	6529.81	6476.50	6529.27	6123.43	5699.03	5954.83	5703.94
Prob > χ^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
γ	0.822	0.821	0.825	0.821	0.792	0.747	0.774	0.748
	(13.20)**	(13.60)**	(13.24)**	(13.55)**	(12.18)**	(10.67)**	(11.42)**	(10.64)**
σ^2	0.830	0.807	0.839	0.808	0.709	0.576	0.652	0.579
	(2.94)**	(3.07)**	(2.89)**	(3.06)**	(3.41)**	(4.01)**	(3.62)**	(3.96)**
Inefficiency effects model								
Constant	-2.942	-3.018	-3.055	-3.020	-2.212	-1.470	-1.867	-1.478
	(1.78)+	(1.86)+	(1.78)+	(1.86)+	(1.78)+	(1.71)+	(1.75)+	(1.70)+

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	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Age	0.002	0.005	0.004	0.005	0.003	0.006	0.005	0.006
	(0.48)	(1.02)	(0.72)	(1.02)	(0.63)	(1.71)+	(1.29)	(1.73)+
Head is female	0.347	0.402	0.379	0.402	0.280	0.283	0.310	0.293
	(1.42)	(1.68)+	(1.51)	(1.68)+	(1.43)	(1.84)+	(1.70)+	(1.87)+
Tenurial status	0.146	0.157	0.160	0.157	0.145	0.140	0.152	0.143
	(1.04)	(1.15)	(1.10)	(1.15)	(1.23)	(1.54)	(1.41)	(1.56)
Irrigation	0.770	0.809	0.774	0.809	0.662	0.467	0.579	0.479
	(0.77)	(0.82)	(0.76)	(0.82)	(0.80)	(0.79)	(0.81)	(0.80)
Village infrastructure	0.049	0.046	0.049	0.046	0.043	0.038	0.040	0.037
	(2.06)*	(2.04)*	(2.03)*	(2.04)*	(2.12)*	(2.33)*	(2.17)*	(2.31)*
Non-agril. income share	1.011	0.987	1.014	0.987	0.891	0.730	0.847	0.740
	(3.12)**	(3.24)**	(3.09)**	(3.23)**	(3.48)**	(3.82)**	(3.53)**	(3.74)**
Head's education					-0.050	-0.004	-0.021	-0.002
					(2.15)*	(0.21)	(1.04)	(0.09)
Adult HH education						-0.057		-0.046
						(2.74)**		(2.08)*
Neighbour's education							-0.045	-0.017
							(2.23)*	(0.99)
N	2357	2357	2357	2357	2357	2357	2357	2357

Note: (1) Absolute value of z statistics in parentheses (2) + significant at 10 per cent; * significant at 5 per cent; ** significant at 1 per cent (3) All specifications include 139 villages dummies in the production frontier model.

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Table 4: Technical efficiency scores of rice farmers

Model specifications	Mean	Standard deviation	Minimum	Maximum
Model 1	0.728	0.133	0.123	0.944
Model 2	0.727	0.134	0.123	0.943
Model 3	0.729	0.133	0.123	0.944
Model 4	0.727	0.134	0.123	0.943
Model 5	0.723	0.134	0.133	0.942
Model 6	0.713	0.136	0.134	0.942
Model 7	0.720	0.135	0.132	0.941
Model 8	0.714	0.136	0.133	0.942

Note: Technical efficiency scores correspond to Table 4.

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Appendix Table A: Hypothesis test results of the stochastic production frontier and inefficiency effect models

Null Hypothesis	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
No village fixed effects (H_0: φ_m = 0 for all m)								
Likelihood Ratio test statistic (χ^2)	738.81	744.69	740.20	744.63	735.6	739.39	740.50	740.74
Degrees of freedom	138	138	138	138	138	138	138	138
p-value (Prob > χ^2)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Decision	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
Effect of all education variables in shifting the production frontier outward are jointly zero (H_0: α_k = 0 for all k)								
Likelihood Ratio test statistic (χ^2)	11.33	24.89	14.74	24.89	--	--	--	--
Degrees of freedom	1	2	2	3	--	--	--	--
p-value (Prob > χ^2)	0.000	0.000	0.000	0.000	--	--	--	--
Decision	Reject	Reject	Reject	Reject	--	--	--	--
No inefficiencies present in the model[a] (H_0: $\mu = \gamma = 0$)								
Likelihood Ratio test statistic (χ^2)	105.13	108.51	105.22	108.44	111.71	122.49	119.06	123.43
Degrees of freedom	3	3	3	3	3	3	3	3
p-value (Prob > χ^2)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Decision	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
No inefficiency effects (H_0: δ_d = 0 for all d)								
Likelihood Ratio test statistic (χ^2)	9.86	9.76	9.02	9.76	12.28	16.17	13.28	15.68
Degrees of freedom	5	5	5	5	6	7	7	8
p-value (Prob > χ^2)	0.079	0.082	0.102	0.082	0.056	0.023	0.065	0.047
Decision	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
Efficiency effects of all education variables are jointly zero (H_0: τ_g = 0 for all g)								
Likelihood Ratio test statistic (χ^2)	--	--	--	--	4.89	9.10	6.99	8.98
Degrees of freedom	--	--	--	--	1	2	2	3
p-value (Prob > χ^2)	--	--	--	--	0.027	0.010	0.030	0.029
Decision	--	--	--	--	Reject	Reject	Reject	Reject

Note: [a] = Since the test involves testing of γ parameter, it has a mixed χ^2 distribution. The mixed $\chi^2_{3,0.95}$ = 7.05 and is taken from Table 1 (Kodde and Palm, 1986).

