FARM PRODUCTIVITY AND EFFICIENCY IN RURAL BANGLADESH: THE ROLE OF EDUCATION REVISITED

M Niaz Asadullah
SKOPE, Department of Economics,
University of Oxford, Oxford, OX1 3UQ, UK.

Sanzidur Rahman
School of Geography, Faculty of Social Science and Business,
University of Plymouth, Plymouth, PL4 8AA, UK
Phone: +44(1752)238411; Fax: +44(1752)233054; e-mail:srahman@plymouth.ac.uk

Contributed paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006

.

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 neighborhoods. 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 externality benefit of schooling. We discuss the implication of these findings for rural education programs in Bangladesh.

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

JEL classifications: I21, Q12, N5.

1. Introduction

Despite common beliefs regarding the benefits of schooling in farm activities, there is inconclusive evidence to advocate educational investment in agrarian societies. For instance, Ali and Flinn (1989), Wang et al. (1996), and Seyoum et al. (1998) demonstrate significant role of farmers' education in raising farming efficiency in Pakistan Punjab, India, and China, 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. Nevertheless, there is some agreement in the literature that education significantly influences adoption of technological innovations in agriculture (e.g., 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 (e.g. Asia) as opposed to being traditional (e.g. Latin America and Africa) (Philips 1994). Bangladesh agriculture has also undergone significant modernization so that a positive return is also more likely for the Bangladeshi data. Surprisingly, a majority of studies on returns to education in farm production in Bangladesh fails to find any significant impact (see for instance, Deb (1995), Wadud and White 2000; and Coelli et al. 2002). 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 generalize for it uses a highly purposive sample.

A potential explanation for the failure of earlier research on farm production function using Bangladeshi data to detect an 'education effect' lies in the methodology. First, the older studies preclude the possibility of centralized decision making in farm work (Yang 1998). Consequently, farm education stock is modeled either as education of the household-head or that of an average householder. Such proxies may contain little information and therefore, undermine the actual returns to education. Second, the existing studies on farm production in Bangladesh exclusively centre on internal returns to schooling, ruling out presence of any externality effect of education in improving productivity and efficiency.

A key aspect of social organization in rural Bangladesh is the clustering of households in a unique residential neighborhood commonly known as 'bari'. Households belonging to the same neighborhood maintain significant social ties which may have implications for farm production activities. Farmers might learn by observing (superior) input choices of their educated neighbors who are engaged in farm work. Alternatively, educated neighbors could simply share their literacy knowledge with uneducated farmers. Externality arising from bari-level education could serve as an important non-market determinant of farm-level productivity and efficiency.

The present study is thus set to examine two important issues in Bangladesh. First, we test for the internal effect of education. That is, whether household's own education raises farm productivity and efficiency. Second, we test for the presence of any external effect of education. It is examined whether in addition to household education; farm production is positively influenced by education of others in the residential neighborhood. 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.

The remaining part of the paper is organized as follows. Section 2 discusses the study area, the methodology, empirical specifications of the production functions and the data. Section 3 discusses the results. Section 4 is conclusion.

2. Methodology

2.1 The study area

The farm households in this study belong to the Matlab Thana of Chandpur district in Bangladesh. The Matlab Thana comprises of a total of 141 villages. The villagers primarily rely on the local economy for their livelihoods. Agriculture constitutes the key source of earnings. Rice is the principal crop item in Matlab villages, in terms of its share in total cereal production. About 50 per cent of the households are landless. Increasing population growth and density has also led to fragmentation of landholdings. Therefore, most of the farmers in the study area operate as smallholders or sharecroppers.

2.2 Modeling 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 internal and external benefit of education on productivity and efficiency. 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, influence production as well as increase potential output), and (b) deviations from the frontier (that is, affect production efficiency). The internal benefit of education on productivity and placement of the frontier is captured by specifying education at the household level 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 neighborhood level education as an independent variable in these models.

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 production function and the stochastic production frontier for the ith farm is expressed, respectively as:

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

$$\ln Q_i = \beta_0 + \sum_{j=1}^{J} \beta_j \ln X_{ji} + \sum_{k=1}^{K} \alpha_k \ln E_{ki} + \sum_{m=1}^{M} \phi_m D_{mi} + v_i - u_i \qquad (2)$$

Where

$$u_i = \delta_0 + \sum_{d=1}^{D} \delta_d W_{di} + \omega_i \qquad (2a)$$

The variable definitions and summary statistics are presented in Table 1. The v_is in eq (2) are the two-sided random error assumed to be IID $N(0,\sigma_v^2)$ independent of the u_is, representing random shocks, and u_is are non-negative random variables, associated with inefficiency in production assumed to be independently distributed as truncations at 0 of the normal distribution with mean, $\mu_i = \delta_0 + \sum_d \delta_d W_{di}$ and variance $\sigma_u^2(|N(\mu_i,\sigma_u^2)|)$, ; ω in eq (2a) is the truncated random variable; ln is the natural logarithm; and α_k, β_0, β_j, φ_m, δ_0, and δ_d are the parameters to be estimated.

