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Access to Markets and Farm Efficiency: A Study of Rice Farms in the Bicol Region, Philippines*

by

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ABSTRACT

This paper presents an empirical investigation of the relationship between the spread, spatially and temporally, of market institutions and improvements in the productivity and efficiency of farmers. The data used in this study were collected over two decades in a sample of rice farms in the Bicol Region of the Philippines. Our estimates reveal a significant inverse relationship between distance from the market and farm productivity and efficiency in 1983. While there are substantial improvements in yields, unit costs, and efficiency in the two decades that followed, the gains are larger in the more remote and sparsely populated villages. This finding suggests that the relationship between remoteness and farm outcomes has weakened over time. We also find that the development of markets in the peripheral villages and the improved connectivity between the peripheral villages and market centers are facilitated by population growth, infrastructural investments (specifically, irrigation and roads), and the availability of agricultural extension programs.

Keywords: Farm Efficiency; Agricultural Markets; Institutional Conditions; Philippines

JEL Classifications: O12, O13, Q12

INTRODUCTION

Rice farming communities in South and Southeast Asia have undergone tremendous change particularly since the introduction of Green Revolution technologies in the 1960s (Evenson and Gollin 2003). Perhaps the most dramatic and lasting difference between a peasant village then and now is the pervasiveness of markets and the consequent integration of previously isolated and subsistence farmers with regional, national, and even global markets for commodities and factors of production.

This paper presents an empirical investigation of the relationship between the spread, spatially and temporally, of market institutions and improvements in the productivity and efficiency of rice farmers over a period of two decades. The analysis synthesizes two lines of research on developing agricultural economies that have benefitted greatly from the contributions of Professor Robert Evenson over four decades: 1) the investigation of the causes and consequences of transaction costs and dysfunctional markets (Evenson and Roumasset 1986; Lanzona and Evenson 1997; DeSilva, Evenson, and Kimhi 2006; Naseer, Evenson, and DeSilva 2007), and 2) the analysis of the determinants of farm productivity and efficiency (Rosegrant and Evenson 1992; Bravo-Ureta and Evenson 1994; Evenson and Mwabu 2001).

Our primary goal is to estimate the effect of the levels and changes in the access to markets on yields, unit costs, and farm efficiency. More broadly, our estimates trace the link between village-level institutional and transaction cost conditions with farm-level outcomes and help us to draw policy inferences regarding the value to farmers of improved institutional conditions that facilitate the functioning of agricultural commodity and factor markets.

DATA

This study utilizes household level data from Camarines Sur, one of the six provinces that form the Bicol Region in the Philippines. Although rainfall is relatively abundant and water is generally plentiful in the Bicol River basin, the predominantly agricultural Bicol has long been the poorest region in the country (Lanzona and Evenson 1997). Among the reasons for the economic backwardness of the Bicol is its location in the relatively isolated southeastern end of the Luzon Island and the terrain that is mostly mountainous. The data were collected as part of the Bicol Multipurpose Survey, a rich multi-year household and barangay (village) survey carried out in 1978, 1983, 1994, and 2003 through a series of collaborations between the Bicol River Basin Development Program and the Economic Growth Center of Yale University (Lanzona 1997; Bicol River Basin Development Program 1998; Naseer, Evenson, and DeSilva 2007).[1] The sample used here contains an unbalanced panel from 413 households in 1983 and 196 households in 2003. The households come from 59 villages (barangays), 40 of which are located in rural areas, 9 are in towns (poblacions), and 10 are in cities. The availability of an unbalanced panel spanning over two decades is unusual for a micro dataset from a rural agricultural region of a developing country and provides us with a sufficiently long time frame to study changes in institutional conditions.

THEORETICAL AND EMPIRICAL BACKGROUND

Spatial differences in the productivity of farms have long attracted the attention of economists. Schultz (1953) predicted in his "urban-industrial impact hypothesis" that the "locational matrix" of economic development has a center that is "primarily industrial-urban in composition" and that "those parts of agriculture which are situated favorably in relation to such a center" will benefit from well functioning economic organizations (147). The urban-industrial center, in Schultz's view, functions as a source of technological innovation and contains relatively efficient factor and product markets. More generally, the advantage of the urban-industrial center can be encapsulated in its ability to minimize transaction costs associated with "information, search, negotiation, screening, monitoring, coordination and enforcement" (Sadoulet and de Janvry 1995, 254). As Evenson and Roumasset (1986) describe, "In highly developed market economies, transactions are low cost. The public sector provides goods and standards that facilitate transactions. Communication is low cost" (141).

The "costs of engaging in market transactions vary a great deal over the development process" and are particularly "significant in rural economies where communications and transportation facilities are poor, markets are segmented, and access for market participation is

[1] Professor Evenson played an instrumental role in the design and implementation of all four waves of the Bicol Multipurpose Survey. His long and fruitful engagement with the Philippines began with the three years he spent at the University of the Philippines at Los Banos from 1974 to 1977 and has resulted in a series of studies including several that are cited in this article.

restricted” (Evenson and Roumasset 1986, 141; Lanzona and Evenson 1997, 1). For example, spot markets for labor are subject to high transaction costs in rural labor markets where “institutions such as labor and contract law and formal employment assistance mechanism are not in place” (DeSilva, Evenson, and Kimhi 2006, 851). In an analysis of the same Bicol villages that are the subject of the present study, DeSilva, Evenson, and Kimhi (2006) find that farmers engage in the costly activity of directly supervising hired labor more intensively in villages that are less urbanized and located far from the market towns.

In the peripheral areas of Schultz’s locational matrix, formal markets are often weak or, in some cases, absent. For example, Bicol villages with high transaction costs have lower wage labor market participation and earnings (Lanzona and Evenson 1997). In place of formal markets, the peripheral villages are typically served by “a pattern of market organizations with heavy reliance on traditional institutions” (Evenson and Roumasset 1986, 141). According to a vast literature in the tradition of New Institutional Economics (NIE), institutions such as the family farm, sharecropping, and social networks respond to and help overcome the information and enforcement problems that arise from missing or incomplete markets (Otsuka, Chuma, and Hayami 1992; Hoff, Braverman, and Stiglitz 1993; Lanjouw 1999). In the Philippines, it has been documented that high transaction cost encourages households with large farms to have larger families and that community-based social organizations help alleviate disadvantages faced by farmers in remote Bicol villages (Evenson and Roumasset 1986; Naseer, Evenson, and DeSilva 2007).

Although there is widespread acknowledgment of the economic role of informal institutions in developing agrarian economies, there is a consensus that these institutions are second best-efficient (Hoff, Braverman and Stiglitz 1993). For example, the reduction in the technical efficiency of rice farmers in the Bicol due to adverse institutional conditions is only partly offset by the direct supervision of workers (Evenson, Kimhi, and DeSilva 2000). Focusing on markets for insurance for price and weather risks, Larson and Plessmann (2009) find that “community-based informal arrangements are subject to failure when adverse events are extreme or occur with unusual frequency” (30). As documented in two studies of the Bicol (Lanzona and Evenson 1997; Larson and Plessmann 2009), weak or absent markets for labor, credit and insurance have adverse implications not only for efficiency but for income distribution when market imperfection imposes disproportionate costs on the poor and the landless.

With the development of market infrastructure, informal institutions lose their advantage vis-à-vis formal markets. Their erosion is accelerated by the weakening of traditional methods of enforcement that typically accompanies the process of development (Hoff, Braverman, and Stiglitz 1993). Larson and Plessmann (2009) find that the technical efficiency of Bicol rice farmers is higher in villages with favorable market conditions, proxied in their study by the barangay level price of rice.

Whether a rural farmer is able to benefit from the transaction cost advantages of well developed markets depends on his or her proximity and connectivity to the core (Benziger 1996; Jacoby 2000). In the context of rural Filipino villages, the core does not need to be urban or industrial as suggested by Schultz; rural towns (e.g., poblacions in the Philippines) can provide access to well functioning markets for commodities and factors of production and serve as sources of technical knowledge and skills. With infrastructural improvements such as new roads and rural electrification and with the development of agricultural extension services (see Birkhaeuser, Evenson, and Feder 1991 and Evenson 2001 for review) that bring ideas and technologies from the center to the periphery, locational disadvantages of remote villages vis-à-vis market towns can be overcome (Flores-Moya, Evenson, and Hayami 1978; Evenson 1986; Jacoby 2000). Development of well-functioning market institutions in the peripheral villages themselves can be promoted through government action (e.g., improvements in legal systems) and is aided by population growth that often accompanies economic development. With good roads, communication networks, extension services, well-developed market supporting institutions, and high population densities, the distance from the center matters less for the peripheral villages.

Based on the insights from the studies discussed, the primary hypothesis of this study is that greater access to markets promotes growth in agricultural productivity and efficiency in the Bicol rice farms. In the next section, we present a descriptive portrait of the correlation between market access and farm outcomes across time and space. In the following section, results of a regression analysis that explores this correlation in greater detail are discussed.

