Do Farmers Choose to be Inefficient?

Evidence from Bicol, Philippines

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SUMMARY FINDINGS

Farming households that differ in their ability or willingness to take on risks are likely to make different decisions when allocating resources and effort among income producing activities with consequences for productivity. In this paper we measure voluntary and involuntary departures from efficiency for rice producing households in Bicol. We take advantage of a panel of observations on households which includes observations from 1978, 1983 and 1994. The unusually long time-span of the panel provides ample opportunities for the surveyed households to learn and apply successful available technologies. We find evidence that diversification and technology choices do effect efficiency outcomes among farmers, although these effects are not dominant; accumulated wealth, past decisions to invest in education, favorable market conditions, and propitious weather are also important determinants of efficiency outcomes among Bicol rice farmers.

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1. INTRODUCTION

Research suggests that poor farming households are less able to cope with shortfalls in production and, as a consequence, tend to diversify labor and land resources as a precaution. This limits the adverse effects of production and market risks; however lower productivity results as well. It is generally held that these choices are rational-- that farmers understand the tradeoff and anticipate the consequences of ex ante production decisions. (See, for example, Binswanger and Sillers 1983; Binswanger and Rosenzweig 1986;Walker and Jodha 1986; Bromley and Chavas 1989; Reardon, Delgardo and Matlon 1992; Fafchamps 1992; Morduch, 1995; Dercon, 1996, and Ellis 2000.) Differing production and livelihood strategies therefore help to explain why productivity and efficiency in farming varies internationally, nationally and even among households living near one another. Less studied however are the quantitative effects of household choices that lead to voluntary inefficiencies. Investigating the cost of risk-coping strategies is worthwhile, since there are good reasons to suspect that voluntary inefficiencies play a central role in explaining rural poverty (World Bank 2001.)

Rice farming is an important and variable source of income and nutrition in many developing countries, especially in poor regions and among poor households. The technical sources of production efficiency and variability for rice are well studied and well known (Anderson and Hazell 1989). In this paper we explore why farmers often fail to achieve outcomes that can be described as efficient and we measure voluntary and involuntary departures from efficient rice production among rice farmers in a region of the Philippines. In particular we measure the relative importance of household decisions about technology and diversification on productivity. We find evidence that diversification and technology choices do effect efficiency outcomes. At the same time, the results suggest that accumulated wealth, past decisions to invest in education, favorable market conditions, and propitious weather are also important in explaining efficiency outcomes among Bicol rice farmers.

Methodologically our measurement relies on a stochastic frontier model that incorporates technical efficiency effects, as pioneered by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) and further developed by Reifschneider and Stevenson (1991); Kumbhakar, Ghosh and McGuckin (1991); Fried, Lovell and Schmidt (1993), and Coelli, Rao and Battese (1997). Empirically, our measurements rely on a three-year panel containing 1,511 observation of Filipino rice producing households in Bicol (Bicol River Basin Development Program 1997 and 1998; and Lanzona, 1997.)

After deriving the model in section 2, the data is described in section 3. Section 4 provides an estimation of the base model and a discussion of the empirical results. Section 5 discusses comparable measures of voluntary and involuntary departures from technical efficiency. Chapter 6 discusses whether results from the original model are sensitive to alternate specifications. Section 6 concludes.

2. THE HOUSEHOLD PROBLEM

We start with the household's time-separable lifetime consumption planning problem:

$$Max_{c,x}\ E_t \int_{t_0}^{\infty} U(c_t; s_t)\, e^{-rt}$$

subject to: $$dw = \{ I[x_t; s_t] - c_t - L[x_t; s_t] \} dt + s\,[x_t, c_t, w_t; s_t] dv$$

$$w_{t_0} = w_0;\ s_{t_0} = s_0;\ w_t \geq 0;\ c_t > 0$$

where t denotes the time period; E_t denotes conditional expectations; U is an atemporal utility function; r is a discount rate; c represents total consumption and is always positive; s is a vector of additional exogenous state variables with an initial value of s_0; w represents wealth with an initial value of w_0 and is bounded below; I_t is a net-income function that maps household activities, $y^i(x;s)$, and input use to household income; x is a vector of net inputs; L is an expected loss function conditioned by the choice of inputs; v is a Wiener process with a zero mean and a unit variance; and $s\,(x,c,w;s)$ is a scaling factor conditioned by the control, (ex ante choice) variables and the state variables, including wealth. Expected income losses are given by:

$$L(x) = \int_0^{R_u} f(R; x, s) dF(R),$$

where *F(R)* is the distribution function for random event, *R*.

In words, the household problem as represented in the model is to choose a consumption path that is constrained by wealth, supplemented by generated income based on input uses and a variety of conditioning state variables, including technology, relative prices, education, etc. The problem is depicted as an infinite horizon multi-generation problem. For the current period, setting $t_0 = 0$, the problem can be expressed as:

$$rV(w;s) = Max_{x,c} E\left[U(c) + V_w(I - c - L) + \tfrac{1}{2} V_{ww} s^{2}\right],$$

where the first order conditions are:

$i)\quad V_w E(I_x - L_x) = 0$

$ii)\quad E(U_c) - V_w = 0$

$iii)\quad E(dw) = E(I - c - L)$

$iv)\quad w(t_0 = 0) = w_0$

To guarantee that the first-order conditions provide a maximum, V must be concave in w; the solution values of *w, c* and *x* must be positive; and the transversality-at-infinity condition must hold[1].

