Journal of Agricultural and Applied Economics, 42,2(May 2010):247–259

Assessing the Technical and Allocative Efficiency of U.S. Organic Producers

Timothy A. Park and Luanne Lohr

We develop measures of technical and allocative efficiency of producers in marketing certified organic products. A stochastic output distance frontier and the associated revenue share equations are estimated using comprehensive U.S. data on certified organic producers. Farm-level measures of technical efficiency are calculated and factors that enhance performance are identified. Factors that systematically influence allocative efficiency are assessed. The revenue mix of organic producers is systematically inefficient as both male and female producers rely too heavily on revenue from organic markets relative to conventional outlets.

Key Words: organic farming, stochastic frontier, technical and allocative efficiency

JEL Classifications: D21, C31, Q01

Sustained growth in the market for organically grown foods in the United States has stimulated new national, state, and private research initiatives to facilitate marketing of organic products and to assist farmers in understanding how to deal with market outlets for organic farm products. Dimitri and Greene (2007) present evidence that growth rates of retail sales have equaled 20% or more annually since 1990. While indicators of budgeting and profitability studies can guide entry of farmers into the organic sector, the identification of efficient marketing strategies is essential to assist farmers in expanding their operations and maintaining a long-term commitment to organic production.

Three trends are highlighted in the marketing of organic products. First, the major marketing outlets for organic foods have shifted over time. Health and natural products stores and direct markets (such as farmers markets) were the major outlets for organic food from 1990–1996. By 2000 conventional supermarkets represented the primary purchasing outlet for organic food products. Even within the retail channel a shift in strategies is emerging. Giant Food Inc., a major supermarket chain owned by the Dutch conglomerate Royal Ahold NV, has introduced a store brand of organic products with the stated goal of preventing national organic brands from dominating their store shelves. Progressive Grocer (2004) commented that merchandising programs of institutional store accounts for organics are now considerably stronger. Large food companies have a growing interest in offering organic foods along with their standard products. Wal-Mart is moving to become the leader in this product line with the goal of selling organic products for only 10% more than their conventional equivalents (New York Times, 2006).

Timothy Park is an economist with the Food Marketing Branch and Luanne Lohr is an economist with the Food and Specialty Crops Branch, Economic Research Service, USDA, Washington, DC.

The authors appreciate the cooperation of the Organic Farming Research Foundation in providing the data used for this project. The judgments and conclusions herein are those of the authors and do not necessarily reflect those of the U.S. Department of Agriculture. The authors are responsible for all errors.

A clear implication is that organic farmers must understand how to assess profitable outlets for marketing their products and to bargain competitively with increasingly sophisticated marketing participants in the supply chain.

Second, organic farmers traditionally utilize a variety of marketing channels such as direct to consumer sales, direct marketing to grocery retailers and restaurants, along with sales through packers, brokers, and food processors. Organic producers have participated in the rejuvenation of farmers markets and developed innovative outlets such as community supported agriculture. Most farmers continue to rely on a variety of marketing outlets and to sell through a diverse set of supply chain entities supporting methods to evaluate marketing efficiency.

Third, buying patterns of the chain supermarkets are shifting as three of the nation's largest food retailers (Safeway, Ahold, and Kroger) have created central procurement systems for buying perishables with the goal of improving inventory control, guiding promotional and seasonal planning, and coordinating business activities across the operating divisions (Progressive Grocer, 2002). Independent regional produce buyers have responded by emphasizing their expertise in featuring high quality perishables for local markets and adapting pricing and promotional materials in response to new market conditions.

Organic farmers develop marketing strategies to maximize total farm income from the organic operation by selling crops and value added products through both conventional and organic channels. Surveys of U.S. organic farmers conducted by the Organic Farming Research Foundation (OFRF) indicate that revenues originating in conventional markets account for the major share of farm income. In the third OFRF survey, 59% of revenue was from organic products sold through conventional channels with revenues from organic outlets comprising the remaining 41% (Walz, 1999). The pattern is stable over time as conventional market revenues accounted for 61% of organic farm income in the fourth OFRF survey (Walz, 2004).

The objective of this article is to measure the technical and allocative efficiency of producers in marketing certified organic products. Using duality theory, a multiple input and output distance function is used to derive measures of allocative efficiency in marketing decisions. The procedure relies on the stochastic frontier approach to estimate the output distance function and associated revenue share equations. Farm-level measures of technical efficiency are calculated and variables, which enhance performance, are identified. Factors that are systematically related to allocative efficiency are assessed. The results from the output distance function identify policy-relevant programs that can improve the marketing performance of organic producers.

Modeling Organic Marketing Decisions

Färe and Primont (1995) demonstrated that the output distance function is a natural generalization of the production function for multiple outputs. The producer uses a set of inputs $x \in \Re_n^+$ to produce a vector of output $y \in \Re_m^+$. The reference technology is represented by an output correspondence mapping $P{:}\Re_n^+ \Rightarrow P(x) \subseteq \Re_m^+$, where the output set $P(x)$ represents the set of all feasible vector of outputs given a vector of inputs x. The output distance function can be defined on the output set as

$$(1) \qquad D_o(y,x) = \min[\theta{:}(y|\theta)\epsilon P(x)]$$

where $D_O\ (y,\ x) \leq 1$ and $0 < \theta \leq 1$. If observed output is on the boundary of the production set and is efficient, the distance function is equal to 1. Farmers whose output choices are not efficient are located below the frontier and the distance function is less than 1. The difference between θ and 1 is how far the organic operation falls short of "best practice" production.