DESCRIPTIVE PORTRAIT

The empirical analysis relies on two proxy variables to measure access to markets at the village level: 1) the distance from the village (barangay) to the market town (poblacion) measures the location of the peripheral rural village in relation to the market core and 2) the population density of the village (barangay) is a measure of the level of market development in the barangay itself. To verify whether these two variables adequately capture barangay level transaction cost conditions, we examine their correlation with the ratio of the buying and selling prices of rice at the barangay level, a variant of the "price wedge" measure of transaction costs developed for the Bicol region by Lanzona and Evenson (1997).[2] As expected, distance to the poblacion is positively correlated (ρ=0.2818) and population density is negatively correlated (ρ =-0.2453) with the "price wedge" measure of transaction costs. [3] In so far as localized price wedges or differences between the buying and selling prices of commodities reflect localized transaction costs (Lanzona and Evenson 1997), this correlation provides evidence that the two measures of market access we have chosen are reasonable proxies for transaction cost conditions at the barangay level. At the same time, the fact that the correlation coefficients are substantially less than 1 tells us that the "price wedge" based transaction cost measures do not fully encapsulate the disadvantages associated with remoteness and low population density.

Yields and Unit Costs

If the hypothesized advantages of market access exist, we would expect villages with greater access to markets to have higher average farm yields (output per hectare) and lower unit costs (cost per unit of output). This is indeed the case for yields in 1983, with the average yield progressively lower in barangays that are located away from the poblacion (Figure 1) and in barangays that are less densely populated (Figure 2).

Over the two decades, the associations between the yield and the two measures of market access have become markedly weaker; while yields have improved across the board by 2003, the improvement is relatively larger in the more distant (Figure 1) and more sparsely populated (Figure 2) barangays. The spatial convergence may be a result of improvements in roads and

2 Their measure was constructed by "measuring the effect of village dummies on the observed prices wedges" between the buying and selling prices of rice (p.2).

3 In Lanzona and Evenson (1997), the distance to poblacion is the variable most strongly correlated with the barangay wedge between the buying and selling price of rice.

communications infrastructure or in the institutional environment, both of which enhance access to the poblacions and promote the development of market institutions in the peripheral barangays. With better roads, electricity, and telephone lines and with better legal systems and contract enforcement, physical distance to the market matters less. There has also been population growth in the peripheral villages (shown in Figures 1 and 2 by the relative size of the bubbles) resulting in a noticeable decline in the variation in population densities (Figure 2). As peripheral villages become more densely populated, an environment conducive to development of efficient markets is created, lowering transaction costs.

Changes in unit costs follow a somewhat different pattern. In 1983, unit costs were not strongly correlated with distance to poblacion (Figure 3) but decreased sharply with barangay population density (Figure 4). Between 1983 and 2003, the unit cost (measured in 1994 prices) decrease is most pronounced in barangays that are close to the poblacion and those with low population densities (Figures 3 and 4).

The relation between distance to poblacion and unit cost is noticeably steeper in 2003 than in 1983, whereas the relation between population density and unit cost is flatter. Conforming to our expectations, unit costs vary with population density much the same way as yields vary with population density. However, the pattern with respect to the distance to poblacion is different: The relatively flat relationship in 1983 arises possibly because lower input costs (land rents and wages) in remote areas compensate for lower yields. The inter-temporal pattern possibly reflects factor prices that have evolved unfavorably for the distant barangays; while greater competition may lower prices for inputs such as fertilizer and tractors in the proximate barangays, the advantage remote barangays had in terms of lower labor and land costs may have eroded with greater labor mobility and improved market infrastructure. Improvements in the markets for factors that are relatively abundant in the remote villages do not necessarily benefit producers.

Table 1 represents the patterns illustrated graphically in the form of simple regression coefficients estimated at the household level. For farms located in the poblacion itself, i.e., 0 distance from the poblacion, the average yield increased by 25% in the two decades. In addition, the elasticity of the yield with respect to distance to the poblacion decreases substantially in magnitude but remains significantly negative. Unit cost decrease by about 25%, but the association between distance to poblacion and unit cost is not statistically significant in either year even though the elasticity increases in magnitude (as seen in Figure 3). In 1983, population density was positively associated with yields and negatively associated with unit costs, whereas both relationships are smaller and statistically insignificant in 2003.

Technical and Cost Efficiency

High yields (partial factor productivity) and low unit costs do not necessarily make a farm efficient (Rosegrant and Evenson 1992; Bravo-Ureta and Evenson 1994). Yields and unit costs are influenced by best-practice technologies, i.e., production and cost frontiers, and the ability of farmers to utilize them. A farm is technically efficient when it maximizes output conditional on input levels and the technology, operating on the production possibilities frontier (or the equivalent iso-quant); a farm is cost efficient when it minimizes costs conditional on the technology, level of output, and factor prices, operating on the cost frontier (or the equivalent iso-cost curve). Stochastic frontier analysis (see Kumbhakar and Lovell 2000 for overview) provides us with a method with which farm-level data on inputs, outputs, and prices are utilized to quantify levels of farm efficiency (Aigner, Lovell, and Schmidt 1977; Meeusen and van der Broeck 1977). Two examples of the application of this method are a study of cotton and cassava farmers in eastern Paraguay by Bravo-Ureta and Evenson (1994) and a study of Bicol rice farmers by Evenson, Kimhi, and DeSilva (2000).

We investigate both channels, technical (or production) efficiency and cost efficiency, keeping in mind that a technically efficient farm may still be cost inefficient if it is unable to achieve allocative efficiency, the utilization a bundle of inputs such that marginal returns equate relative factor prices (Farrell 1957; Coelli 1996). We compute the technical and cost efficiency of farm households by estimating the following production and cost frontier equations.

The Cobb-Douglas production frontier estimated is the version proposed for unbalanced panel data by Battese and Coeli (1992).

$$y_{it} = \beta_0 + \beta_1 x_{it} + u_{it} - v_{it}$$

where y_{it} is the logarithm of the output of farm i at time t=1,..,T, x_{it} is a vector of the logarithms of inputs and dummy variables for type of irrigation and year, u_{it} is an error term that is distributed i.i.d.$N\sim(0,\sigma_u^2)$, $v_{it} = v_i \exp\left(-\vartheta(t-T)\right)$, and $v_i$follows an i.i.d. distribution that is truncated at zero of $N\sim(\mu,\sigma_v^2)$,. The non-negative error term v_{it} is assumed independently distributed from the random error u_{it} and represents the technical inefficiency, or distance from the production frontier, for each farm i at time t.

The dual cost frontier estimated has the following analogous form:

$$c_{it} = \beta_0 + \beta_1 y_{it} + \beta_2 p_{it} + u_{it} + w_{it}$$

Here, c_{it} is the logarithm of the total cost of farm i at time t, p_{it} is a vector of factor prices, and w_{it} is an analogous truncated non-negative error term that represents cost inefficiency, or the distance from the cost frontier. Note that cost inefficient farms are located above the cost frontier, whereas technically inefficient farms are located below the production frontier.

The results are reported in Table 2: Both production and cost frontier models are estimated in two specifications. The first assumes that the non-negative error term is drawn from a distribution that is truncated at zero, whereas the second estimates the truncation point as a parameter (μ). The second model is favored because the estimates of the more flexible model reveal that the truncation point is significantly different from zero. Two findings in the frontier estimates deserve mention: first, there is evidence from both the production and cost frontiers that there are scale economies in rice farming; second, the production frontier has shifted inward from 1983 to 2003, whereas the cost frontier has not remained unchanged. The inward shift in the production frontier is puzzling and it is possible that the year dummy has absorbed measurement errors between the two waves and other omitted variables.

Our focus, however, is not so much on the properties of frontier itself but on the distance of farms from the frontier. At the farm level, the technical efficiency can be estimated by computing the ratio of observed to maximum feasible output where the latter is determined by the stochastic production frontier (Lovell 1993). The technical efficiency is interpreted as mean distance below the production frontier and is defined (for a Cobb-Douglas frontier) as follows:

$$TE_{it} = \frac{\exp\,(\beta_0 + \beta_1 x_{it} + u_{it} - v_{it})}{\exp\,(\beta_0 + \beta_1 x_{it} + u_{it})} = \exp\,(-v_{it})$$

Analogously, the cost efficiency of a farm can be interpreted as the mean distance above the cost frontiers and is defined as follows:

$$CE_{it} = \frac{exp(\beta_0 + \beta_1 y_{it} + \beta_2 p_{it} + u_{it} + w_{it})}{\exp\,(\beta_0 + \beta_1 y_{it} + \beta_2 p_{it} + u_{it})} = \exp\,(w_{it})$$

Note that technical efficiency varies between 0 (inefficient) and 1 (efficient), whereas cost efficiency varies from 1 (efficient) to infinity (inefficient).

The estimates (reported in Table 2) show that the average technical efficiency in our sample increased from 0.642 to 0.846 in the twenty years; conditional on technology and inputs, the average farm's production has increased from 64.2% to 84.6% of the maximum attainable output. Analogously, cost inefficiency has decreased from 1.997 to 1.129; the production costs of the average farm decreased from 99.7% to 12.9% above the minimum attainable costs. Both results indicate substantial improvements in efficiency.