The first-order conditions require that expected marginal gains and loss from additional input use are offsetting (condition i) and that the expected marginal utility equals the shadow-value of marginal wealth (condition ii). Expected wealth changes equal the expected savings (or dis-savings (condition iii). In turn, the shadow value of marginal wealth depends in part on the distribution of risks. This relationship can be expressed by applying the envelope theorem to the value function and considering condition ii:

$$E(U_c) = V_w(w;s) = \tfrac{1}{r}(V_{ww}\dot{w} + \tfrac{1}{2} V_{www} s^{2})$$

that is, expected utility from marginal consumption must also equal the present value of the foregone stream of future wealth. When $V_{www} \geq 0$ the value of the foregone income stream includes a "precautionary" value of wealth based partly on the variability of wealth outcomes. Conditions iii) and iv) restate constraints on the optimum. Together, the conditions state

[1] In this case the traversality condition is given by $\lim_{t \to 0} V_w(t) w(t) e^{-r(t-t_0)} = 0$. The condition guarantees that the ending-value of the problem diminishes with the length of the horizon. See Malliaris and Brock (1987) for a discussion of stochastic control models and the transversality condition.

formally the common sense notion that the solution to one among several household activities will be condition by constraints on the overall household problem. Operationally, this means that, as we estimate the efficiency of a particular activity such as rice farming, we need to carry with us as state variables the larger set of variables that define the household problem.

The solution then to a given activity, y^1, is found by substituting values from the general household problem and the solved value of *I*. In order to derive an empirical model, we make some additional limiting assumptions regarding *I*. We assume that *I* can be expressed as a separable combination of activities so that at the solution value, $E[I] = E\sum_i y^i(\hat{y}^i, x; s)$ --where $\hat{y}^i$ is a vector of outputs produced jointly with y^i and x is the vector of inputs used in the joint production activity. For the applied model, we must also make additional assumptions about the error component of the stochastic variable y^i, a topic we take up in the next section.

The applied model

Following the general model, we expect that the production solution to the stochastic optimization problem, will depend on other household activities and will be conditioned by ex ante expectations about the distribution of random weather events as well as other initial conditions. We make the additional assumption that we can represent the rice-producing activity of Bicol households as a single technology frontier production function, with systematic and accidental variation from this production frontier. That is:

$$y_{it}(x;z) = y_{it}^*(x) - u_{it}(z) + v_{it} \qquad 2.1)$$

where y^* is the frontier production function and u are random variables that depend on *z*, a vector of state variables (*s* and *w*), and that denote distance from the frontier objective, where *i* and *t* are subscripts denoting household and year[2]. More specifically, as is common practice in technical efficiency models (Battese and Coelli, 1995), we specify a log-linear frontier production function and expand the *u* linearly in the state variables so that 2.1 is specified as:

$$\ln(y_{it}) = b^o + \sum_1^J b^j \ln(x_{it}^j) + v_{it} - u_{it} \qquad 2.2)$$

[2] To be consistent with the general model, we use the price of rice as the numeraire for income so that *y* can be measured as a quantity.

The expression $\ln(y_{it})$ denotes the natural logarithm of rice production for household i in period t; $\ln(x_{it}^{j})$ denotes the natural logarithm of the jth input; b are estimated parameters; and v_{it} are random errors, assumed to be iid $N(0, s_v^2)$. Also by assumption, the u_{it} are non-negative random variables that account for inefficiency in production, where $u_{it} = d_{0t} + \sum_{1}^{K} d_{it}^{k} z_{it}^{k} + w_{it}$ and where the z_{it}^{k} are K state variables and d are estimated parameters. The u_{it} are assumed to be independently distributed. Additionally, the random variable, w_{it}, is defined by the truncation of the normal distribution with zero mean and variance, s_u^2, such that the point of truncation is $-(d_{0t} + \sum_{1}^{K} d_{it}^{k} z_{it}^{k})$ to insure that u_{it} are positive. The time-varying intercept, d_{0t}, is included to take into account changes in available technologies.

In addition, we follow Battese and Coelli (1995) and define the test statistic $g = s_u^2/(s_u^2 + s_v^2)$ to check whether the u_{it} are deterministic. Later, we provide estimates where the additional assumptions on u are dropped in favor of standard fixed-effects assumptions. Finally, for some observations in the sample, farmers have chosen not to apply all inputs – this is especially true for some fertilizers. Consequently, dummy-variables are employed. (See Battese, 1997.)

3. THE DATA

We derived the data for this analysis from the Multi Purpose Survey (MPS), collected in the Bicol Region in the Philippines in the years 1978, 1983 and 1994. The 1978 and 1983 surveys included farmers from three provinces Camarines Sur, Albay and Sorsogon; however, in 1994, data was collected in the Camarines Sur province only[3]. The MPS was collected to analyze different social and economic aspects of households, villages and communities.

Most results reported in this paper are based on 1,511 observations from 912 rice-planting households. The panel is unbalanced and only 144 households appear in all three

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[3] Descriptions of the data and the survey instrument are given in: Bicol River Basin Development Program: Bicol Multipurpose Survey (BMS) (Philippines), 1978 and 1983 as reported by the Inter-university Consortium for Political and Social Research, Ann Arbor, 1997 and 1998; and Lanzona, Bicol Multipurpose Survey (BMS), 1994 (Philippines); Inter-university Consortium for Political and Social Research, Ann Arbor, 1998

surveys. Later, we discuss results based on the balanced component of the sample and compare them to results from the unbalanced panel. Table 1 reports the mean value for key variables from both the balanced and unbalanced panels.

For households in the sample, rice production per household averaged 84 cavan[4] in 1978, 92 cavan in 1983 and 135 cavan in 1994. The differences in the averages are due partly to the composition of the sample as the Camarines Sur households grew rice on a larger scale. In addition, nature was more kind to rice growers in 1994 and yields for Camarines Sur households improved from 43 cavans per hectare in 1983 to 59 cavans in 1994. Nevertheless, as can be seen in figure 1, the spread in production and yields was generally greater among households than among years.

In addition to production, table 1 reports averages for two other types of variables. We associate the first group with the production frontier and the later with technical efficiency.

Inputs to the production function include land of differing type.. Land types include upland rain-fed, lowland rain-fed, gravity irrigated and pump irrigated land. Area planted to rice averaged about two hectares for each household and shows no clear trend over time. Irrigation costs, seed use, fertilizer use, other chemical use, machine usage and labor comprise the remaining input variables.