To estimate technical and allocative efficiency we formulate a dual output distance function and system of revenue shares for the pth producer as:

$$(2) \qquad \begin{aligned} \ln 1 &= ln\, D_o(y_p, x_p) + v_p - u_p \\ \frac{R_{op}}{R_p} &= \frac{\partial ln D_o}{\partial ln y_{op}} + v_{op} + A_{op} \\ \frac{R_{cp}}{R_p} &= \frac{\partial ln D_o}{\partial ln y_{cp}} + v_{cp} + A_{cp} \end{aligned}$$

where $D_O\ (y_p,\ x_p)$ is the short-run output distance function. Actual revenue is $R_p = R_{cp} + R_{op}$

which depends on revenue from conventional markets R_{cp} and revenue from organic markets R_{op}. In stochastic frontier analysis the firm is constrained to produce at or below the deterministic production frontier, a condition recognized by inclusion of a composite error term consisting of two random variables.

The first element in the composite error, v_p, is a symmetric noise term reflecting random factors driving the output distance function, such as measurement error and unobserved inputs and their quality features. This component of the error term can take on both positive and negative values. The second element of the error term u_p reflects the impact of inefficiency in firm operations and environmental conditions that reduce output. The inefficiency component assumes negative values only and represents the magnitude of technical inefficiency. By contrast, the error term from a cost function frontier approach mixes together the cost of technical and allocative inefficiency.

Technical efficiency is estimated as $TE_i = \exp(\hat{u}_p)$, which has a value between 0 and 1, with 1 indicating the producer is 100% technically efficient. While only the difference between the random error terms $\varepsilon_p = v_p - u_p$ can be observed, Kumbhakar and Lovell (2000) discuss how to obtain estimates of technical efficiency for each producer by deriving $\hat{u}_p$ from the conditional distribution $E(u_p \mid \varepsilon_p)$.

Allocative efficiency is obtained from the second line of the equation set shown in Equation (2). This equation shows the revenue share obtained from organic production. In the revenue share equation v_{ip} accounts for idiosyncratic shocks. The component A_{ip} delineates the impact of allocative inefficiency on the deviation between actual and stochastic shadow revenue shares. A positive value indicates that the revenue share obtained from that output is too high relative to other outputs marketed by the farm and the inputs used. Allocative inefficiency for the ith output is modeled as

$$A_{ip} = \alpha_{ipa} + \alpha_{ipb} Z_b + \alpha_{ipc} Z_c \tag{3}$$

where Z is a vector of nonstochastic variables specified in more detail below and the parameters to be estimated are represented by α_{ipa}, α_{ipb}, and α_{ipc}. Note that the error component u_p accounts for the magnitude of technical inefficiency alone, highlighting an advantage of estimating the output distance function system. Following Rodríguez-Álvárez, Fernández-Blanco, and Lovell (2004), the u_p and the A_{ip} effects are inherently independent in the distance function approach.

Functional Form

Empirical application of the output distance function requires a flexible functional form. Building on extensive work in duality theory for cost and profit functions, Morrison Paul, Johnston, and Frengley (2000) proposed a translog distance function for the pth producer as:

$$\begin{aligned} ln1 = {} & \beta_0 \\ & + \sum_r \alpha_r lny_{rp} + \frac{1}{2}\sum_r\sum_s \alpha_{rs} lny_{rp}\, lny_{sp} \\ & + \sum_i \beta_i lnx_{ip} + \frac{1}{2}\sum_i\sum_j \beta_{ij} lnx_{ip}\, lnx_{jp} \\ & + \xi_f lnxf_p + \frac{1}{2}\xi_{ff} lnxf_p^2 \\ & + \sum_r\sum_i \rho_{ri} lny_{rp}\, lnx_{ip} \\ & + \sum_i \xi_{fp}\, ln\, xf_p lnx_{ip} \\ & + \sum_r \xi_{fr} \ln xf_p lny_{rp} \\ & + \sum_g \gamma_g G + v_p + u_p. \end{aligned} \tag{4}$$

The output distance function is based on the output vector $y = (y_1, \ldots, y_m)$, the variable input vector $x = (x_1, \ldots, x_n)$, and a set of farm-specific factors xf. The outputs are revenue obtained from selling through organic channels and revenue received from conventional marketing channels. Regional variation in climate, organic cropping history, crop production practices, and regulatory environments are accounted for with a set of regional fixed effects, denoted by G. The organic revenue share equation is

$$\begin{aligned} \frac{R_{op}}{R_p} = {} & \alpha_r + \sum\nolimits_s \alpha_{rs} lny_{sp} + \sum\nolimits_i p_{ri} x_{ip} \\ & + \xi_{fr} lnxf_p + v_{op} + A_{op} \end{aligned} \tag{5}$$

with a similar form for the conventional revenue share. Homogeneity of degree one in the outputs along with symmetry in cross effects is imposed on the distance function. Allocative inefficiency for the ith output is modeled as:

$$A_{ip} = \alpha_{ipa} + \alpha_{ipb} Z_b + \alpha_{ipc} Z_c \tag{6}$$

where Z is a vector of nonstochastic variables specified in more detail below.