Our hypothesis is that access to markets enhances both the technical and cost efficiency of farms. With high transaction costs and incomplete markets, the input mix used by farmers may not equate marginal returns with factor prices and the farming methods used may not reflect the best-practice technologies. With greater access to markets, farmers in peripheral villages benefit from technological change, shifting the production possibilities frontier outward and the cost frontier inward, and experience gains in the technical and allocative efficiency. Figures 5 and 6 correlate the estimated distance from the production frontier (technical efficiency) of farms against the distance from the barangay to the poblacion and the barangay population density.

The variation in technical efficiency across barangays mirrors that of the yield. In 1983, technical efficiency is higher, on average, in barangays that are close to the poblacion and in barangays that are relatively densely populated. In 2003, both relationships are much weaker even though there is a general increase in technical efficiency across all barangays and the variation in technical efficiency has decreased substantially. The picture that emerges is consistent with widespread development of markets across the region.

Figures 7 and 8 correlate the estimated distance from the cost frontier (cost inefficiency) against the distance from the barangay to the poblacion and the barangay population density. The pattern that emerges supports our hypothesis of market development further; the strong negative relationship between cost efficiency and distance to the poblacion and the strong positive relationship between cost efficiency and barangay population density observed in 1983 is weakened considerably by 2003. Both the mean and the variance of cost inefficiency are also much smaller in 2003 than in 1983. The pattern of cost efficiency is different from what we observed for unit costs; this is because, unlike unit costs, cost efficiency is conditional on factor prices. The relatively high unit costs in remote barangays in 2003 appear to be caused by higher factor prices rather than the cost inefficiency, i.e., the ability to use the optimal input mix given factor prices, of farmers.

MULTIVARIATE ANALYSIS

This section investigates the underlying causes of the differences in farm productivity and efficiency that was observed over time and across barangays in the previous section, paying particular attention to the role played by the two market access variables. In the cross-sectional estimates, we are interested in examining how differential access to markets across barangays manifest in differences in farm productivity and efficiency. In the inter-temporal comparison, we distinguish changes in productivity and efficiency that is attributable to inter-temporal changes in the market access variables from the changes in productivity and efficiency that arise from inter-temporal changes in the marginal influence of these variables. For example, a distant and small barangay may have experienced population growth over the two decades; at the same time, the construction of new roads may have alleviated the disadvantages that arise from its small size and remoteness[4]. Both of these developments have implications for the productivity and efficiency of farmers in this barangay.

Yield and Unit Cost Estimates

Table 3 reports coefficient estimates of the two market access variables obtained in four sequential regression model specifications: the first model contains only the two market access variables. The next three models sequentially add control variables for household characteristics, barangay level factor prices, and barangay level institutional conditions. Estimates are carried out separately for each year and for the two dependent variables, yield and unit cost. For institutional conditions, we add a dummy variable for whether the barangay has roads in good condition, a dummy variable for whether the barangay has access to extension services, and a “price wedge” transaction cost measure, specifically the premium received by rice bought over paddy (palay) sold in the same barangay. By adding these sets of variables sequentially, we are able to ascertain how each set mediates the relation between the two market access variables, on the one hand, and the farm yields and unit costs, on the other hand.

4 Unlike population density, the distance to the poblacion is relatively time invariant.

In the model that contains only the two market access variables (column 1), a 1% increase in the distance to the poblacion lowers the yield, on average, by 13.1% in 1983 and 8.2% in 2003, whereas controlling for distance to the poblacion, population density has a statistically insignificant effect of 5.5% and 0.2% respectively. For every 1% increase in the population density, unit costs decreased by 14.2% in 1983. Neither the effect of population density on unit costs in 2003 nor the effect of distance to poblacion on unit costs in both years is statistically significant. In both years, the market access variables are jointly significant at the 5% level in the determination of yields but not unit costs. The results of this simple benchmark model suggest that lack of market access created two problems for farmers, with distance to poblacion negatively influencing yields and low population density negatively influencing unit costs in 1983 and that both these disadvantages have been reduced by 2003.

When we add household level control variables, the qualitative results are not affected. The disadvantage of remote farms in 1983 is in part attributable to the less favorable attributes (e.g., lower levels of education) of the farmers themselves. However, now the distance to poblacion has a larger effect on yields in 2003 than in 1983. When we introduce controls for barangay level factor prices, the same pattern is reinforced; now the effect of distance to poblacion on yield is not statistically significant. When controls are introduced for barangay level institutional conditions—road quality, transaction costs, and availability of extension services—the effect of population density on unit costs also becomes smaller and statistically insignificant. This exercise reveals that, in 1983, distance to the poblacion influences yields because the distant barangays have unfavorable household attributes and factor prices, and that population density influences unit costs because the sparsely populated barangays have insufficient roads, inadequate access to extension services and, more generally, high transaction costs. In both years, market access effects, if they exist, are explained by the control variables. The one exception, however, is the effect of distance to poblacion on yields in 2003; this effect remains robust and statistically significant in all four specifications, suggesting that remoteness influences yields in ways that are not accounted for by the included variables.

In Table 4, we report five variants of the fully specified model for the determination of yields. The OLS (first column) and random effects (fourth column) specifications for the pooled sample yield similar results.[5] These models identify several important determinants of

[5] This is not surprising because our unbalanced panel contains very few households for which data are available in both years.

high yields: 1) The availability of gravity and pump irrigation improves yields by as much as 35.5% and 32% respectively. 2) Elementary schooling (of the household head) improves yields by 32.1% and secondary schooling brings an additional gain of 15.3%. Tertiary schooling, on the other hand, has no effect. Such diminishing returns to schooling, with especially high gains at the elementary level, have been observed widely in developing country farms. 3) Farm size has a negative effect on yields, confirming another well-established finding in the literature that there are diseconomies of scale in rice farming. 4) Low prices for fertilizer and tractors—two factors associated most with the modernization of agriculture—are associated with high yields with elasticities of -0.21 and -0.09 respectively. The seed price has the opposite effect, possibly because seeds are heterogeneous and higher seed prices are associated with better high-yielding varieties. Neither wages nor the price of animals—two traditional inputs—has a significant effect on yields. 5) At the barangay level, distance to the poblacion decreases yields with an elasticity of -0.071 and the availability of extension services boosts yields by 29.2%. Neither the condition of roads nor the transaction cost index has a significant effect.

The estimates by year (reported in the second and third columns) show that the variables included predict yields quite well in 1983 but not in 2003. Two notable exceptions are the dummy variable for upland rain-fed farming and distance to poblacion. Although the advantage of gravity and pump irrigation over lowland rain-fed farming has decreased in 2003, upland farms have lower yields compared to all other farms. Distance to poblacion has a strong negative effect on yields even after controlling for other barangay level variables, none of which has a significant effect on yields in 2003.

The fixed effects estimates (reported in the fifth column) rely exclusively on within-household covariance of the yields with the independent variables, allowing us to establish the sources of the growth in yields over the two decades. The results indicate that the two primary determinants of within-household inter-temporal changes in yields are the increased availability of gravity irrigation at the household level and the improvement in road conditions at the barangay level. The fixed-effects results suggest that weakening of the relationship between market access and farm productivity over the two decades is caused by infrastructural improvements in the peripheral villages.

Table 5 reports results of a similar set of regressions estimated for unit costs. In the pooled sample (OLS in first column and random effects in fourth column) estimates, only the factor prices have a significant effect on unit costs; wages and fertilizer prices increase unit costs, whereas seed prices have a negative effect. The latter result is consistent with what we found in the yield regression, which may be a consequence of the positive association of price and quality of seeds. When the models are estimated for each year, there is little predictive power in 2003 except for a negative coefficient for farm size, suggesting the presence of scale economies. This contrasts with the previous finding, in the yield regression, that there were diseconomies of scale in 1983. The barangay level institutional conditions do not explain any cross-sectional differences in unit costs. The fixed effects estimates reveal, however, that increases in the population density and improvements in road conditions are associated with reductions in unit costs. In addition, inter-temporal changes in farmer age and fertilizer prices are positively correlated with inter-temporal changes in unit costs.

The results reported in Tables 3 and 4 provide several insights on how barangay level accessibility of markets influences farm outcomes: 1) Remote barangays have lower yields in 2003. 2) Increases in the population density has a positive effect on reductions in unit costs from 1983 to 2003. 3) Improvements in road conditions has a positive effect on improvement in yields and reduction of unit costs from 1983 to 2003. 4) Farms in barangays with access to extension services had higher yields in 1983. 5) The transaction cost index in the rice market has no effect on either the levels or changes in yields and unit costs.

Technical and Cost Efficiency Estimates

Unlike in the case of yields and unit costs, linear regressions are not suited for the estimation of the determinants of technical and cost efficiency because the dependent variable, by construction, follows a truncated normal distribution (Kumbhakar, Ghosh, and McGuckin 1991; Reifschneider and Stevenson 1991). We utilize the panel data variant of a two equation stochastic frontier model (Battese and Coelli 1995) where each frontier is estimated using a maximum likelihood estimator jointly with a corresponding linear equation for the determination of the one-sided error term:

$$v_{it} = \delta_0 + \delta_1 z_{it} + \epsilon_{it}$$

$$w_{it} = \gamma_0 + \gamma_1 z_{it} + \varepsilon_{it}$$

The vector z_{it} represents a vector of determinants of farm efficiency. These two equations modify the simple production frontier by asserting that the non-negative error terms, v_{it} and w_{it}, come from truncated (at zero) distributions of the N($\delta_0 + \delta_1 z_{it}, \sigma_\epsilon^2$) and N($\gamma_0 + \gamma_1 z_{it}, \sigma_\varepsilon^2$) respectively. In our model, the predictors of farm efficiency are the same household-level and barangay level attributes that were included in the yield and unit cost regressions.