Among the variables influencing efficiency, two represent explicit short-term choices. The first, seed-use, includes a choice concerning technology, since rice farmers in the Bicol region could choose to plant either high yield rice varieties or traditional ones[5]. Survey results indicate three outcomes. Farmer chose to plant i) a high yielding rice variety only; ii) traditional varieties only; or iii) a combination of high yield and traditional rice varieties. Area devoted to other crops is another choice farmers make with potential consequences for efficiency.

Other state variables are likely to influence efficiency, but the farmer must take these as given – at least in the short run. Relative rice prices were included to measure economic incentives for greater efficiency[6]. Because it is likely to influence the capacity to farm efficiently, education is included. Wealth is also included since the variable potentially

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[4] A cavan equals 44 kg. of unmilled rice.
[5] Irrigation techniques represent technology choice as well, but this technology is fixed in the short-run.

influences the ability of the farmer to employ riskier techniques associated with higher productivity.

Because weather influences ex-ante decisions and ex-post outcomes, several weather-based variables are included in the estimation. Weather data were available from two official weather stations, Deat and Lagazpi City, within the Bicol region. The data include, on a monthly basis, average temperature and rainfall. Rice producing households are allocated to one of these weather stations depending on proximity. Since the growing months of rice are reported in the MPS-data, it is possible to calculate household specific indicators of weather conditions. Six indicators are calculated. For each household, average rainfall and temperature are calculated for the indicated growing months. Additionally, average deviations from historic mean temperatures and rainfall are calculated. To measure variability within the growing seasons, mean squared monthly deviations are calculated as well. Finally, time-dummy variables are included to test for fixed year effects.

4. ESTIMATION RESULTS

In this section we discuss the parameter estimates from the base model, given in table 2[7].

Frontier parameters

The parameters estimated for the stochastic frontier production function indicate elasticities for land between 0.44 for lowland gravity irrigated and 0.30 for upland. These elasticities are similar to other production functions estimated elsewhere – for example, Mundlak, Larson and Butzer (1999) estimated an elasticity for land of 0.47, in their cross-country analysis of agricultural production.

The elasticity of irrigation fuel costs is positive, but not significantly different from zero. Other inputs-- seeds, fertilizer, chemical costs and aggregated machine hours-- have typical positive elasticities that are all significantly different from zero.

There is an inconsistency in the questionnaires concerning labor data that requires special treatment for hired labor in 1978. Nonetheless the estimated elasticity of 0.07 associated with

[6] Price incentives may be fully measured by observed input choices, including family labor. However, prices may have an additional effect on unmeasured management.

[7] The model was estimate using Frontier 4.1 (Coelli, 1996.)

hired labor hours in the years 1983 and 1994 is statistically significant and consistent with Mundlak, Larson and Butzer. The elasticity of family labor hours is also significant, but quantitatively lower with an estimated value of 0.03.

Finally, it is worth noting that, while homogeneity has not been imposed on the empirical model, the unconstrained sums of the frontier input elasticities range from 0.82 to 0.96, depending on the type of irrigation employed.

Technical inefficiency parameters

By convention, model parameters not included in the frontier are expressed in terms of inefficiency – that is u_{it} is a subtraction from y_{it}. Consequently, variables with negative (positive) coefficients will have a positive (negative) relationship with output.

The estimates associated with the two short-term choices have the expected signs and are statistically significant. The estimated parameter for the variable "area planted with other crops" is positive, indicating that rice productivity declines with crop diversification. The result is consistent with the notion that rice producing households that diversify pay a price in terms of lost efficiency in rice production. The estimates also indicates that the use of high-yielding varieties or a combination of high and traditional varieties boosts productivity and, consequently, that the few farmers that chose to rely exclusively on traditional varieties gave up on potentially efficiency gains by doing so.

Longer term decisions to save and invest in education also significantly affect efficiency according to the estimated results. The coefficient on educational obtainment is positive and significant, as is the coefficient on wealth. The later result is consistent with the assertion that wealthier households are better positioned to pursue strategies that are more efficient, but also riskier. However, it is possible that wealth proxies greater managerial endowments.

The price of rice sold by the farmer also had a highly significant coefficient. High relative prices will directly offer incentives for greater productivity; however this is potentially fully captured in adjustments made to allocated labor and other inputs. Still, higher prices will most likely result in added care and management, which potentially explains the result. However, field visits indicate that some households remain remote, suggesting that low costs may be associated with high transaction costs, the full consequences of which are not captured by the other choice variables. Consequently, in addition to providing incentives for voluntary action, prices may also reflect involuntary losses associated with poor communications and other unmeasured factors that contribute to lower efficiency.

As mentioned, the weather variables depend on calculations based on proximity to one of two weather stations in Bicol and on planting decisions by farmers. The estimated parameters reflect a quadratic specification that includes weighted averages of the long-term monthly averages for temperature and rain – which can be know ex ante – as well as ex post outcomes. As such, little meaningful can be said about the individual weather parameters. As it turns out, the parameters are significant, taken as a whole and that weather is significant in explaining the range of production outcomes. We return to this topic in the next section.

The two constant terms, associated with the frontier and with the technical inefficiency variables, are both significant. Fixed effects for panel years are also significant. The values indicates that on average the rice farmers moved closer to the frontier with time – that is, the inefficient measure association with the dummy value for 1978 (1.577) is greater than the value for 1983 (1.241) and both represent greater inefficiency relative to the (excluded) 1994 dummy. However, it is also possible that the result may reflect differences in the sample composition since the year-effects are not significant when the balanced panel is used for estimation. We take up the balanced panel results in section 6.