Application of the model to measure the technical and allocative efficiency of organic farmers relies on capturing the unique aspects of these operations. Production characteristics of organic farms are just beginning to be cataloged and compared with conventional farms. As an initial effort in quantifying efficiency, we used measures of factors identified by practitioners and researchers as having special significance for organic productivity. Besides the direct relationship between inputs, x, and outputs, y, expressed by the production frontier, features of the farms and regions which impact the marketing efficiency of the farmer are included in the model. The farm effects in the output distance function model identify significant constraints to productivity that would otherwise be attributed to farmer inefficiency.

Data and Model Formulation

National survey data were accessed from the OFRF surveys collected from U.S. certified organic farmers, based on grower lists maintained by organic certification organizations. The OFRF surveys are designed to provide the most comprehensive picture currently available about the state of organic farming in the United States. The data on production practices, demographic characteristics, and farm attributes represent all crops grown organically, and all regions in which organic production is conducted.

Appropriateness of the Model

Table 1 shows the descriptions and summary statistics for the variables. Information from the OFRF survey is used to derive the revenues (outputs) and revenue shares for the distance function: the share of farming income sold as certified organic output (ORGSHR) and the share sold as conventional production (CONVSHR). Organic farmers of necessity operate diverse enterprises, partly to offset risk and partly to exploit natural cycles for pest and nutrient management (Kroma and Butler Flora, 2001). Farmers also develop marketing strategies to maximize total farm income from the organic operation by selling crops and value added products through both conventional and organic channels.

Revenues originating in conventional markets accounts for 59% of family farm income with revenue from products sold as organic comprising the remaining 41%. Female organic farmers tend to market a higher percentage of production as conventional (65%) compared with male farmers (58%). The average organic farm income of female farmers is about \$27,000, which is about 45% of the figure reported by male organic farmers.

From OFRF survey information on acreage allocated to specific crops, we defined three categories—field crops (including grains, beans, oilseeds, and the like), vegetable crops (vegetables, herbs, flowers, ornamentals), and fruit crops (fruits, nuts, and tree crops). We examine organic farm income for producers who concentrate acreage in any one of the crop production categories (more than 50% of acreage in either field crops, vegetable crops, or fruit crops). Conventional production channels provide the dominant share of farm income across these production categories, with at least 56% of farm income accruing from conventional sales for each category. The importance of assessing the allocative efficiency of decisions to market through conventional and organic channels is underscored by these patterns.

Input Variables

The input variables comprising the vector x were the variable factors including labor and acreage. Our analysis focuses on how organic farmers adjust decisions on variable inputs such as labor and acreage and our model specification is consistent with other stochastic frontier models such as Kurkalova and Carriquiry (2003).

Labor management decisions are a critical factor on farms. Labor on organic farms

Table 1. Variable Descriptions and Summary Statistics (n = 662 Farms)

Variable	Description	Mean	Standard Deviation
TOTFINC	Total farm income of the organic farmer (>000s of dollars)	142.667	263.767
ORGINC	Total farm income from sales in organic markets (>000s of dollars)	53.149	263.767
CVFINC	Total farm income from sales in conventional markets (>000s of dollars)	89.517	263.767
CONVSHR	Revenue share from conventional production	59.21	29.84
ORGSHR	Revenue share from organic production	40.79	29.84
FLABR	Managers and full-time employees	4.50	9.62
PLABR	Part-time employees	4.38	18.68
ACRE	Total acreage farmed	135.96	367.38
INFOSRC	Effectiveness rating for information sources, rating (1–4) multiplied by number used (1–10), from 1 to 16	14.81	6.34
RESCOM	Resources provided by farmer for research efforts, number from 0 to 7 Share of farmers providing the resource	1.30	2.53
	Provided land	0.22	0.41
	Helped define problem for study	0.21	0.40
	Provided financial support	0.17	0.38
	Provided materials and/or equipment	0.20	0.40
	Provided staff and/or labor	0.19	0.39
	Helped publish research results	0.17	0.37
	Distributed results	0.16	0.37
MALE	Organic farmer is a male, 1 if yes	0.81	0.39
ORIGAORG	Farmer was originally an organic producer, farms only organic acres, 1 if yes	0.48	0.50
WEST	Farm is in SARE Region 1, 1 if yes	0.33	0.47
NORCENT	Farm is in SARE Region 2, 1 if yes	0.34	0.48
SOUTH	Farm is in SARE Region 3, 1 if yes	0.07	0.26
NOREAST	Farm is in SARE Region 4, 1 if yes	0.26	0.43

consists of production tasks, monitoring, information-seeking, and management decision making. Organic farmers heavily rely on ecological processes for nutrient management, pest control, and yield enhancement. The ability of a farmer to collect and interpret localized information and use it in marketing decisions is an important determinant of success, and information sharing can be critical to this process (Kroma and Butler Flora, 2001).