Table 6 presents the results of the joint maximum likelihood estimates of the production frontier and the associated mean efficiency function for the pooled sample and the two years separately. For each sample, estimates are carried out with and without the three barangay level institutional variables—road conditions, availability of extension services, and the transaction cost index—to determine whether the efficiency effects of distance to poblacion and population density are mediated by these three variables. In the pooled sample, technical efficiency is negatively affected by the age of the farmer and distance to poblacion and positively affected by education and population density. When the three institutional variables are added, the population density effect becomes insignificant but the distance to poblacion remains significant. We also see that good roads and access to extension service has a positive effect on technical efficiency while transaction costs have a negative effect. The year dummy tells us that there has been an increase in technical efficiency over the twenty years. The results are broadly similar in the subsample of 1983. In 2003, however, none of the included variables significantly predict technical efficiency. In the frontier itself, the results conform to our expectations; land, labor, seeds, fertilizer, and tractors are significant contributors to farm output; gravity and pump irrigation improves output, whereas upland irrigation decreases it; there are increasing returns to scale and there has been no significant shift of the production frontier from 1983 to 2003.

Table 7 present the analogous estimates for a cost frontier and the associated efficiency equation. In the pooled sample, only the secondary education of the household head has a positive effect on cost efficiency among the household level variables. At the barangay level, distance to poblacion increases and population density decreases cost inefficiency as hypothesized, and these effects are robust to the inclusion of the three other institutional variables. Among the institutional variables, transaction costs increase cost inefficiency and availability of extension services decreases it. Road conditions do not affect cost efficiency. The results for 1983 are qualitatively similar, whereas there are no significant predictors of cost efficiency in 2003. In the frontier itself, the results mostly conform to that of the previous models; there is evidence of scale economies in both years; wages and fertilizer prices increase costs in the pooled sample and in 1983, whereas higher seed prices and tractor prices are associated with lower costs possibly due to the heterogeneity of the quality of these inputs. In 2003, the results for prices are different, with fertilizer and tractor prices negatively correlated with costs and seed prices positively correlated.

The frontier analysis reported in Tables 5 and 6 present several additional insights on how barangay level accessibility of markets influences farm outcomes in 1983: 1) Distance to poblacion and transaction costs increase both technical and cost inefficiency. 2) Availability of extension services increase both technical and cost efficiency. 3) Population density has a positive effect on cost efficiency but not technical efficiency. 4) Road conditions improve technical efficiency but not cost efficiency. None of the barangay level variables predict technical or cost efficiency in 2003. It appears that the relationship between barangay level institutional conditions and farm efficiency has weakened dramatically in the two decades.

CONCLUSIONS

Four broad themes emerge from the analysis of Bicol rice farms presented in this paper. First, as predicted by the urban-industrial hypothesis of Schultz (1953), there was a significant inverse relationship between distance from the market and farm productivity and efficiency in 1983. Second, in the two decades from 1983 to 2003, rice farms in the Bicol have experienced substantial (about 25-35%) gains in terms of yields, unit costs, and efficiency. Third, gains in productivity and efficiency are larger in the more remote and sparsely populated villages, weakening the relationship between institutional conditions and farm outcomes. Fourth, development of markets in the peripheral villages and the improved connectivity between the peripheral villages and market centers is facilitated by population growth, infrastructural investments (specifically, irrigation and roads), and the availability of agricultural extension programs.

Compared to twenty years ago, farmers in the more remote villages of the Bicol face fewer disadvantages in obtaining access to technologies and factors of production relative to those in and around market towns. This convergence of peripheral villages with the poblacions is a reflection of the spread of markets that is in part attributable to rapid population growth; costs of market transactions are lower in densely populated areas. However, our analysis suggests that public investments—in irrigation, roads, and extension services—have played a vital role in developing market institutions and helping the more remote villages overcome their locational disadvantages. With better roads and extension services, farmers in the previously isolated corners in the periphery are now able to receive information on market prices, learn new farming technologies, and obtain modern inputs such as tractors and fertilizer at competitive prices. With greater connectivity between the villages and the cities and market towns, the physical isolation of a rice farm no longer matters and the Schultz hypothesis may no longer be relevant even in the poorest region of the Philippines.

REFERENCES

Aigner, Dennis.J., C.A.Knox Lovell, and Peter Schmidt. 1977. "Formulation and Estimation of Stochastic Frontier Production Function Models." *Journal of Econometrics* 6: 21–37.

Battese, G.E. and T.J. Coelli. 1992. "Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India" *Journal of Productivity Analysis* 3: 153–169.

————. 1995. "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data." *Empirical Economics* 20: 325–332.

Benziger, Vincent. 1996. "Urban Access and Rural Productivity Growth in Post-Mao China." *Economic Development and Cultural Change* 44 (3): 539–570.

Bicol River Basin Development Program. 1998. Bicol Multipurpose Survey (BMS), 1983: Philippines [Computer File]. ICPSR Version. Camarines Sur, Philippines: Bicol River Basin Development Program [producer], 1983. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor].

Birkhaeuser, Dean, Robert E. Evenson, and Gershon Feder. 1991. "The Economic Impact of Agricultural Extension: A Review." *Economic Development and Cultural Change* 39 (3): 607–650.

Bravo-Ureta, Boris E. and Robert E. Evenson. 1994. "Efficiency in Agricultural Production: The Case of Peasant Farmers in Eastern Paraguay." *Agricultural Economics* 10 (1): 27–37.

Coelli, Tim J. 1996. "A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation." CEPA Working Paper 96/7. Department of Econometrics. University of New England, Armidale NSW Australia.

DeSilva, Sanjaya, Robert E. Evenson, and Ayal Kimhi. 2006. "Labor Supervision and Institutional Conditions: Evidence from Bicol Rice Farms." *American Journal of Agricultural Economics* 88 (4): 851–865.

Evenson, Robert E. 1986. "Infrastructure, Output Supply and Input Demand in Philippine Agriculture: Provisional Estimates." *Journal of Philippine Development* 13 (1 and 2): 62–76.

————. 2001. "Economic impacts of agricultural research and extension." In Prabhu Pingali and Robert Evenson, eds., *Handbook of Agricultural Economics*. Oxford UK: Elsevier BV.

Evenson, Robert E. and Douglas Gollin. 2003. "Assessing the Impact of the Green Revolution, 1960–2000." *Science* 300 (2 May): 758–762.

Evenson, Robert E., Ayal Kimhi, and Sanjaya DeSilva. 2000. "Supervision and Transaction Costs: Evidence from Rice Farms in Bicol, the Philippines." Center Discussion Paper No. 814. Economic Growth Center: Yale University.

Evenson, Robert E. and Germano Mwabu. 2001. "The Effect of Agricultural Extension on Farm Yields in Kenya." *African Development Review* 13: 1–23.

Evenson, Robert E. and James A. Roumasset. 1986. "Markets, Institutions and Family Size in the Rural Philippines." *Journal of Philippine Development* 23 (18): 141–162.

Farrell, M. J. 1957. "The Measurement of Productive Efficiency." *The Journal of the Royal Statistical Society* 120 (3): 253–290.

Flores-Moya, Piedad, Robert E. Evenson, and Yujiro Hayami. 1978. "Social Returns to Rice Research in the Philippines: Domestic Benefits and Foreign Spillover." *Economic Development and Cultural Change* 26 (3): 591–607.

Hoff, Karla, Avishay Braverman, and Joseph E. Stiglitz. 1993. *The Economics of Rural Organization: Theory, Practice, and Policy*. Oxford University Press.

Jacoby, Hanan C. 2000. "Access to Markets and the Benefits of Rural Roads." *Economic Journal* 110 (465): 713–737.

Kumbhakar, Subal C., Soumendra Ghosh, and Thomas J. McGuckin. 1991. "A Generalized Production Frontier Approach for Estimating the Determinants of Inefficiency in U.S. Dairy Farms." *Journal of Business and Economic Statistics* 9: 279–286.

Kumbhakar, Subal C. and C.A. Knox Lovell. 2000. *Stochastic Frontier Modeling*. Cambridge University Press.

Lanzona, Leonardo A. 1997. Bicol Multipurpose Survey (BMS), 1994: Philippines [Computer File]. ICPSR Version. New Haven, CT: Yale University [producer], 1994. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor].

Lanzona, Leonardo A. and Robert E. Evenson. 1997. "The Effects of Transaction Costs on Labor Market Participation and Earnings: Evidence from Rural Philippine Markets." Center Discussion Paper No. 790. Economic Growth Center: Yale University.