The production efficiency of the farm *i* is defined as:

$$EFF_i = E[\exp(-u_i) \mid (v_i - u_i)] = E\left[\exp(-\delta_0 - \sum_{d=1}^{D} \delta_d W_{di}) \mid (v_i - u_i)\right] \quad (3)$$

Where *E* is the expectation operator. This is achieved by obtaining the expressions for the conditional expectation u_i upon the observed value of $(v_i\text{-}u_i)$. 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).

The internal benefit of education is measured by two variables: (a) education level of the household-head (completed years of schooling), and (b) maximum education (completed years of schooling) among adult householders (aged 19 years and over). The external benefit of education is measured by the maximum years of schooling among adult neighbors[1]. Eight specifications were adopted using three types of education variables to examine 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 neighborhood 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 omitted village determinants positively affect farm productivity and are positively correlated with our neighborhood education measures, the estimate of education externality is likely to be upwards. Nonetheless, we cannot rule out the possibility that a bias may prevail due to the omission of neighborhood level unobserved correlates of farm productivity so that our estimates of externalities are likely to be upward biased.

2.3 Data

Data for this study comes from the Matlab Health and Socio-economic Survey (MHSS). The survey was conducted in all villages of the Matlab Thana in the year 1996 (Rahman et al. 2001). The sample households were selected in two steps. First, a random sample of 2678 residential neighborhoods – baris – was selected from the entire Matlab Thana. In the second

[1] The neighbourhood variable is constructed by excluding all members of the index household.

step, households were sampled. If a bari had just one household, it was always selected. In 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.

While all the households completed the module on farm production, only 56.5 per cent (2469 households) of them were engaged in agricultural production. After purging this sample of potential outliers, the final sample contains a total of 2357 rice producing households. Of these, the majority (85%) comes from multiple-household neighborhoods 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 neighborhood. The remaining 352 households (15% of the sample), however, belong to single-household baris so that neighborhood education is set to zero for these households.

3. Results

The summary statistics of the variables used appear in Table 1. OLS regression is used to estimate the parameters of the average production function models and 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. 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 significance of fixed-effects in all specifications rejected the null hypothesis of 'no influence' at 1 per cent level of significance.

3.1 Productivity effects of education

Table 2 presents OLS estimates (with fixed effects) of extended Cobb-Douglas (C-D)[2] production functions incorporating alternative specifications of the education variables to account for internal and external benefits of education on rice production. Overall, these six specifications are able to explain 63-65 per cent of variation in rice production which is much higher than the explanatory power of the OLS models of average production function (with/without fixed-effects) reported in other studies.

---

[2] The rationale to use C-D specification as opposed to a flexible Translog specification is that we are specifying our models with 139 village dummies to control for village level correlates of productivity and efficiency, leaving our variable list to vary from 144 to 149 variables in production frontier models alone. Other studies with similar specification also used C-D model, for example Weir and Knight (*Forthcoming*).

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, Cobb-Douglas model is used, sum of coefficients of all basic farm variables provides a direct estimate of the 'returns to scale' in rice production. The 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' seems consistent with expectation.

The internal (household-level) benefits of education in rice production are first explored in neighborhood fixed-effects models (1) and (2) in Table 2. The motivation underlying joint control for head's schooling and that of other householders (Model 2) is that production decisions are likely to be collectively made 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 in the household is likely to play the lead role. We find that the effect of household education is 6.4%, comparable to the labor market returns to education (7%) in the study villages (Berman and Stepanyan 2003). Household-head's education has no effect, however.

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

We find that an additional year of household-head's education increases rice production by 4 per cent (Model 3). But controlling for maximum adult education in the household, head's education 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. The external benefit of education, measured by neighbor's education level is weak (Models 3 and 4). When specified jointly with household head's education, one year of additional schooling at the neighborhood 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, additionally controlling for maximum schooling among other householders, the neighborhood effect disappears. We also re-estimated the regressions with alternative measures of neighbor's education (e.g. mean education of adults or education of the head in the neighboring 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 predicted farm specific inefficiencies are then modeled 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.