The two labor inputs included in the model are full-time labor (FLABR) which is the sum of managers and other full-time employees and part-time employees (PLABR). The average farm in this sample used two managers, as well as two full-time and four part-time paid employees. The majority of organic farmers in the sample relied on personal or family labor. About 58% hired only part-time workers and 25% hired no workers.

The mean farm size (ACRE) in the sample was 133 acres, with the largest farm in the sample topping out at 6,000 acres. Organic farm size is moderately correlated with organic farm income (at 0.42) but is negatively correlated with the share of farm income originating from conventional sales outlets.

Farm-specific and regional factors may shift efficiency below the frontier by their indirect influence on how inputs are used. We focus on three factors that have been identified as significant influences on the efficiency and performance of organic farmers. Organic farmers must file a multiyear farm plan that details a program for improving soil organic matter and resource conservation, including proposed management activities, particularly planning beyond the current crop year. Effective experimentation requires information sharing, which takes management effort to identify sources, collect and interpret information, and implement trials. By explicitly recognizing these factors as possible constraints to efficient production, the nature of management inefficiencies can be unraveled.

The first factor measures the impact of the farmer's involvement in collaborative research (RESCOM). On-farm research is related to the producer's entrepreneurial and management expertise, consistent with labor theories of the research process. Lazear's (1997) model of the incentives for initiating basic research demonstrated that more productive individuals tend to initiate and become involved in research projects. In measuring agricultural productivity of sustainable agricultural systems, Jaenicke and Drinkwater (1999) also documented an important role for both experimental on-farm learning and "tinkering" as farmers adjust production techniques.

Experimentation with new practices and systems is consistent with organic farmers' entrepreneurial goals and is necessary to adapt technologies to the local agroecology. The OFRF survey revealed that 87% of respondents had conducted their own on-farm experiments. Observation of and experimentation on their own farms and information gathered from books, other farmers, and researchers were reported by more than 70% of respondents to be very important elements in shaping their personal knowledge base. Links among farmers, researchers, and extension professionals were formalized by the United States Department of Agriculture (USDA)'s producer grants program under the Sustainable Agriculture Research and Education Program, which promotes farmer participatory research, and by the Organic Farming Research Foundation's grants program, which encourages university-farm collaborations.

The OFRF survey queried farmers about their contribution of seven different resources required for collaborative experimental or research efforts. The seven resources were providing land, financial support, labor, materials, research advice, and publishing and distributing research results. We measured the farmer's research involvement by counting the number of resources the farmer provided in collaborative research.

The distribution of organic farmers who participate in on-farm research is distinctly bimodal, as 77% of farmers remain uninvolved and contribute no resources. The second highest category of farmers (13%) showed the maximum commitment to collaborative research by providing all seven resources listed. The percentage of farmers providing research inputs in each category is fairly uniform, ranging from a maximum of 22% of farmers who commit land to a minimum of 20% who assisted defining the research problem. Organic producers with the largest acreage are the dominant group among the farmers showing the most commitment to collaborative research. Farmers with over 100 acres commit an average of 1.53 resources compared with an average of 1.17 resources from producers with less than 20 acres.

Kalirajan and Shand (2001) suggested that a main constraint in achieving technical efficiency in agricultural production is the lack of information about best practice techniques. With limited information farmers benefit from gradual "learning by doing" in adopting new production and management methods, highlighting the value of on-farm research projects. Information accessibility and reliability are of particular importance in the adoption of management strategies for organic systems. As Padel (1994) pointed out, direct costs of information and experience gathering constitute major barriers to organic conversion.

The second farm-specific factor measures the information sources consulted by organic farmers. A composite variable (INFOSRC) of the usefulness ratings for 13 information sources was formed. The OFRF survey asked organic farmers to identify the sources they most frequently consulted regarding organic practices, indicating the frequency of use and rating their usefulness. This variable was constructed by summing the ratings (from 1 to 4 with 1 indicating no useful information and 4 representing very useful) across the sources, given that farmers indicated they had consulted that source. The information sources include cooperative extension advisors, university researchers, organic certification personnel, and various state and federal agricultural organizations. A score of 13 indicated that all the information sources that were actively consulted received the lowest effectiveness rating while a score of 52 meant the maximum rating was given for each source. The mean effectiveness rating for private information sources was 14.81.

Regional variation exists in climate, organic cropping history, crop production practices, and regulatory environments which we accounted for with a set of regional fixed effects. Variations in resources allocated to the extension service are also apparent at the regional level, with the result that sustainable agriculture practices advocated by extension have been unevenly adopted (Comer et al., 1999).