Larson, Donald F. and Frank Plessmann. 2009. "Do Farmers Choose To Be Inefficient? Evidence from Bicol." *Journal of Development Economics* 90: 24–32.

Lovell, C.A.Knox. 1993. "Production Frontiers and Productive Efficiency." In Fried, H.O., Lovell, C.A.K., and Schmidt, S.S., eds., *The Measurement of Productive Efficiency*. New York: Oxford University Press.

Meeusen, Wim and Julien van den Broeck. 1977. "Efficiency Estimation from Cobb-Douglas Production Functions With Composed Error." *International Economic Review* 18: 435–444.

Naseer, Farooq, Robert E. Evenson, and Sanjaya DeSilva. 2007. "Social Capital, Efficiency and Transaction Costs in the Philippines." Unpublished Manuscript.

Otsuka, Keijiro, Hiroyuki Chuma, and Yujiro Hayami. 1992. "Land and Labor Contracts in Agrarian Economies: Theories and Facts." *Journal of Economic Literature* 30: 1965–2018.

Reifschneider, David and Rodney Stevenson. 1991. "Systematic Departures from the Frontier: A Framework for the Analysis of Firm Inefficiency." *International Economic Review* 32 (3): 715–723.

Rosegrant, Mark and Robert E. Evenson. 1992. "Agricultural Productivity and Sources of Growth in South Asia." *American Journal of Agricultural Economics* 74 (3): 757–761.

Sadoulet, Elisabeth, and Alain de-Janvry. 1995. *Quantitative Development Policy Analysis*. Baltimore: The Johns Hopkins University Press.

Schultz, Theodore W. 1953. *The Economic Organization of Agriculture*. New York: McGraw-Hill.

Table 1: Simple Regression Results

	ln Yield 1983	ln Yield 2003	ln Unit Cost 1983	ln Unit Cost 2003
ln dist pob	-0.160***	-0.078**	0.016	0.051
	(0.036)	(0.037)	(0.037)	(0.034)
_cons	7.624***	7.879***	1.453***	1.194***
	(0.073)	(0.070)	(0.074)	(0.064)
N	387	195	387	195
ln pop density	0.132***	0.065	-0.087**	-0.050
	(0.041)	(0.045)	(0.042)	(0.041)
_cons	6.845***	7.473***	1.825***	1.479***
	(0.160)	(0.195)	(0.163)	(0.178)
N	398	187	398	187

* p<0.1, ** p<0.05, *** p<0.01; Standard errors in parentheses

Table 2: Production and Cost Frontier Estimates

Ln output	Production Frontier (1)		(2)		Ln cost	Cost Frontier (3)		(4)	
Intercept	4.963	***	4.981	***	Intercept	2.169	***	2.353	**
	0.262		0.290			0.571		0.976	
Ln land	0.886	***	0.920	***	Ln output	0.737	***	0.767	***
	0.096		0.099			0.023		0.027	
Ln labor	0.205	***	0.188	***	Ln male wage	0.341	**	0.262	
	0.046		0.049			0.135		0.214	
Ln seed	0.119	**	0.130	***	Ln pr fertilizer	0.093	*	0.060	
	0.048		0.048			0.054		0.068	
Ln fert	0.064	***	0.059	***	Ln pr seed	-0.200		-0.198	
	0.013		0.013			0.149		0.251	
Ln animal	0.018		0.011		Ln pr tractor	-0.051	*	-0.043	
	0.014		0.015			0.029		0.032	
Ln machine	0.080	***	0.058	***	Ln pr animal	-0.072	*	-0.050	
	0.020		0.021			0.042		0.048	
Upland rainfed (d)	-0.369	***	-0.367	***					
	0.106		0.105						
Gravity irr (d)	0.298	***	0.291	***					
	0.061		0.057						
Pump irr (d)	0.194	***	0.176	***					
	0.068		0.066						
2003 (d)	-0.314	***	-0.152	**		0.297	***	0.083	
	0.103		0.076			0.092		0.119	
σ^2	0.209	***	0.393	***		0.217	***	0.272	***
	0.031		0.047			0.018		0.032	
γ	0.113		0.569	***		0.001		0.331	***
	0.133		0.049			0.001		0.065	
μ			-0.946	***				-0.600	***
			0.210					0.233	
ϑ	1.685	***	1.241	***		4.259	***	1.604	***
	0.643		0.166			1.025		0.322	
Log Likelihood	-510.6		-502.2			-488.5		-489.6	
LR Test	73.812		90.585			40.312		38.159	
Df	2		3			2		3	
No. Households	503		503			476		476	
No. Years	2		2			2		2	
No. Observations	586		586			561		561	
Mean distance from frontier									
1983	0.589		0.642			2.099		1.997	
2003	0.885		0.846			1.009		1.129	

Table 3: Step by Step Regression Estimates of the Market Access Effect

	(1) Market Access	(2) (1) + Household Attributes	(3) (2) + Factor Prices	(4) (3) + Barangay Conditions
ln Yield 1983				
ln dist pob	-0.131***	-0.079**	-0.031	-0.046
	(0.038)	(0.039)	(0.055)	(0.053)
ln pop density	0.055	0.036	0.016	-0.010
	(0.057)	(0.059)	(0.065)	(0.063)
Joint significance of added variables				
F-statistic	13.04	9.39	5.37	2.96
p-value	0.00	0.00	0.00	0.03
N	373	372	329	329
ln Yield 2003				
ln dist pob	-0.082**	-0.101**	-0.116***	-0.108**
	(0.040)	(0.043)	(0.041)	(0.042)
ln pop density	0.002	-0.029	-0.040	-0.044
	(0.057)	(0.069)	(0.070)	(0.075)
Joint significance of added variables				
F-statistic	3.20	2.83	3.21	0.53
p-value	0.00	0.01	0.01	0.66
N	187	164	164	153
ln Unit Cost 1983				
ln dist pob	-0.046	-0.044	-0.004	0.023
	(0.044)	(0.044)	(0.059)	(0.059)
ln pop density	-0.142**	-0.130*	-0.124*	-0.098
	(0.065)	(0.069)	(0.074)	(0.074)
Joint significance of added variables				
F-statistic	2.45	0.77	4.87	3.40
p-value	0.09	0.63	0.00	0.02
N	373	372	329	329
ln Unit Cost 2003				
ln dist pob	0.039	0.027	0.030	0.035
	(0.050)	(0.049)	(0.049)	(0.051)
ln pop density	-0.021	-0.013	0.010	0.028
	(0.049)	(0.060)	(0.063)	(0.067)
Joint significance of added variables				
F-statistic	0.82	1.02	1.87	1.44
p-value	0.44	0.42	0.12	0.24
N	187	164	164	153

Standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.01

Table 4: Yield Equation Estimates

	(1) Pooled OLS	(2) 1983 OLS	(3) 2003 OLS	(4) Random Effects	(5) Fixed Effects
Production Environment					
Ln area	-0.149***	-0.170***	-0.103*	-0.149***	-0.161
	(0.037)	(0.048)	(0.060)	(0.036)	(0.137)
Irrigation Dummies (Reference = Lowland Rainfed)					
Upland rainfed	-0.301*	-0.224	-0.621**	-0.301*	-0.600
	(0.180)	(0.220)	(0.305)	(0.155)	(0.642)
Gravity irr	0.355***	0.402***	0.145	0.355***	0.724**
	(0.079)	(0.101)	(0.134)	(0.081)	(0.345)
Pump irr	0.320***	0.456***	0.108	0.320***	-0.010
	(0.084)	(0.112)	(0.130)	(0.093)	(0.371)
Household Head Characteristics					
Age	-0.001	-0.001	0.000	-0.001	-0.026
	(0.002)	(0.003)	(0.003)	(0.002)	(0.023)
Education Dummies (Reference = No Schooling)					
Primary	0.321**	0.400***	0.002	0.321**	0.221
	(0.126)	(0.142)	(0.241)	(0.130)	(0.758)
Secondary	0.474***	0.590***	0.160	0.474***	0.796
	(0.145)	(0.173)	(0.258)	(0.151)	(0.915)
Tertiary	0.297	0.182	0.250	0.297	0.000
	(0.219)	(0.304)	(0.293)	(0.210)	(.)
Barangay Conditions					
Ln dist pob	-0.071**	-0.047	-0.111**	-0.071*	-0.028
	(0.036)	(0.054)	(0.042)	(0.037)	(0.278)
Ln pop density	-0.004	-0.010	-0.035	-0.004	0.335
	(0.048)	(0.064)	(0.078)	(0.045)	(0.303)
Good roads (dummy)	0.103	0.100	-0.064	0.103	0.685*
	(0.103)	(0.117)	(0.190)	(0.093)	(0.374)
Trans cost index	0.005	-0.029	-0.344	0.005	-0.098
	(0.051)	(0.056)	(0.272)	(0.055)	(0.172)
Extension (dummy)	0.292*	0.366**	-0.262	0.292**	0.615
	(0.151)	(0.160)	(0.692)	(0.118)	(0.519)
Barangay Level Prices					
Ln male wage	-0.035	-0.019	-0.501	-0.035	0.219
	(0.205)	(0.238)	(0.979)	(0.203)	(0.599)
Ln pr paddy	0.075	-0.035	-0.636	0.075	-0.781
	(0.240)	(0.294)	(0.714)	(0.262)	(0.885)
Ln pr fertilizer	-0.205***	-0.270***	-0.433	-0.205***	-0.277
	(0.075)	(0.085)	(0.592)	(0.070)	(0.287)
Ln pr seed	0.572**	-0.154	1.326	0.572**	0.192
	(0.240)	(0.371)	(1.044)	(0.246)	(1.511)
Ln pr tractor	-0.093**	-0.135***	-0.053	-0.093**	0.045
	(0.043)	(0.050)	(0.484)	(0.041)	(0.130)