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 upward shift of the rice production frontier. Once again, we find strong evidence of internal benefits of education in shifting the rice production frontier outward. The level and magnitude of influence mirrors those obtained in the average production function estimation results reported in Table 2. An additional year of schooling of household head or adult members within the household will shift the rice production frontier by 3–6 per cent. However, when head's education and that of other adult householders are controlled simultaneously, coefficient on the former becomes insignificant. This is consistent with the argument of centralized planning. To sum, the most educated member raises farm output not only through boosting average output, but also by shifting the production frontier.

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

3.2 Efficiency effects of education

Given robust internal benefits of education in rice productivity and placement of the production frontier and 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 briefly highlight the farm-specific efficiency scores presented in Table 4. The mean efficiency level varies between 71 to 73 per cent across specifications indicating that rice production can be increased up to 27 to 29 per cent by improving technical efficiency alone with no additional use of resources. The minimum efficiency level is 12 per cent while 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.

Models 5 through 8 in Table 3 present the results of 4 alternative specifications of 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 internal and external effects of education (for details, see lower panel of Table 1). 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 higher opportunity to engage in non-agricultural activities fail to pay high attention to their rice production activities and therefore, are highly inefficient. The result is similar and consistent with findings of Ali and Flinn (1989), Wang et al. (1996) and Rahman (2003). Rice producers also benefit significantly from better infrastructure[3]. Underdeveloped infrastructure has negative effects 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 than the tenants is also found.

Turning to our variables of interest, we find weak evidence of external benefits of education on improving technical efficiency (Models 7 and 8). The coefficient on the neighbor's education variable is significant in Model 7 only. Once we additionally control for adult education within the household, neighborhood education becomes insignificant (Model 8).

4. Conclusions and policy implications

This study reassessed the puzzle over low returns to schooling in farm work in Bangladesh using a large dataset on rural rice producing households spread over 141 villages. Three sets of results follow from our empirical analysis. First, the results espouse existence of internal benefits of education in rice production: education matters in raising productivity, boosting

[3] The infrastructure index is defined as the level of underdevelopment of infrastructure. Hence, a positive coefficient on this variable indicates positive effect on efficiency.

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 labor 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 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 equally worse-off in farm work. Earlier studies (for example, Sharif and Dar, 1996) 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. If the education effect merely reflects the impact of basic literacy and numeracy skills, then a well-designed adult literacy programs could serve as a potential intervention.

Our data supports the relative importance of basic education over higher education in agriculture. Household head's education, when decomposed by levels of education shows that having primary and secondary education over and above zero year of education has a significant impact on productivity (results suppressed). Farmers who complete secondary schooling also enjoy significant efficiency gains (results suppressed) suggesting that basic literacy skill, usually attained during primary and secondary schooling is more relevant in farm production than tertiary education.

The third important finding relates to education externalities. The absence of a 'neighborhood education effect' in farm production is at 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 HYV varieties/technologies. But adoption rate is higher in Bangladesh (including the study villages) compared to 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 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 to other regions such as Africa and Latin America where farm production is largely traditional. Despite such returns, distribution of education stock is sparse in rural Bangladesh. A vast majority of the farming population remains uneducated or live in isolation of other educated individuals (in own household or in the residential neighborhood). 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 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 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.

Acknowledgements

We are thankful to Stefan Dercon, Sharada Weir and Francis Teal for comments on an earlier version of the paper. However, usual disclaimers apply.

References

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.

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.

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.

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.

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

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.

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

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 Arbor, Michigan.

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

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., 1996, 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.

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*, Education externalities in rural Ethiopia: evidence from average and stochastic frontier production functions. 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.

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

Table 1: Summary statistics of variables

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

Note: [a] = We have aggregated the volume of rice produced over all three seasons covering a crop year because data do not distinguish between the varieties of rice produced in each season. In this specification, we implicitly assume that the production function of both traditional and modern rice is same. Also, 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.

[b] = Purchased inputs include seeds/seedlings, fertilizers, pesticides, irrigation, hired labor, and hired animal power services.

[c] = Home supplied inputs include all family labor, animal power services, manures, and seeds.

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

[f] = 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, headquarter, bus stop, boat station and telephone office.

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 Neighbor'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
Neighborhood 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.

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 Neighbor'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)+
Age	0.002	0.005	0.004	0.005	0.003	0.006	0.005	0.006

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	(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)*
Neighbor'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.

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	0.722	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	0.713	0.136	0.133	0.942

Note: Technical efficiency scores correspond to Table 3.