To assess institutional support and information availability for organic production and marketing systems, we used the four USDA Sustainable Agriculture Research and Education (SARE) regions (see http://www.sare.org/ for listings of states in each region). These regions reflect the U.S. government's demarcation for sustainable agriculture extension-research support. A dichotomous variable for each region was created which was equal to one if the respondent's farm was in that region, and zero otherwise. In our sample, 33% of farmers were in the SARE 1 region (WEST), 36% in the SARE 2 region (NORCENT), 7% in the SARE 3 region (SOUTH), and 24% in the SARE 4 region (NOREAST).

The West region has historically received the strongest institutional support for organic agriculture and is home for two of the nation's oldest organic farm and certifying organizations, California Certified Organic Farmers and Oregon Tilth. California enacted the first state law to define organic foods in 1982. California and Washington were among the first extension services to conduct outreach and applied research on organic agricultural systems using teams of extensionists rather than individuals. The locality-specific research needed for successful organic farming emerged earlier in the West than in the other regions. Estimation results are expected to show higher returns in the West region.

Factors Influencing Allocative Efficiency

Lohr and Park (2002) showed that length of experience with organic systems positively affects the number of management practices implemented on a farm. Farmers with greater experience were hypothesized to be better able to manage a wide range of practices and to be more open to using new strategies. We measure the quality of organic production experience by using a dichotomous variable (ORIGAORG) for those who initiated their farming careers as organic producers and exclusively farmed certified organic acreage. Farmers who meet this definition have allocated continuous time and resources to learning about the full complement of organic practices available and designing an optimal organic system, compared with those operating parallel systems that include both organic and nonorganic acreage. More than 75% of OFRF respondents had committed their whole farm to organic production and 58% of respondents had farmed continuously as organic farmers. In the sample, 48% of farmers met both criteria.

Significant regional variation is evident in the proportion of original organic farmers who commit their complete farm operation to organic methods. Over half of the farmers meet this criterion in the West, South, and Northeastern regions, with the South showing the highest percentage at 62%. Only 32% of organic producers from the North Central region are described as original, all organic farmers.

Estimation Results

The system of equations represented by the translog output distance function and the revenue share equation (Equations 4 and 5) is estimated by maximum likelihood in a seemingly unrelated regression, imposing the implied cross equation restrictions. Coefficient estimates and t-statistics for the model are presented in Table 2 and are invariant to the omitted revenue share equation. The measures of output mix in the Farrell efficiency framework are considered to be exogenous following the discussions in Grosskopf et al. (1997) and Cuesta and Zofio (2005). Empirical models of distance functions have been estimated with exogenous right-hand side output and input mixes that are uncorrelated with the firm effects and with the stochastic error (Morrison Paul, Johnston, and Frengley, 2000; Morrison Paul and Nehring, 2005).

The translog model is estimated by imposing the restrictions implied by homogeneity of degree one in outputs by normalizing by one output (organic farm income) along with the symmetry restrictions. The left side of Equation (2) was respecified as *ln* ORGINC, reversing the signs of the coefficients from the typical distance function. Elasticities with respect to the output variables should be negative, consistent with tradeoffs along the production possibility frontier. Marginal product relationships for inputs take on positive signs in the respecified model. The restrictions implied by the Cobb-Douglass output distance function are decisively rejected as the calculated χ^2 value was 4436.07.

The presentation of the results centers around two main issues. First, the key factors that influence the technological structure of production through the distance function are assessed. Second, the overall technical and allocative efficiency of organic farmers is discussed and performance is compared across specific explanatory variables.

4.1 Factors Influencing the Distance Function

Input and output substitution patterns are evaluated in the elasticities of y_1 or D_O with respect to the arguments of the distance function including organic farm inputs and the factors influencing performance. Tradeoffs between the produced outputs along the production possibility frontier and returns to an input measured as its impact on organic farm income are assessed using elasticity measures. An example for the output elasticity is shown:

Table 2. Estimated System of Equations for Organic Producers ($n = 662$ Farms)

Variable	Estimate	T-ratio[a]
CONSTANT	8.437*	37.053
CVINC	0.242*	5.903
ORGINC*ORGINC	−0.012*	−48.311
CVINC*CVINC	0.084*	7.209
ORGINC*CVINC	−0.043*	91.039
PLABR	0.012*	2.837
ACRE	0.345*	9.022
PLABR*ACRE	0.001*	1.766
ACRE*ACRE	0.002	0.310
PLABR*PLABR	0.007E-04	0.042
ORGINC*PLABR	0.0001*	6.079
ORGINC*ACRE	0.003*	16.407
CVINC*PLABR	−0.003*	−2.830
CVINC*ACRE	−0.060*	−14.711
FLABR	0.033*	2.384
FLABR*ACRE	0.00009	0.069
FLABR*FLABR	0.0001*	2.108
FLABR*PLABR	−0.00001	−0.420
ORGINC*FLABR	0.0003*	7.634
CVINC*FLABR	−0.007*	−7.344
WEST	0.056*	2.238
SOUTH	−0.008	−0.209
NORTHEAST	0.029	1.173
ORGINC*RESCOM	0.002*	5.109
CVINC*RESCOM	−0.024*	−2.625
ORGINC*INFOSRC	0.001	1.494
CVINC*INFOSRC	−0.013	−0.957
FLABR*RESCOM	0.0009	0.748
PLABR*RESCOM	−0.0001	−0.123
ACRE*RESCOM	0.006	0.806
FLABR*INFOSRC	−0.003	−0.732
PLABR*INFOSRC	−0.002	−1.063
ACRE*INFOSRC	−0.003	−0.304
RESCOM*INFOSRC	0.032	0.971
RESCOM*RESCOM	0.086	0.815
INFOSRC*INFOSRC	−0.088*	−1.794
RESCOM	0.036	0.042
INFOSRC	0.333*	2.547
MALE	−0.004	−1.621
ORIGAORG	0.00008	0.037
CONSTANTCONVSHR	0.908*	74.814