Ln pr animal	0.021	0.032	-0.091	0.021	-0.355
	(0.060)	(0.068)	(0.230)	(0.057)	(0.262)
Year 2003 (dummy)	-0.001			-0.001	
	(0.007)			(0.007)	
Intercept	9.388	8.415***	10.392***	9.388	7.606**
	(14.471)	(1.302)	(3.082)	(14.681)	(3.247)
N	482	329	153	482	482
R-sq	0.267	0.283	0.196		0.470

Standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 5: Unit Cost Equation Estimates

	(1) Pooled OLS	(2) 1983 OLS	(3) 2003 OLS	(4) Random Effects	(5) Fixed Effects
Production Environment					
Ln area	-0.054	-0.017	-0.145**	-0.053	0.073
	(0.040)	(0.054)	(0.065)	(0.038)	(0.135)
Irrigation Dummies (Reference = Lowland Rainfed)					
Upland rainfed	-0.010	-0.068	0.354	-0.007	0.372
	(0.208)	(0.261)	(0.321)	(0.162)	(0.631)
Gravity irr	-0.027	0.000	0.024	-0.026	-0.162
	(0.088)	(0.121)	(0.115)	(0.084)	(0.339)
Pump irr	0.029	0.007	0.052	0.030	0.002
	(0.088)	(0.121)	(0.135)	(0.097)	(0.365)
Household Head Characteristics					
Age	0.002	0.001	0.003	0.002	0.043*
	(0.002)	(0.003)	(0.004)	(0.003)	(0.023)
Education Dummies (Reference = No Schooling)					
Primary	-0.088	-0.111	0.165	-0.088	0.045
	(0.134)	(0.150)	(0.250)	(0.136)	(0.745)
Secondary	-0.152	-0.252	0.127	-0.153	-1.003
	(0.146)	(0.170)	(0.257)	(0.159)	(0.900)
Tertiary	-0.051	0.038	0.014	-0.050	0.000
	(0.235)	(0.325)	(0.307)	(0.220)	(.)
Barangay Conditions					
Ln dist pob	0.017	0.018	0.036	0.017	-0.032
	(0.041)	(0.059)	(0.051)	(0.039)	(0.273)
Ln pop density	-0.052	-0.094	0.025	-0.052	-0.543*
	(0.052)	(0.075)	(0.070)	(0.047)	(0.298)
Good roads (dummy)	-0.045	-0.083	0.123	-0.047	-0.761**
	(0.112)	(0.132)	(0.228)	(0.097)	(0.368)
Trans cost index	0.048	0.067	0.295	0.046	0.020
	(0.048)	(0.055)	(0.243)	(0.057)	(0.169)
Extension (dummy)	-0.224	-0.269	-0.846	-0.223*	-0.096
	(0.171)	(0.182)	(0.554)	(0.124)	(0.510)
Barangay Level Prices					
Ln male wage	0.208	0.392	0.138	0.208	0.193
	(0.220)	(0.265)	(0.783)	(0.212)	(0.589)
Ln pr paddy	-0.394	-0.206	0.203	-0.399	0.334
	(0.255)	(0.339)	(0.581)	(0.273)	(0.870)
Ln pr fertilizer	0.196**	0.300***	-0.252	0.196***	0.545*
	(0.077)	(0.087)	(0.467)	(0.074)	(0.282)
Ln pr seed	-0.293	0.280	0.612	-0.297	-1.435
	(0.265)	(0.397)	(0.899)	(0.257)	(1.486)

Ln pr tractor	0.000	0.039	-0.398	0.001	0.153
	(0.047)	(0.057)	(0.428)	(0.043)	(0.128)
Ln pr animal	-0.041	-0.048	0.182	-0.041	0.071
	(0.064)	(0.073)	(0.207)	(0.059)	(0.257)
Year 2003 (dummy)	-0.009			-0.009	
	(0.008)			(0.008)	
Intercept	19.222	-0.549	0.621	19.257	1.326
	(15.843)	(1.507)	(2.864)	(15.341)	(3.193)
N	482	329	153	482	482
R-sq	0.097	0.097	0.145		0.394

Standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 6: Production Frontier and Efficiency Estimates

	Pooled				1983				2003			
Production Frontier												
Intercept	5.134	***	5.059	***	4.957	***	4.929	***	5.391	***	5.006	***
	0.242		0.247		0.278		0.296		0.517		0.470	
Ln land	0.966	***	0.946	***	0.867	***	0.869	***	1.123	***	0.984	***
	0.088		0.088		0.104		0.108		0.174		0.158	
Ln labor	0.181	***	0.197	***	0.177	***	0.183	***	0.207	**	0.311	***
	0.042		0.042		0.050		0.050		0.085		0.084	
Ln seed	0.100	**	0.105	**	0.164	***	0.166	***	0.015		0.035	
	0.044		0.043		0.051		0.055		0.072		0.073	
Ln fertilizer	0.063	***	0.063	***	0.069	***	0.067	***	0.059		0.024	
	0.011		0.011		0.012		0.012		0.037		0.036	
Ln animal	0.008		0.002		-0.001		-0.006		0.034		0.028	
	0.013		0.013		0.014		0.015		0.025		0.024	
Ln tractor	0.066	***	0.059	***	0.066	***	0.062	***	0.047		0.028	
	0.018		0.017		0.017		0.020		0.042		0.041	
Upland rainfed (d)	-0.302	***	-0.267	***	-0.248	**	-0.193	*	-0.426	**	-0.392	*
	0.093		0.098		0.106		0.116		0.212		0.205	
Gravity irr (d)	0.253	***	0.238	***	0.240	***	0.242	***	0.273	***	0.214	**
	0.055		0.055		0.071		0.070		0.089		0.091	
Irr Pump (d)	0.172	***	0.140	**	0.145	*	0.132		0.193	**	0.105	
	0.062		0.061		0.086		0.084		0.097		0.091	
2003 (d)	0.046		0.045									
	0.063		0.060									
Distance from Frontier												
Intercept	-2.806		-4.827		-1.364		-6.080		-3.491		-8.333	
	1.975		3.465		2.789		4.856		8.256		10.585	
Age	0.017	*	0.020	*	0.005		0.026		0.012		0.013	
	0.010		0.012		0.012		0.022		0.024		0.028	
Primary ed (d)	-1.656	**	-1.318		-2.768	**	-2.178	**	1.203		1.053	
	0.723		0.827		1.352		1.051		2.597		2.005	
Secondary ed (d)	-3.157	**	-3.121	*	-5.693	**	-4.922	**	1.092		0.911	
	1.374		1.736		2.896		2.292		2.570		2.141	
Tertiary ed (d)	-1.670	*	-1.436		-2.073		-0.662		0.041		-2.714	
	1.004		1.209		1.415		0.992		1.900		5.920	
Ln dist pob	0.721	**	0.886	**	0.679		0.969	**	0.325		0.395	
	0.300		0.410		0.437		0.493		0.554		0.521	
Ln pop density	-1.248	**	-0.682		-1.677	**	-0.702		-0.065		0.054	
	0.600		0.429		0.804		0.494		0.296		0.353	
Good roads (d)			-1.701	*			-3.037	*			3.292	
			0.889				1.653				4.283	
Trans cost index			0.518	**			0.585	**			1.752	
			0.256				0.274				1.679	
Extension (d)			-3.627	**			-4.652	*			-2.359	
			1.731				2.458				2.942	
2003 (d)	-3.119	**	-1.862	*								

	1.522	1.076				
σ^2	4.588 **	5.380 *	5.547 *	6.798 *	1.093	1.323
	1.925	2.930	2.898	3.959	1.650	1.367
γ	0.978 ***	0.982 ***	0.983 ***	0.986 ***	0.918 ***	0.932
	0.010	0.010	0.010	0.009	0.103	0.073
Log Likelihood	-432.0	-416.2	-317.0	-310.7	-110.6	-96.4
LR Test	140.14	152.66	110.33	122.92	14.13	23.62
Restrictioms	9	*	8	*	8	*
No. households	461	456	372	372	164	153
No. years	2	2	1	1	1	1
No. obs	536	525	372	372	164	153