5. MEASURING IMPACT

In this section we provide comparative measures of the effects of state variables. Technical efficiency, ?, is defined for each household-time observation as $T_{it} = e^{-u(z_{it})}$ and we present examples of how discrete and reasonable changes in state variables effect efficiency, where $\Delta T = -d_k T(\bar{z})\Delta z_k$. We present a similar measure for output where $\Delta y = -d_k y(\bar{x}, \bar{z})\Delta z_k$ [8]. Recalling from 2.2 that the technical efficiency term is multiplicative, the elasticity of y with

[8] For temperature and rain, quadratic terms are included in the efficiency term and consequently in the impact measures. For example, the percentaage output change for a given deviation in average rainfall is given by: $\frac{\Delta y}{y} = d^7\Delta r + d^8\Delta r + 2d^9\Delta r^2$, where Δr is a given deviation from average rainfall, $\Delta r = r - \bar{r}$. The change in output due to a switching seed type is given by $\frac{\Delta y}{y} = \exp(-d^4 - 1)$. (See Halvorsen and Palmquist, 1980.)

respect to the efficiency variables is equivalent to the elasticity of *T* with respect to the efficiency variables, that is: $\frac{\partial y}{\partial z}\frac{z_k}{y} = \frac{\partial T}{\partial z_k}\frac{z_k}{T} = -d_k z_k$.

The results of the calculations, given in table 3, show that the gain from making use of high-yielding seeds is large. This is a one-time gain however and the data shows that few households in the survey relied exclusively on seeds from traditional varieties.

The results also indicate that diversification extracts a cost in foregone efficiency. The measure calculates the average reduction in output for a given plot of land when the household manages additional plots devoted to other crops. Though significant, the cost of foregone specialization – estimated at 2.9% for a reduction in diversification of 0.5 hectares-- is not especially large.

The measures indicate that past investment in education and past savings are quantitatively important. The simulations show that relatively small increased in wealth and education lead to significant and repeated gains in efficiency.

Random shocks from market prices and weather also appear to be important determinants of ex ante output. The quantitative results suggest that a small change in price or a small shortfall in rainfall will result in production losses that match or overwhelm positive gains that farmers can obtain through voluntary choices.

6. ALTERNATIVE MODELS

In this section we examine whether the results are sensitive to the choice of estimation technique, omitted variables, or the composition of the panel used to estimate the model. We find that results related to the frontier variables are fairly robust on all accounts. With few exceptions, the same can be said of the direction of impact associated with efficiency variables. However, the quantitative values and, in some cases the statistical significance of the parameters, are effected when observations are excluded in order to balance the panel, when variables are omitted or when assumptions regarding the composition of the error term are dropped.

Comparison with least squares

As mentioned, the test statistic $g = s_u^2/(s_u^2 + s_v^2)$ can be used to test whether the additional restrictions on the specification of the error term in the stochastic frontier model is justified. Specifically, the null hypothesis, $g = 0$, is true when the estimated stochastic frontier model is equivalent to a traditional average response model. A one-sided likelihood ratio test can be used to test the null; however because of asymmetries, the test statistic is, asymptotically, distributed as an average of two chi-square distributions (Coelli, 1995.) Critical values, appropriate for testing the null can be found in Kodde and Palm, 1986.

As reported in table 2, the estimated value of γ, 0.95, indicates that the variations association with *u* comprise a large portion of the overall spread of the model's error term. In addition, a comparison of the likelihood values produced by the stochastic frontier and an average response model estimated with least squares produces a large test statistic[9]. For that reason, the least-squares version of the model can be rejected in favor of the stochastic frontier model with a very high degree of confidence.

Setting aside for the moment the statistical comparison of the models, what are the quantitative differences in the estimated parameters? The least-squares estimates of the frontier parameters are similar to the stochastic model. However there seems to be a tendency that for the land parameters to be larger in the stochastic model and for the non-land parameters to be slightly smaller (table 4.) For the state variables, the signs – with the exception of the year dummies – are consistent for both set of estimates, but the parameter values of generally smaller in the least-square estimation – especially relative to the standard errors associated with the least square parameters.

Parameter restrictions

Table 5 reports the estimated parameters that result from applying zero-restrictions to several sets of state-variable parameters. Table 6 presents a statistical test of the applied restrictions. Generally, the parameter values are not overly sensitive to the restrictions. However, omitting variables always significantly reduces the explanatory power of the model

[9] The calculated value of the likelihood ratios was 238. Consequently, the null hypothesis can be rejected at a 99% level of confidence.

and the restrictions can be rejected with a high degree of confidence. The single-parameter restrictions – those for education, wealth, the price of rice and the technical efficiency intercept – provide alternative tests for the t-scores reported earlier; the test yield identical results.

The restrictions on the rice-variety dummies, the year dummies and the weather variables are joint. Each set of restrictions could be rejected with at a 95% level of confidence and the restrictions on weather and varietal type at higher levels.

Finally, it is worth pointing out that all estimated frontier elasticities are positive and, generally, significantly so. This is consistent with the expectation that the underlying production function is strictly monotonically increasing in inputs.

A balanced panel

Mechanically, the overall variation in panel data that estimated models attempt to explain can be decomposed along the dimensions of the panel. In practice, this means that the composition of a sample can affect estimation results (Mundlak and Larson 1992). Separately, for technical efficiency models, it is reasonable to expect that some sources of technical efficiency will vary with time – for example, because of "learning" (Kumbhakar 1990; Lee and Schmidt 1993.) With unbalanced panels, the two effects are inseparable.

In this section, we use a balanced panel to estimate the base model in order to examine whether the significant time effects observed in the base period are due to a changing composition in the unbalanced panel. We pay a heavy price for doing so, reducing the number of observations from more than 1,500 to 432. Nonetheless, we find evidence that the previously measured time-effects are due to the changing composition of the sample. Moreover, keeping in mind that the significant changes in the two samples on which the estimates are based, the remaining parameter estimates from the balanced panel are very similar to the results from the unbalanced panel. The results are reported in table 7.