[a] Asterisk indicates asymptotic t-values with significance at $\alpha = 0.10$ level.

$$(7) \qquad \varepsilon_{D_o,r} = \frac{\partial lnD_o}{\partial lny_r} = \frac{\partial lny_1}{\partial lny_r}.$$

The distance function is used to assess how a change in organic farm income impacts conventional farm income. The marginal effects of the farm-specific factors (such as RESCOM) are computed as:

$$(8) \qquad \varepsilon_{D_o,xf} = \frac{\partial lnD_o}{\partial lnxf} = \frac{\partial lny_1}{\partial lnxf}.$$

The output elasticities measure the change in organic farm income due to a specified change in the use of an input. The resulting output elasticities indicate that a 1% increase in full-time labor used increases the organic farm income by 0.02% (0.01% for part-time labor), while expanding the acreage farmed by 1% increases income by 0.38%. Higher input levels lead to increased organic production values ensuring that the monotonicity condition for the output distance function is met for each input (full-time, part-time labor, and acreage).

Given a fixed amount of farm resources (labor and acreage), involvement in collaborative research efforts increases organic farm income by 14.1%, an effect which is significantly different from zero. The research effect is positive across all farm sizes, ranging from a high of 17.7% for farms ranging from 7 to 30 acres (the second quartile) to 10.7% for farms over 120 acres (the fourth quartile). The SARE administered by the Cooperative State Research, Education, and Extension Service is a competitive grants program directing resources to researchers, agricultural educators, farmers and ranchers, and students in the United States. The program offers research and education grants (ranging between $30,000 to $150,000 or more) to develop projects that involve scientists, producers, and others in an interdisciplinary approach. These findings demonstrate the value of this approach in enhancing organic farm incomes for participating farmers.

The ratings of information sources consulted by organic farmers had a slight negative impact on organic farm income of about 1.7%. For farmers in the Western SARE region, the information sources variable had the smallest impact on farm income at −1.5%. These farmers also reported the lowest ratings of information sources at 14.22 across the regions.

Measuring Technical and Allocative Efficiency

Table 3 shows the mean technical efficiency of the sample of organic farmers, overall and broken down by specific explanatory variables. The estimated mean efficiency was 0.73 across the complete set of 662 organic producers, which means that the farms are attaining about 73% of the hypothetically best practice organic farm income that could be achieved. The efficiency estimates were fairly constant when organic farms are ranked by farm size quartiles, indicating that farms of all sizes were constrained. Tzouvelekas, Pantzios, and Fotopoulos (2001) reported an output-oriented technical efficiency score of 0.69 for organic olive growing farms along with similar scores of 0.74 for cotton production, and 0.76 in raisin production for Greek organic farms.

We explored the effects of the research commitment variable on technical efficiency in more detail in Table 3. The estimates for all firms were grouped and averaged according to this variable. Producers who are involved in on-farm research see a boost in their technical efficiency, a result that aligns with the prediction from Lazear's (1997) model that more productive individuals tend to participate in research projects. Producers who allocate effort to on-farm research had a mean technical efficiency of 0.85, while farmers who did not participate had a score of 0.69.

We estimated separate models to determine whether the technical efficiency-enhancing effects of research involvement were due to the type of research partner, including other farmers, university colleagues, or private companies or research organizations. None of these factors significantly influenced technical efficiency, suggesting that gains in achieving expansion of organic acreage are not linked to specific collaborative partnerships but are due to the on-farm research effort itself. Table 3 also confirms that the differences in the information sources variable had little impact on technical efficiency of organic farmers.

Allocative inefficiency is represented by the error component A_{ip} which measures the

Table 3. Technical and Allocative Efficiency of Organic Producers, Overall and by Fixed Effects

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Technical Efficiency	662	0.725	0.094	0.632	1.000
By Research Involvement					
No Involvement[a]	502	0.699	0.038	0.630	0.841
Positive Involvement	160	0.847	0.073	0.643	1.000
By Evaluation of Information Effectiveness					
Above Mean Rating	179	0.722	0.107	0.632	0.913
Below Mean Rating	483	0.725	0.089	0.662	1.000
By Farm Size Quartiles					
Less than 7 acres	172	0.716	0.083	0.638	0.968
Between 7 and 30 acres	165	0.727	0.094	0.635	0.977
Between 30 and 120 acres	172	0.725	0.094	0.635	1.000
More than 120 acres	171	0.735	0.105	0.633	0.988
Allocative Efficiency	662	0.148	0.002		
By Gender					
Male Farmers[a]	536	0.147	0.00004		
Female Farmers	126	0.151	0.00004		
By Experience					
Original, All Organic	315	0.148	0.001		
Other Farmers	347	0.148	0.002		