Table 7: Cost Frontier and Efficiency Estimates

	Pooled		1983		2003	
Cost Frontier						
Intercept	1.454 ***	1.703 ***	-0.503	-0.895	4.561 ***	1.928
	0.556	0.618	0.940	0.967	1.301	1.592
Ln output	0.759 ***	0.778 ***	0.760 ***	0.800 ***	0.741 ***	0.750 ***
	0.026	0.022	0.034	0.036	0.035	0.036
Ln male wage	0.595 ***	0.420 ***	0.820 ***	0.662 ***	-0.194	0.467
	0.138	0.151	0.160	0.161	0.416	0.498
Ln pr fertilizer	0.096 *	0.116 **	0.168 **	0.205 ***	-0.206	-0.551 *
	0.055	0.054	0.067	0.066	0.265	0.311
Ln pr seed	-0.285 *	-0.147	0.174	0.402	0.790	1.210 **
	0.153	0.155	0.285	0.272	0.543	0.583
Ln pr Tractor	-0.119 ***	-0.128 ***	-0.094 **	-0.074 **	-0.592 **	-0.648 **
	0.032	0.032	0.043	0.038	0.270	0.279
Ln pr animal	-0.032	-0.041	-0.040	-0.039	0.182	0.089
	0.046	0.046	0.052	0.045	0.144	0.157
2003 (d)	-0.110	-0.077				
	0.101	0.102				
Distance from Frontier						
Intercept	1.996 ***	-0.098	3.478 ***	0.385	-20.824	-9.107
	0.876	1.260	1.247	1.796	20.163	8.419
Age	0.008	0.011 *	0.002	0.011	0.087	0.033
	0.006	0.007	0.008	0.016	0.089	0.023
Primary ed (d)	-0.274	-0.423	-0.457	-0.773	5.741	4.460
	0.343	0.350	0.489	0.584	3.963	4.189
Secondary ed (d)	-0.546	-0.858 *	-1.211	-2.353 *	7.215	5.153
	0.416	0.452	0.769	1.356	5.720	4.465
Tertiary ed (d)	0.140	0.115	0.198	0.740	3.351 *	2.582
	0.624	0.659	0.764	1.040	1.722	2.956
Ln dist pob	0.216 ***	0.387 ***	0.265	0.633 **	0.238	0.130
	0.104	0.132	0.188	0.313	0.445	0.193
Ln pop density	-1.020 ***	-0.870 ***	-1.542 ***	-1.789 **	0.160	0.222
	0.106	0.161	0.526	0.823	0.577	0.256
Good roads (d)		0.164		-0.231		1.720
		0.215		0.446		2.191
Trans cost index		0.640 ***		0.838 *		2.185
		0.193		0.450		1.466
Extension (d)		-1.079 **		-1.907 *		-6.311
		0.464		1.188		4.667
2003 (d)	-3.066 ***	-3.412 ***				
	0.375	0.364				
σ^2	1.297 ***	1.842 ***	1.288 ***	3.126 *	3.050	1.110 *
	0.142	0.586	0.257	1.952	2.345	0.665
γ	0.858 ***	0.909 ***	0.813 ***	0.935 ***	0.970 ***	0.917 ***

	0.029	0.033	0.032	0.048	0.021	0.051
Log Likelihood	-435.4		-313.6	-310.0	-104.8	-93.3
LR Test	68.497		39.624	46.841	21.576	33.804
Restrictions	9		8	*	8	*
No. households	437		330	330	185	174
No. years	2		1	1	1	1
No. obs	515		330	330	185	174