Except for the coefficient on upland rice, the parameters associated with the frontier variables are similar for both sample estimates. We suspect that the value associated with upland rice, which is large relative to the other land coefficients and relative to the unbalanced-sample result, may be an artifact of the sample reduction since only 7 households in the balanced sample produced upland rice.

The share of the model variance, s^2, that can be attributed to the inefficiency component of the model – as measured by g -- remains high at 0.97 in the balanced-panel results and statistically different from zero at a very high level of confidence. In contrast to the unbalanced panel, the year dummy variables are quantitatively smaller and statistically indistinguishable from zero. The finding is consistent with the notion that there are no unexplained effects proxied by time – at least in Camarines Sur. However, because the balanced panel includes only households from Camarines Sur, it is impossible to say whether the result generalizes to households in other provinces.

The balanced panel results do not contradict the conclusion that specialization, education and wealth all contribute positively to technical efficiency. Quantitatively, the balanced panel significantly larger effects for education and wealth. The technology results are unclear; they suggest that farmers improve efficiency significantly by introducing high-yielding varieties to their seed mix. However, the sign on the "high yield" variety is counter-intuitive and not statistically significant.

7. CONCLUSIONS

Based on panel data from rural households in Bicol, we find evidence that farmers take voluntary decisions of the kind normally attributed to risk coping strategies that lead to reduced productivity. The result is not sensitive to variations in the underlying model. Although short to medium term decisions regarding diversification and technology choice effect efficiency, these decisions are not the only source, or quantitatively a dominant source of foregone efficiency. Evidence suggest that small changes in weather and market outcomes are often more crucial. At the same time, the results indicate that short-term decisions and outcomes that, in accumulation, effect wealth and education have lasting and repeated consequences for technical efficiency.

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9. FIGURES AND TABLES

Figure 1: Area planted to rice and rice production in Bicol for 1978, 1983 and 1994.

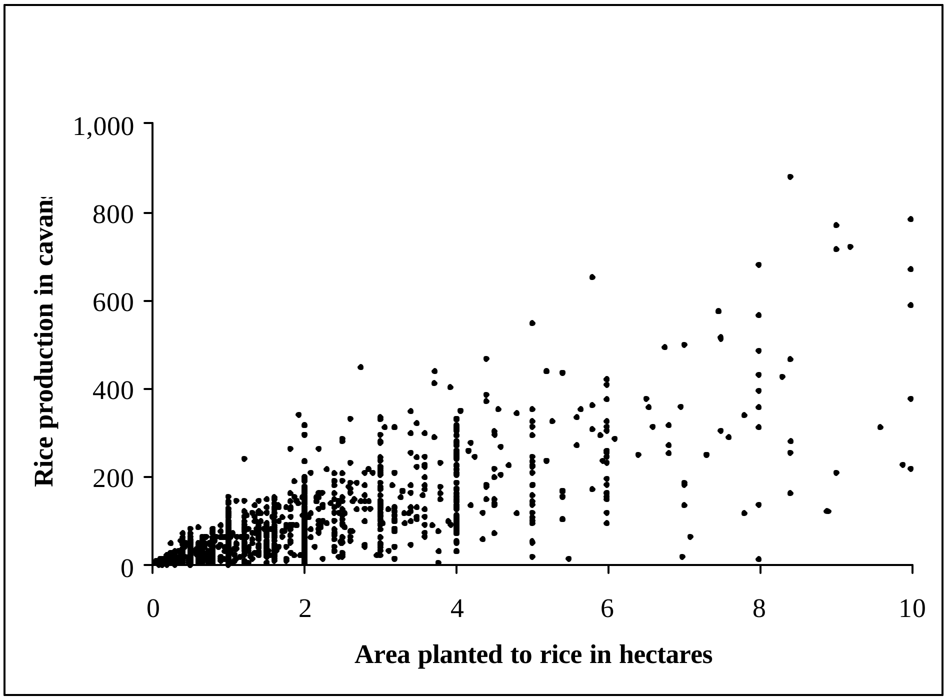

Table 1: Household averages for selected variables, 1978, 1983 and 1994

	All observations			**Balanced panel**		
Survey year	*1978*	*1983*	*1994*	*1978*	*1983*	*1994*
Output measures						
Rice production (cavans)	83.60	92.03	135.24	128.53	125.49	157.37
Rice yield (cavans/hectare)	43.68	45.78	59.06	47.33	46.48	60.10
Input measures						
Area Planted (hectares)	1.91	2.01	2.29	2.72	2.70	2.62
Type of land (hectares)						
Upland rain fed	0.07	0.07	0.02	0.02	0.02	0.02
Other rain fed	0.73	0.62	0.86	0.91	1.16	1.02
Gravity irrigated	0.69	0.94	0.63	0.84	0.78	0.58
Pump irrigated	0.42	0.38	0.78	0.95	0.74	1.00
Seeds (cavans)	3.53	3.96	5.51	5.48	5.74	6.34
Irrigation costs (1994 pesos)	56	75	104	101	155	115
Fertilizer costs (1994 pesos)	701	832	982	750	990	1,018
Other chemical input costs (1994 pesos)	774	954	2,100	1,284	1,351	2,473
Machine hours	62	45	107	130	70	140
Hired labor						
1978 definition, (hours)	2,053	-	-	2,164	-	-
1983 and 1994 definition (hours)	-	991	950	-	1,113	1,167
Family labor (hours)	400	493	318	468	642	348
Efficiency variables						
Price of rice per cavan (1994 pesos)	286	211	220	294	215	220
Area planted to corn and coconuts	1.35	0.92	0.76	0.76	0.54	0.54
Use of high yield varieties (share of households)	0.78	0.86	0.85	0.88	0.92	0.85
Use of traditional seeds (share of households)	0.22	0.14	0.15	0.13	0.08	0.15
Use of mixed high yield and traditional seeds (share of all households)	0.07	0.03	-	0.08	0.04	-
Education of household head (years of schooling)	5.97	6.41	6.86	6.38	6.65	6.91
Wealth proxy (value of home in 1994 pesos)	22,338	27,648	49,278	19,775	33,433	49,784
Weather variables						
Average weighted monthly rainfall (mm)l	265	262	317	272	260	326
Average weighted difference in rainfall from historic mean (mm)	(9.61)	(12.43)	48.81	(7.22)	(16.65)	53.33
Weighted quadratic mean difference in rainfall from historic mean (thousand mm^2)	26.37	20.75	22.50	27.74	19.94	23.61
Average weighted monthly temperature (C °)	23.54	23.43	23.78	23.55	23.23	23.78
Average weighted difference in temperature from historic mean (C°)	(0.03)	0.16	0.35	(0.02)	0.09	0.36
Weighted quadratic mean difference in temperature from historic mean ($C^{2\circ}$)	0.11	0.45	0.36	0.11	0.47	0.37