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Appendix Table B: Alternative estimates of stochastic production frontier (Dependent variable: Natural log of rice produced)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Production frontier model								
Constant	3.688	3.626	3.650	3.624	3.696	3.744	3.727	3.748
	(10.98)**	(10.81)**	(10.88)**	(10.80)**	(10.86)**	(11.24)**	(10.97)**	(11.21)**
Farm variables								
ln Land	0.667	0.657	0.664	0.657	0.667	0.657	0.662	0.657
	(47.86)**	(46.79)**	(47.46)**	(46.80)**	(47.10)**	(45.49)**	(46.31)**	(45.49)**
ln Purchased inputs	0.113	0.112	0.113	0.112	0.113	0.112	0.113	0.112
	(11.47)**	(11.46)**	(11.53)**	(11.46)**	(11.39)**	(11.21)**	(11.36)**	(11.23)**
ln Home supplied inputs	0.020	0.019	0.019	0.019	0.020	0.019	0.019	0.019
	(5.12)**	(4.89)**	(5.08)**	(4.89)**	(5.13)**	(4.88)**	(5.05)**	(4.89)**
ln Farm assets	0.016	0.015	0.015	0.015	0.016	0.015	0.015	0.015
	(4.03)**	(3.87)**	(3.89)**	(3.86)**	(4.10)**	(3.93)**	(3.96)**	(3.90)**
Education variables								
Primary education (grade 1-5)	0.042	0.004	0.026	0.004				
	(1.73)+	(0.16)	(1.00)	(0.14)				
Secondary education (grade 6-10)	0.067	0.006	0.042	0.005				
	(2.26)*	(0.17)	(1.31)	(0.15)				
Higher secondary and above (grade 11+)	0.075	-0.004	0.042	-0.005				
	(1.38)	(0.07)	(0.75)	(0.08)				
ln Adult education in HH		0.069		0.068				
		(4.18)**		(3.51)**				
ln Neighbour's education			0.033	0.003				
			(2.27)*	(0.15)				
Model diagnostics								
Log Likelihood	-1696.78	-1688.10	-1694.21	-1688.09	-1696.69	-1688.69	-1691.56	-1688.13
Wald χ^2	6454.24	6530.14	6475.66	6533.24	6192.15	5723.25	5996.17	5727.56
Prob > χ^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
γ	0.825	0.822	0.822	0.822	0.807	0.747	0.781	0.748
	(13.55)**	(13.43)**	(13.43)**	(13.75)**	(12.44)**	(10.61)**	(11.57)**	(10.59)**

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	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
σ^2	0.840	0.270	0.270	0.264	0.767	0.575	0.672	0.577
	(2.95)**	(0.64)	(0.64)	(0.62)	(3.13)**	(3.98)**	(3.49)**	(3.95)**
Inefficiency effects model								
Constant	-2.962	-3.042	-3.094	-3.049	-2.575	-1.474	-1.994	-1.469
	(1.80)+	(1.85)+	(1.80)+	(1.88)+	(1.78)+	(1.72)+	(1.77)+	(1.71)+
Age	0.003	0.006	0.004	0.006	0.003	0.007	0.006	0.007
	(0.54)	(1.12)	(0.82)	(1.13)	(0.72)	(1.87)+	(1.41)	(1.89)+
Head is female	0.363	0.421	0.400	0.422	0.307	0.297	0.333	0.306
	(1.47)	(1.73)+	(1.57)	(1.74)+	(1.40)	(1.91)+	(1.73)+	(1.94)+
Tenurial status	0.129	0.144	0.147	0.145	0.136	0.127	0.139	0.129
	(0.92)	(1.06)	(1.02)	(1.07)	(1.05)	(1.41)	(1.26)	(1.43)
Irrigation	0.766	0.806	0.768	0.806	0.736	0.475	0.609	0.484
	(0.78)	(0.82)	(0.76)	(0.82)	(0.80)	(0.81)	(0.82)	(0.82)
Village infrastructure	0.049	0.045	0.049	0.045	0.047	0.039	0.042	0.039
	(2.05)*	(2.02)*	(2.02)*	(2.03)*	(2.17)*	(2.46)*	(2.26)*	(2.44)*
Non-agricultural income share	1.013	0.984	1.017	0.985	0.955	0.713	0.861	0.721
	(3.13)**	(3.18)**	(3.11)**	(3.24)**	(3.22)**	(3.78)**	(3.42)**	(3.72)**
Primary education (grade 1-5)					-0.256	-0.034	-0.101	-0.023
					(1.52)	(0.33)	(0.78)	(0.22)
Secondary education (grade 6-10)					-0.424	-0.020	-0.157	-0.004
					(1.85)+	(0.13)	(0.88)	(0.02)
Higher secondary and above (grade 11+)					-0.173	0.322	0.150	0.340
					(0.62)	(1.32)	(0.57)	(1.37)
Adult HH education						-0.064		-0.052
						(2.94)**		(2.33)*
Neighbour's education							-0.051	-0.017
							(2.35)*	(1.00)
N	2357	2357	2357	2357	2357	2357	2357	2357

Note: (1) Absolute value of z statistics in parentheses (2) + significant at 10 per cent; * significant at 5 per cent; ** significant at 1 per cent (3) All specifications include 139 villages dummies in the production frontier model.

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