[a] Within category comparison is statistically different at the 0.10 level.

difference between actual and stochastic shadow revenue shares. A negative value indicates that the revenue share obtained from that output is too low relative to other outputs marketed by the farm. Allocative inefficiency for the ith output is:

$$A_{ip} = \alpha_{ipa} + \alpha_{ipb} MALE + \alpha_{ipc} ORIGAORG \quad (9)$$

where MALE indicates male farmers and ORIGAORG represents original, all organic farmers. Table 3 shows the estimated coefficients and standard errors for the allocative inefficiency parameters. The allocative inefficiency components must sum to one so that only information for the revenue share of organically marketed produce is directly estimated.

Total farm income and organic farm income of female farmers are substantially lower than male incomes (about 45% of the male levels). Both female and male farmers obtain the major share of their revenues from conventional markets, at 65% and 58% respectively. Yet the revenue mix of organic producers is systematically inefficient as both male and female producers rely too heavily on revenue from organic markets relative to conventional outlets, given the inputs that are used in the farm operation.

Male farmers exhibit a slightly lower degree of allocative inefficiency in selling to organic outlets compared with female farmers at 14.7% against 15.1%, a difference which is statistically significant at the 10% level. The OFRF survey elicited information on marketing problems faced by organic farmers and the responses provide some insight into the factors that may impinge on allocative efficiency of female organic farmers. Marketing problems related to finding organic markets, obtaining access to organic markets, and difficulty in establishing marketing networks were mentioned more frequently by female organic farmers than the male farmers. A secondary constraint that female farmers identified related to pricing of organic products with specific problems related to finding the best organic prices. Male farmers again reported lower levels of concern with pricing problems compared with female farmers. By contrast, there are no gender differences in technical efficiency estimates.

Female farmers indicate in the OFRF survey the sources where they seek information on marketing and production strategies and the farmers evaluated the usefulness of these sources in providing information. University-based personnel such as extension experts and university researchers involved in organic agriculture both receive high ratings from female farmers. In the private sector, growers associations and personnel from organic certification agencies are viewed as credible information providers. Information on solving marketing problems such as identifying profitable and sustainable marketing channels and developing pricing strategies could be targeted in seminars, meetings, and presentations by these consultants and experts in these organizations.

The OFRF survey provides some illuminating information on the outlets used by farmers. Male farmers market the major share of their output through wholesale outlets such as supermarket or natural food chains, producer cooperatives, or handlers, brokers and distributors. Female organic farmers rely on direct to consumer marketing methods, including farm stands, farmers markets, and community supported agriculture subscriptions. The survey lacks information on the organic and conventional breakdowns on these marketing outlets. Additional analysis of the impact of marketing outlet on performance would be interesting but is beyond the scope of the available survey information.

Farming experience may be qualitatively different between those who began farming and converted to organic systems and those who always farmed organically. Original, all organic farmers tend to rely more heavily on sales through conventional markets, which account for 61% of farm income. We hypothesized that these farmers would show lower levels of allocative inefficiency than converted organic farmers. Table 3 however indicates that this assumption is not valid as both sets of farmers show about the same level of allocative inefficiency at 14.8%.

Discussion and Conclusion

Our results showed that there is significant variation in both the technical and allocative efficiency of organic farmers and these differences may be systematically related to identifiable farm and managerial indicators. The most striking result was that farmer research commitment increases technical efficiency to 0.84 compared with 0.69 for nonparticipants in collaborative research. The research effect is positive across all farm sizes and provides support for the programmatic emphases initiated by the National Institute of Food and Agriculture (NIFA) on directing resources to collaborative efforts between researchers, agricultural educators, farmers and ranchers, and students. NIFA was formerly known as the Cooperative State Research, Education, and Extension Service (CSREES).

This result could be related to the intensely local nature of organic farming systems as it relates to field agroecology and microclimates. The on-farm research itself contributes to a farmer's ability to respond to these conditions. As well, collaboration encourages the discussion and exchange of ideas to counter production and marketing constraints. Programs encouraging farmer-participatory research are extremely important in promoting improvements in organic efficiency and actively supported by NIFA.

Within the organic sector, technical efficiency measures confirm that there are high performers and low performers. The 90th percentile exhibited efficiency above 0.91, and the 10th percentile averaged 0.65. High performers are more experienced organic farmers than the low performers (averaging 13 years versus 8 years) and exhibit much lower involvement in on-farm research projects. The implication is that farmers require experience to develop technical skill in organic farming methods but also need active engagement with the research and extension community. This argues for devoting more effort to teach and mentor original organic farmers in production methods and for expanding availability of NIFA programs designed to encourage farmer-researcher collaboration.