Source: Authors' calculation from survey and weather data

Table 2: Estimation results for the base model.

				Missing-value dummies	
	Frontier variables	*Estimate*	*t-score*	*Estimate*	*t-score*
ß0	Constant	2.929	21.381		
ß1	Gravity irrigated area planted	0.437	12.952	0.623	8.674
ß2	Pump irrigated area planted	0.356	7.425	0.553	6.750
ß3	Lowland rain-fed area planted	0.394	13.129	0.391	5.780
ß4	Upland rain-fed planted	0.303	5.614	0.196	2.321
ß5	Irrigation fuel costs	0.009	0.276	-0.080	-0.350
ß6	Seeds	0.142	5.993		
ß7	Fertilizer costs	0.093	5.138	-0.448	-3.471
ß8	Other chemical costs	0.106	6.077	-0.328	-3.079
ß9	Machine hours	0.076	4.467	-0.029	-0.296
ß10	Hired labor, 1978	0.087	1.508	-0.435	-0.959
ß11	Hired labor, 1983 and 1994	0.068	3.694	-0.257	-2.167
ß12	Family labor	0.025	1.770	-0.245	-2.140
	Technical inefficiency variables				
d0	Constant	-17.434	-11.047		
d1	Diversification	0.058	4.010		
d2	Education	-0.101	-3.786		
d3	Wealth	-0.590	-4.405	4.344	3.801
	Seed types				
d4	Mixed varieties	-0.444	-1.257		
d5	High yielding varieties	-0.162	-0.834		
d6	Price	-0.004	-23.588		
d7	Average weighted monthly rainfall	0.003	2.044		
d8	Average weighted difference in rainfall from historic mean	-0.007	-3.305		
d9	Weighted quadratic mean difference in rainfall from historic mean	0.017	2.910		
d10	Average weighted monthly temperature	0.605	21.528		
d11	Average weighted difference in temperature from historic mean	-1.253	-4.982		
d12	Weighted quadratic mean difference in temperature from historic mean	1.218	1.500		
d13	Year-effect, 1978	1.577	2.856		
d14	Year-effect, 1983	1.241	3.035		
	$s^2 = s_u^2 + s_v^2$	2.245	4.709		
	?	0.954	90.852		

Source: Bicol MPS data and authors estimation.

Table 3: Simulated changes in production for selected variables.

Assumed change	Impact on production		elasticity
	cavans	%	
Production decisions			
Switch to high-yield seeds	16.5	17.5%	0.18
Reduce diversify by an additional 0.5 ha.	2.7	2.9%	0.05
Investment decisions			
One-year increase in education level	9.5	10.1%	0.65
1,000 peso increase in wealth	2.0	2.1%	0.59
External shocks			
20 peso fall in the relative price of rice	-7.6	-8.0%	0.99
Rain level averages 10 cm below normal	-3.7	-3.9%	-10.62
Temperature averages 0.02° C below normal	-1.3	-1.4%	-0.33

Table 4: Comparison of stochastic frontier and least-squares estimates

	Stochastic frontier				Ordinary least squares			
			Dummies on missing values				Dummies on missing values	
	Estimate	t-score	Estimate	t-score	Estimate	t-score	Estimate	t-score
Frontier variables								
Constant	2.929	21.38			2.010	4.07		
Gravity irrigated rice land (hectares)	0.437	12.95	0.623	8.67	0.356	8.60	0.657	7.82
Pump irrigated rice land (hectares)	0.356	7.42	0.553	6.75	0.264	4.62	0.586	6.13
Lowland rain fed rice land (hectares)	0.394	13.13	0.391	5.78	0.324	8.98	0.370	4.63
Upland rice land (hectares)	0.303	5.61	0.196	2.32	0.295	4.47	0.224	2.17
Irrigation fuel costs (pesos)	0.009	0.28	-0.080	-0.35	0.015	0.33	-0.130	-0.40
Seeds (cavans)	0.142	5.99			0.162	5.56		
Fertilizer (pesos)	0.093	5.14	-0.448	-3.47	0.097	4.37	-0.453	-2.90
Other Chemicals (pesos)	0.106	6.08	-0.328	-3.08	0.102	4.64	-0.323	-2.54
Aggregated machine hours	0.076	4.47	-0.029	-0.30	0.090	4.56	-0.132	-1.17
Hired labor proxy for 1978	0.087	1.51	-0.435	-0.96	0.153	2.17	-0.877	-1.59
Hired labor in hours for 1983 and 1994	0.068	3.69	-0.257	-2.17	0.084	3.82	0.264	1.51
Family labor in hours	0.025	1.77	-0.245	-2.14	0.068	4.02	-0.218	-1.55
Technical efficiency variables								
Constant	-17.434	-11.05						
Area planted to other crops (hectares)	0.058	4.01			0.013	3.03		
Schooling of rice farmer (years)	-0.101	-3.79			-0.013	-2.59		
Wealth (ln pesos)	-0.590	-4.41	4.344	3.80	-0.080	-6.54	0.592	4.39
Dummy for high and traditional rice varieties	-0.444	-1.26			-0.006	-0.07		
Dummy for high yield rice varieties	-0.162	-0.83			-0.004	-0.06		
Selling price for rice (pesos)	-0.004	-23.59			-0.001	-3.08		
Average monthly rainfall in mm per growing months (mm(	0.003	2.04			-0.000	0.43		
Aver. monthly difference in rainfall from the long-term mean in mm	-0.007	-3.31			-0.001	-1.52		
Aver. quadratic difference in rainfall from long-term mean in mm²/1000	0.017	2.91			0.004	2.26		
Average temperature in C° of the growing months	0.605	21.53			0.023	1.26		
Aver. monthly difference in temperature from the long-term mean in C°	-1.253	-4.98			-0.099	-1.77		
Aver. quadratic difference in temperature. from long-term mean in C°²	1.218	1.50			0.105	0.82		
Dummy for the year 1978	1.577	2.86			-0.394	-2.69		
Dummy for the year 1983	1.241	3.03			0.155	2.57		