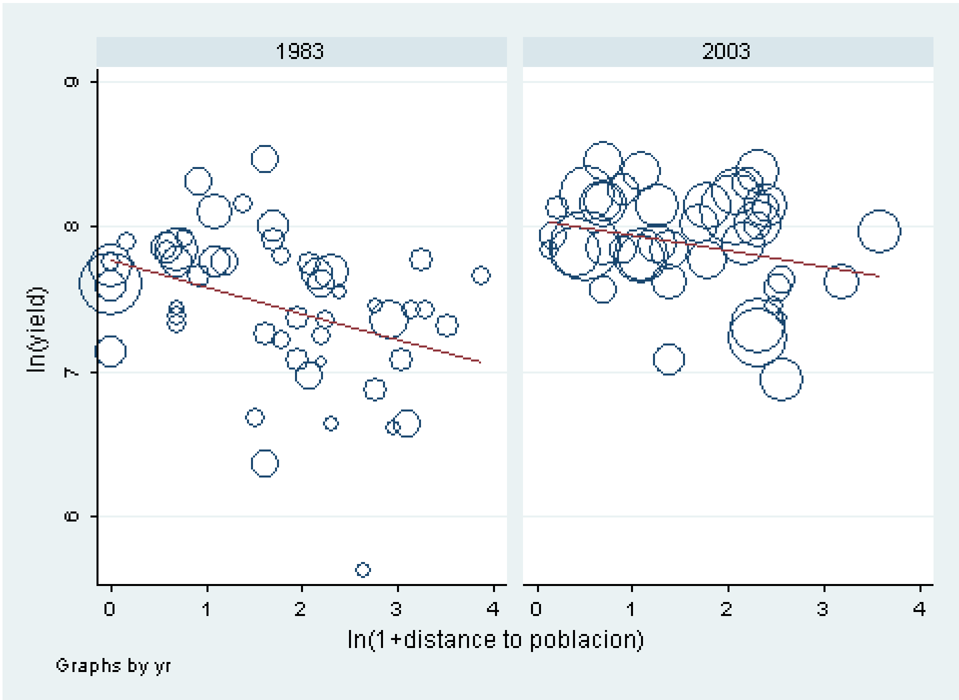

Figure 1: Yields and Distance to Poblacion

Figure 2: Yields and Population Density

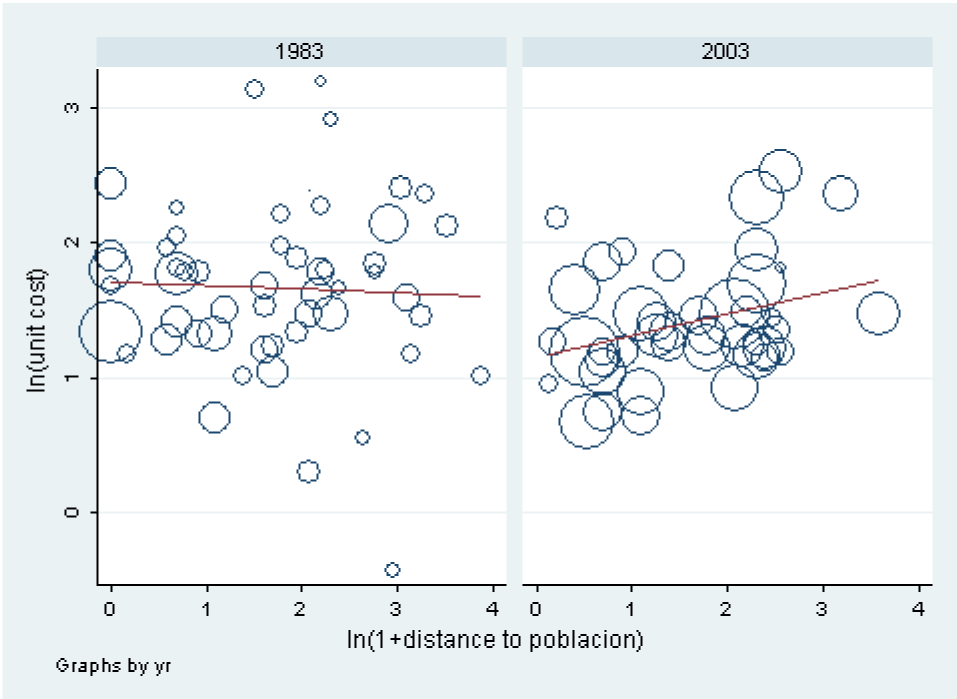

Figure 3: Unit Costs and Distance to Poblacion

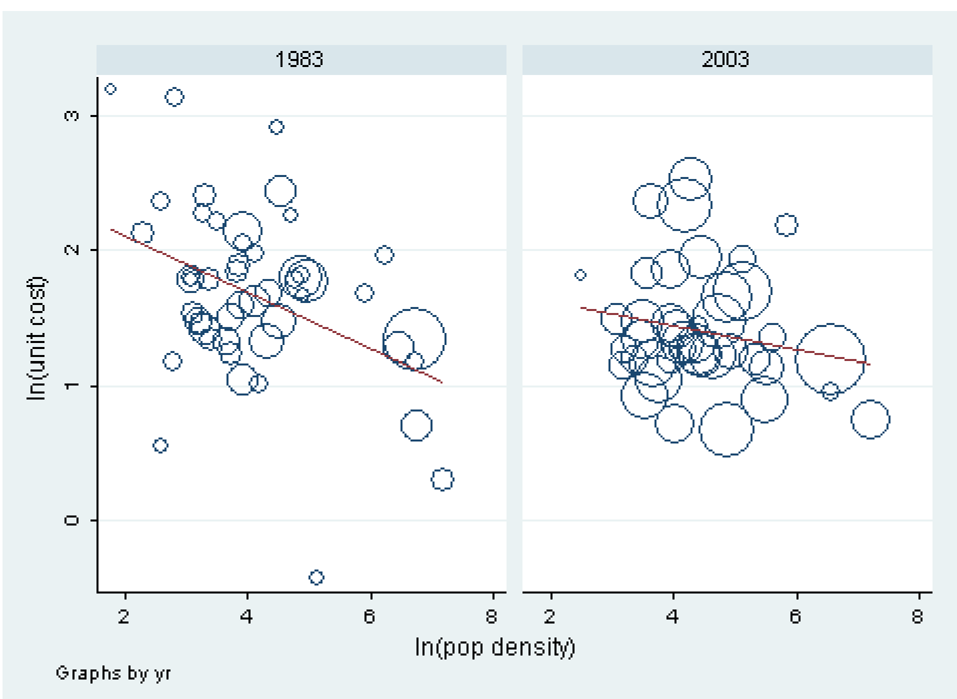

Figure 4: Unit Costs and Population Density

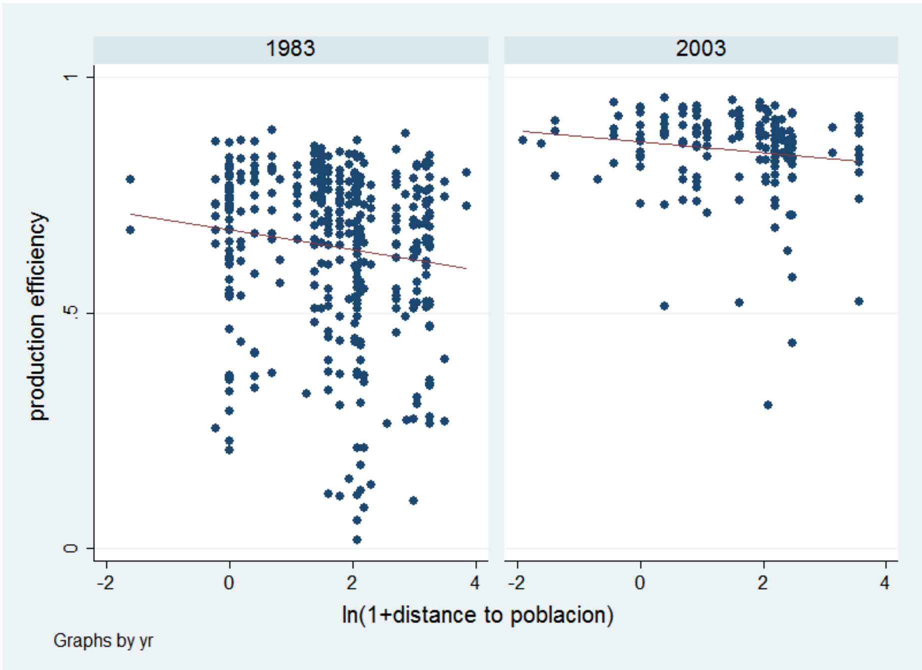

Figure 5: Production Efficiency and Distance to Poblacion

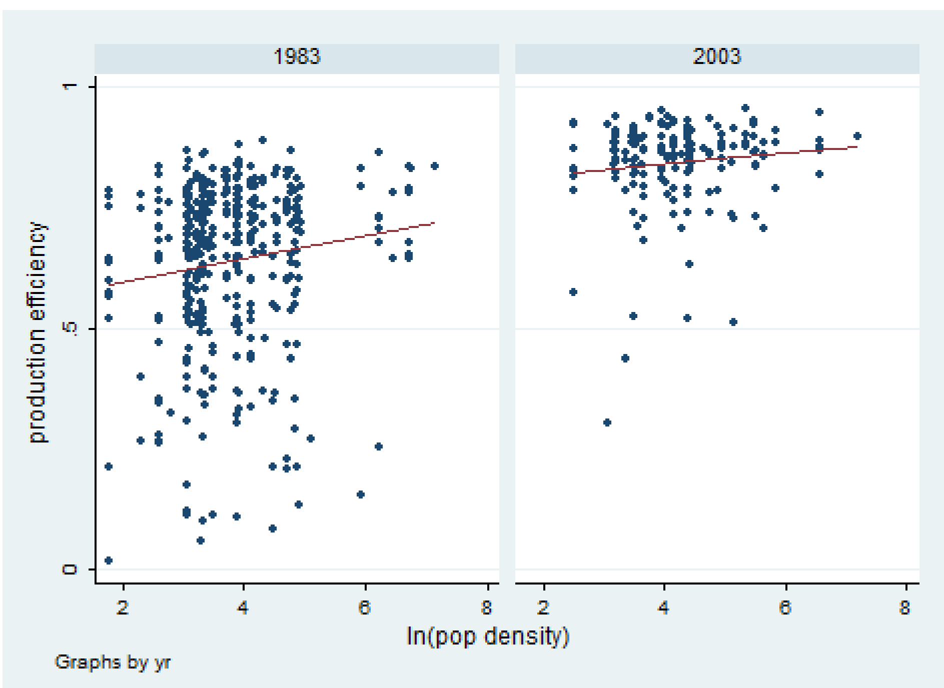

Figure 6: Production Efficiency and Population Density

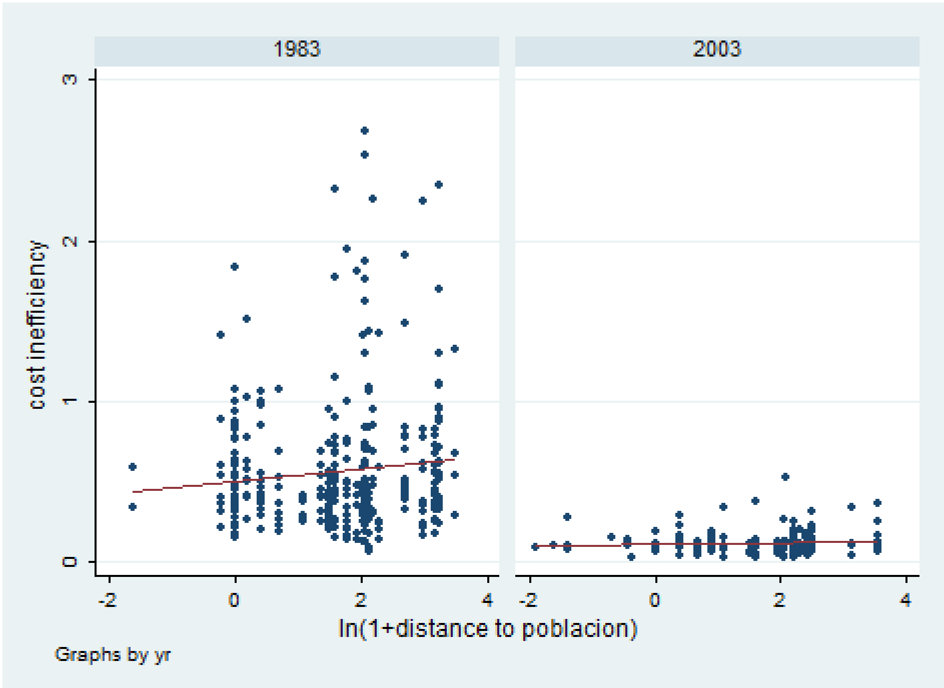

Figure 7: Cost Efficiency and Distance to Poblacion

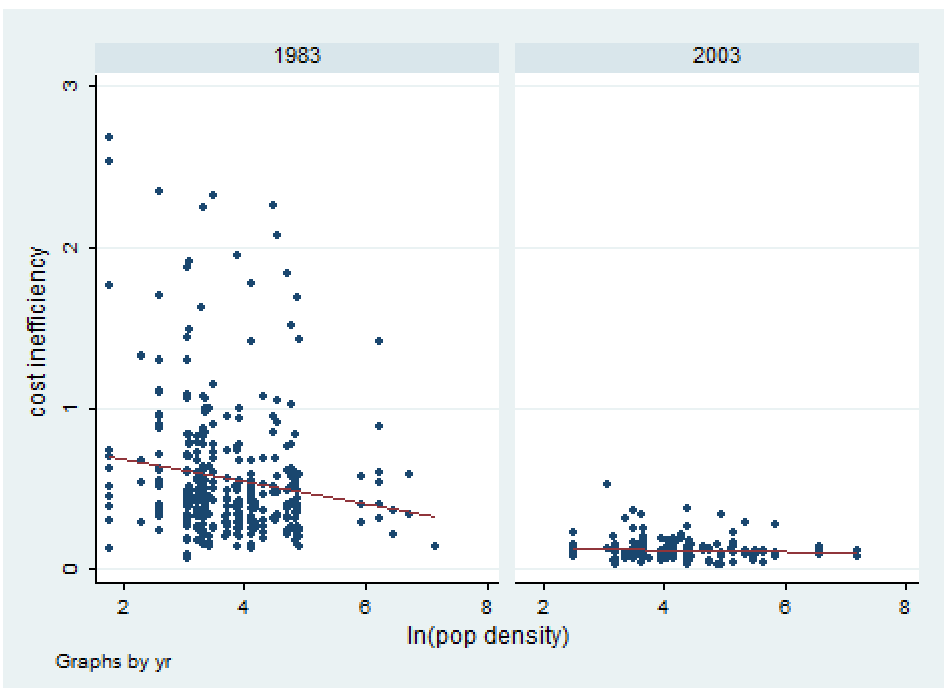

Figure 8: Cost Efficiency and Population Density