Allocative efficiency in marketing decisions of organic farmers is assessed for the first time. Wal-Mart's push into organics with plans to double its offerings of organic products along with an aggressive pricing strategy to narrow the markup over conventional products will make marketing a priority for organic farmers. The revenue mix of organic producers is systematically inefficient as both male and female producers rely too heavily on revenue from organic markets relative to conventional outlets. Allocative efficiency is more closely linked to gender effects than to farming experience. Additional work on the pricing and competitive strategies of the different marketing outlets used by organic farmers is a priority to enhance the performance of these producers. Stephenson (2009) provides information on how organic farmers adjust their direct marketing strategies over time and diversify across multiple marketing channels.

[Received July 2009; Accepted February 2010.]

References

Comer, S., E. Ekanem, S. Muhammad, S.P. Singh, and F. Tegegne. "Sustainable and Conventional Farmers: A Comparison of Socio-economic Characteristics, Attitudes, and Beliefs." *Journal of Sustainable Agriculture* 15(1999):29–45.

Cuesta, R.A., and J.L. Zofio. "Hyperbolic Efficiency and Parametric Distance Functions: With Application to Spanish Savings Banks." *Journal of Productivity Analysis* 24(2005): 31–48.

Dimitri, C., and C. Greene. "Recent Growth Patterns in the U.S. Organic Food Market." *Organic Agriculture in the U.S.A.* J. Wellson, ed. New York: Nova Science Publishers, 2007.

Färe R., and D. Primont. *Multi-output Production and Duality: Theory and Applications*. Boston: Kluwer Academic Press, 1995.

Grosskopf, S., K.J. Hayes, L.L. Taylor, and W.L. Weber. "Budget-Constrained Frontier Measures of Fiscal Equality and Efficiency in Schooling." *The Review of Economics and Statistics* 79(1997):116–24.

Jaenicke, E.C., and L.E. Drinkwater. "Sources of Productivity Growth during the Transition to Alternative Cropping Systems." *Agricultural and Resource Economics Review* 28(1999):169–81.

Kalirajan, K.P., and R.T. Shand. "Technology and Farm Performance: Paths of Productive Efficiencies over Time." *Agricultural Economics* 24(2001):297–306.

Kroma, M.M., and C. Butler Flora. "An Assessment of SARE-Funded Farmer Research on Sustainable Agriculture in the North Central U.S." *American Joural of Alternative Agriculture.* 16(2001):73–80.

Kumbhakar, S., and C.A.K. Lovell. *Stochastic Frontier Analysis*. New York: Cambridge University Press, 2000.

Kurkalova, L.A., and A. Carriquiry. "Input- and Output-Oriented Technical Efficiency of Ukrainian Collective Farms, 1989–92." *Journal of Productivity Analysis* 20(2003):191–211.

Lazear, E.P. "Incentives in Basic Research." *Journal of Labor Economics* 15(1997):S167–97.

Lohr, L., and T.A. Park. "Choice of Insect Management Portfolios by Organic Farmers: Lessons and Comparative Analysis." *Ecological Economics* 43(2002):87–99.

Morrison Paul, C.J., and R. Nehring. "Product Diversification, Production Systems, and Economic Performance in U.S. Agricultural Production." *Journal of Econometrics* 126(2005): 525–48.

Morrison Paul, C.J., W.E. Johnston, and G.A.G. Frengley. "Efficiency in New Zealand Sheep and Beef Farming: The Impacts of Regulatory Reform." *The Review of Economics and Statistics* 82(2000):325–37.

New York Times. Wal-Mart Eyes Organic Foods. May 12, 2006.

Padel, S. "Conversion to Organic Farming: An Overview." *The Economics of Organic Farming.* N.H. Lampkin, and S. Padel, eds. University of Wales, Aberystwyth, U.K.:, CAB International, 1994.

Progressive Grocer. The Central Question. 81(2002):14–16.

———. "Standard Bearers: Grocers, Producers, and Especially Consumers are All Reaping the Reward of More Consistent Organic Produce." 83(2004):99–103.

Rodríguez-Álvárez, A., V. Fernández-Blanco, and C.A.K. Lovell. "Allocative Inefficiency and its Cost: The Case of Spanish Public Hospitals." *International Journal of Production Economics* 92(2004):99–111.

Stephenson, G. *Direct Marketing Channels & Strategy for Organic Products. eXtension.*

Internet site: http://www.extension.org/article/18381. Accessed March 18, 2010.

Tzouvelekas, V., C. Pantzios, and C. Fotopoulos. "Technical Efficiency of Alternative Farming Systems: The Case of Greek Organic and Conventional Olive-growing Farms." *Food Policy* 26,6(2001):549–69.

Walz, E. *Final Results of the Third Biennial National Organic Farmers' Survey*. Santa Cruz, CA: Organic Farming Research Foundation. Internet site: http://ofrf.org/publications/pubs/3rdsurvey_results.pdf. Accessed March 18, 2010.

———. *Final Results of the Fourth National Organic Farmers' Survey*. Santa Cruz, CA: Organic Farming Research Foundation. Internet site: http://ofrf.org/publications/pubs/4thsurvey_results.pdf. Accessed March 18, 2010.