Note: In order to comply with technical efficiency conventions, the signs on the OLS fixed-effect technical-efficiency parameters have been reversed. Consequently, a negative sign indicates that technical inefficiency (efficiency) increases (decreases) with an increase in the value of the associated variable.

Table 5: Estimation results from restricted models.

Frontier variables	param.	t-score	param.	t-score	param.	t-score	param.	t-score	param.	t-score	param.	t-score	param.	t-score	param.	t-score	param.	t-score
Constant	2.93	21.38	2.93	21.64	2.91	22.05	2.93	21.88	2.95	22.27	2.90	22.04	2.88	22.20	2.91	21.54	2.93	20.79
Gravity irrigated rice land in ha	0.44	12.95	0.44	13.10	0.43	13.07	0.43	12.62	0.45	13.13	0.44	13.18	0.44	13.12	0.44	12.49	0.44	12.87
Pump irrigated rice land in ha	0.36	7.42	0.36	7.36	0.35	7.30	0.35	7.24	0.36	7.35	0.36	7.47	0.36	7.42	0.36	7.22	0.36	7.26
Lowland rain fed rice land in ha	0.39	13.13	0.39	13.00	0.39	13.13	0.39	12.89	0.40	13.16	0.40	13.33	0.40	13.30	0.39	12.69	0.39	12.97
Upland rice land in ha	0.30	5.61	0.30	5.63	0.29	5.28	0.31	5.69	0.31	5.73	0.31	5.72	0.31	5.64	0.31	5.73	0.30	5.62
Irrigation fuel costs in pesos	0.01	0.28	0.01	0.27	0.01	0.21	0.01	0.35	0.01	0.37	0.01	0.24	0.01	0.22	0.03	0.77	0.00	0.16
Seeds in cavan	0.14	5.99	0.14	5.96	0.14	6.00	0.14	5.92	0.15	6.14	0.14	6.03	0.14	6.03	0.13	5.43	0.15	6.22
Fertilizer in pesos	0.09	5.14	0.09	4.88	0.09	5.20	0.09	5.14	0.10	5.26	0.09	5.17	0.09	5.32	0.09	4.80	0.09	4.97
Other Chemicals in pesos	0.11	6.08	0.11	6.13	0.11	6.02	0.11	5.99	0.11	6.12	0.10	5.86	0.10	5.91	0.10	5.86	0.11	6.18
Aggregated machine hours	0.08	4.47	0.08	4.52	0.08	4.41	0.08	4.52	0.07	4.33	0.07	4.46	0.07	4.47	0.07	4.15	0.08	4.62
Hired labor proxy for 1978	0.09	1.51	0.09	1.49	0.09	1.34	0.09	1.48	0.10	1.58	0.08	1.31	0.08	1.47	0.07	0.63	0.09	1.50
Hired labor in hours for 83 & 94	0.07	3.69	0.07	3.68	0.07	3.81	0.07	3.67	0.07	3.83	0.07	3.51	0.07	3.57	0.07	3.85	0.06	3.30
Family labor in hours	0.02	1.77	0.03	1.83	0.03	1.96	0.02	1.67	0.02	1.55	0.02	1.76	0.02	1.74	0.03	1.85	0.02	1.54
Efficiency variables																		
Constant d0	-17.43	-11.05			-16.53	-2.63	-16.49	-2.84	-20.10	-2.88	-17.53	-3.08	-17.91	-3.85	0.22	0.44	-15.40	-2.56
Area planted to other crops	0.06	4.01	0.05	4.54			0.05	4.78	0.05	4.84	0.06	5.02	0.06	5.16	0.03	2.88	0.06	4.98
Schooling of rice farmer	-0.10	-3.79	-0.10	-3.72	-0.09	-3.99			-0.14	-5.06	-0.09	-4.16	-0.10	-4.52	-0.04	-2.28	-0.10	-4.18
Wealth	-0.59	-4.41	-0.54	-5.60	-0.55	-5.56	-0.56	-6.02			-0.56	-5.58	-0.57	-6.53	-0.26	-6.35	-0.58	-5.87
Dummy for mixed rice varieties	-0.44	-1.26	-0.51	-1.49	-0.46	-1.30	-0.49	-1.50	-0.73	-1.58			-0.44	-1.05	-0.16	-0.51	-0.31	-0.89
Dummy for high yield rice varieties	-0.16	-0.83	-0.34	-1.69	-0.21	-1.09	-0.18	-0.92	-0.52	-2.40			-0.18	-0.86	-0.07	-0.42	-0.08	-0.50
Selling price for rice	0.00	-24.15	0.00	-21.43	0.00	-25.60	0.00	-23.40	0.00	-25.69	0.23	0.87			0.00	-3.60	0.00	-25.36
Average monthly rainfall	0.00	2.04	0.00	1.26	0.00	2.03	0.00	1.98	0.00	2.34	0.00	2.10	0.00	2.19			0.00	2.30
Difference in rainfall from long-term mean	-0.01	-3.31	0.00	-2.38	-0.01	-2.91	-0.01	-2.89	-0.01	-3.76	-0.01	-2.96	-0.01	-3.23			-0.01	-4.13
Quadratic difference in rainfall	0.02	2.91	0.01	2.60	0.02	2.82	0.02	2.82	0.02	3.27	0.01	2.66	0.02	2.89			0.02	3.16
Average temperature	0.60	21.53	-0.07	-1.88	0.60	2.62	0.57	2.77	0.70	2.79	0.59	2.89	0.61	3.64			0.59	2.62
Difference in temperature from average	-1.25	-4.98	-0.45	-2.20	-1.13	-2.89	-1.14	-3.05	-1.42	-3.31	-1.14	-3.23	-1.17	-3.70			-1.34	-3.47
Quadratic difference in temperature from average	1.22	1.50	0.79	1.09	0.93	1.06	1.03	1.34	1.11	1.78	0.94	1.30	1.00	1.45			0.82	1.86
Dummy for the year 1978	1.58	2.86	1.24	2.96	1.48	3.27	1.51	3.63	1.95	3.86	1.14	2.74	1.20	2.80	1.01	3.51		
Dummy for the year 1983	1.24	3.03	0.92	2.75	1.15	3.70	1.17	3.90	1.60	3.86	1.21	3.74	1.25	3.71	0.74	2.99		
s2 (Sigma-squared)	2.25	4.71	2.00	4.57	1.94	5.60	1.90	5.80	2.25	5.97	1.91	6.08	1.97	7.23	1.07	11.03	2.01	5.48
? (Gamma)	0.95	90.88	0.95	84.28	0.95	96.68	0.95	93.33	0.95	113.87	0.95	101.93	0.95	105.10	0.91	75.99	0.95	93.28

Table 6: Tested restrictions about model specification

Omitted variables tests	?^{2} - statistic
Technical inefficiency constant, $d_0 = 0$	10.45
Area diversification, $d_1 = 0$	7.69
Education, $d_2 = 0$	6.79
Wealth, $d_3 = 0$	38.01
Rice varieties, $d_4 = d_5 = 0$	14.99
Price, $d_6 = 0$	14.08
Weather, $d_7 = d_8 = d_9 = d_{10} = d_{11} = d_{12} = 0$	32.77
Year effects, $d_{13} = d_{14} = 0$	6.56

Note: The test statistic, calculated as a likelihood ratio, is based on a mixed ?^{2} – distribution (Kodde and Palm, 1986). The null hypothesis could be rejected in all cases with a 95% degree of confidence.

Table 7: Estimated model parameters from full panel and from balanced panel

	Full panel				Balanced panel			
			Missing-value dummies				Missing-value dummies	
	Estimate	t-score	Estimate	t-score	Estimate	t-score	Estimate	t-score
Frontier variables								
Constant	2.929	21.38			2.511	6.80		
Gravity irrigated rice land in ha	0.437	12.95	0.623	8.67	0.396	7.62	0.498	5.15
Pump irrigated rice land in ha	0.356	7.42	0.553	6.75	0.299	4.45	0.299	4.45
Lowland rain fed rice land in ha	0.394	13.13	0.391	5.78	0.358	7.83	0.276	3.07
Upland rice land in ha	0.303	5.61	0.196	2.32	0.933	2.69	0.145	0.80
Irrigation fuel costs in pesos	0.009	0.28	-0.080	-0.35	0.019	0.55	-0.121	-0.49
Seeds in cavan	0.142	5.99			0.050	1.60		
Fertilizer in pesos	0.093	5.14	-0.448	-3.47	0.070	2.54	-0.382	-1.82
Other Chemicals in pesos	0.106	6.08	-0.328	-3.08	0.206	7.56	-0.339	-1.04
Aggregated machine hours	0.076	4.47	-0.029	-0.30	0.066	2.54	0.259	1.16
Hired labor proxy for 1978	0.087	1.51	-0.435	-0.96	-0.003	-0.04	0.144	0.23
Hired labor in hours for 83 & 94	0.068	3.69	-0.257	-2.17	0.056	1.80	-0.248	-1.15
Family labor in hours	0.025	1.77	-0.245	-2.14	0.059	2.90	-0.483	-3.28
Technical inefficiency influencing variables								
Constant	-17.434	-11.05			-3.755	-0.41		
Area planted to other crops in ha	0.058	4.01			0.466	2.17		
Schooling of rice farmer in years	-0.101	-3.79			-0.115	-1.70		
Wealth, natural log of family home value	-0.590	-4.41	4.344	3.80	-0.832	-1.91	5.700	1.88
Dummy for high and traditional. rice varieties	-0.444	-1.26			-1.636	-1.01		
Dummy for high yield rice varieties	-0.162	-0.83			1.776	1.35		
Selling price for rice	-0.004	-23.59			-0.012	-1.78		
Average monthly rainfall in mm per growing months	0.003	2.04			-0.004	-1.05		
Aver. monthly difference in rainfall from the long-term mean in mm	-0.007	-3.31			-0.011	-1.36		
Aver. quadratic difference in rainfall from long-term mean in mm²/1000	0.017	2.91			0.061	2.01		
Average temperature in C° of the growing months	0.605	21.53			0.107	0.31		
Aver. monthly difference in temperature from the long-term mean in C°	-1.253	-4.98			-1.610	-1.53		
Aver. quadratic difference in temperature from long-term mean in C°²	1.218	1.50			2.994	1.28		
Dummy for the year 1978	1.577	2.86			-0.233	-0.24		
Dummy for the year 1983	1.241	3.03			-0.166	-0.39		
s2 (Sigma-squared)	2.245	4.71			2.130	1.81		
? (Gamma)	0.954	90.85			0.967	55.42		