Technical Efficiency of U.S. Organic Farmers: The Complementary Roles of Soil Management Techniques and Farm Experience

Luanne Lohr and Timothy A. Park

Agricultural policymakers place increasing emphasis on developing efficiency measures for organic producers in order to evaluate regulatory strategies and evolving organic market conditions. We develop technical efficiency measures for U.S. organic farmers using a stochastic production frontier. Farm decisions about acquiring and managing organic soil materials from on-farm and local sources are incorporated into the technical efficiency measure. Productivity differences between newer entrants to organic farming and more experienced producers are estimated in order to isolate the impact of learning and management expertise on farm-level technical efficiency.

Key Words: organic farming, frontier production function, soil organic matter, performance measurement, technical efficiency

Impressive and sustained growth in the market for organically grown foods in Europe, Latin America, and the United States has stimulated new national, state, and private research initiatives to understand the key factors driving expansion. Economic factors that influence organic production including yields, input costs, income, profitability, and other financial indicators have been documented, and comparisons to conventional farming systems are readily available. Tzouvelekas, Pantzios, and Fotopoulos (2001a, 2001b) assessed the technical efficiency of organic and conventional farms of olive-growing and cotton farms in Greece. Compared to conventional farms, the organic farms operated closer to their production frontiers, although average technical efficiency is low for both farming methods. An emerging issue focuses on variation of production efficiency within the organic sector itself, recognizing that the productivity of sustainable agricultural production systems evolves in concert with the experience of the manager. Farm earnings and long-term economic viability, along with productive management and input acquisition strategies, are indicators that can be readily observed and linked back to the performance of the farm operations.

Policymakers examining impacts of support programs such as the Conservation Security Program in the United States and policies to promote organic farming in European countries need efficiency measures that can track national and regional organic production trends. The OECD (Organization for Economic Cooperation and Development) Joint Working Party on Agriculture and the Environment (OECD 2003) has promoted the development of agri-environmental indicators that are readily measurable at the farm level and communicate essential information about the viability and environmental performance of farm operations to policymakers and the wider public.

Private and state organic certification agencies and extensionists value indicators that can readily identify the most productive and efficient farms and management techniques. Increasing emphasis has been placed on indicators of agri-environ-

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mental efficiency, under the assumption that conventional agriculture's productivity has been gained at the expense of environmental quality (OECD 2001). Linking environmental measures with earnings-achieved profitability measures offers insight into achieving this goal, but no research has focused directly on this issue for organic farms.

We use a frontier production function approach, explicitly incorporating environmental measures recommended by the OECD, in order to assess the technical efficiency of organic farming. Organic farmers frequently comment on difficulties in obtaining organic inputs from sources close to the farm, and the sampled farmers used in this study rate this problem among the top three most important barriers to organic production (Walz 1999, p. 87). El-Hage Scialabba and Hattam (2002) mentioned the social performance of organic production in revitalizing communities and noted that local employment opportunities flowing from organic production "encourage people to remain in agriculture, reinvigorating rural communities" (p. 15). Duram (2005) commented on consumer preferences for local or regionally grown food that relies on local inputs in the production process.

A related issue is how the efficiency of organic agricultural systems depends on the experience of the farmer with organic methods. The productivity and performance efficiency of the organic farm operation depends on the managerial strategies of the farmer and the timing of the farmer's decision to convert to organic methods. El-Hage Scialabba and Hattam (2002) pointed out that farmers transitioning to organic production methods initially face reduced productivity. As expertise increases over time, the performance of the organic agriculture system improves in response to improved management skills. Tauer and Lordkipanidze (2000) reported that productivity of U.S. farmers appears to increase slightly with age and then decline. Huffman (2001) suggested that as agricultural production is dominated by biological processes that are controlled by climate and are land-surface–area intensive, the potential for raising labor productivity through skill acquisition and specialization of labor is greatly limited. Tzouvelekas, Pantzios, and Fotopoulos (2001a) found that education and age, as proxies for entrepreneurial skill, have positive impacts on the efficiency of organic farmers. The specific role of experience in organic production efficiency has not been addressed in any research, highlighting the value of the comprehensive survey of U.S. organic farmers that is used here.

This paper addresses two related research issues. First, we assess the technical efficiency of U.S. organic producers in acquiring soil-improving inputs from local sources and identify factors that influence farm economic performance. Second, we distinguish newer entrants to organic farming from more experienced producers and examine the impact of learning and management expertise on farm-level technical efficiency. The framework for assessing the technical efficiency of organic farmers is an econometric model based on a stochastic production frontier. Farm decisions about acquiring and managing organic soil materials are incorporated into the technical efficiency measure. Estimates of technical efficiency are compared for farmers grouped by management experience with organic production methods and by total years of farming experience.

The implementation of the model relies on farm-level information about production and management practices for the U.S. organic sector gathered by the Organic Farming Research Foundation (OFRF), a private research organization in the United States. The data are from a comprehensive national survey of organic farmers and represent a cross-section of crops, production regions, management choices, and farm sizes.

Modeling Efficiency in Organic Production

Stochastic production frontier models, summarized in comprehensive detail by Kumbhakar and Lovell (2000), allow for both technical inefficiency and random shocks that are uncontrolled by producers. Stochastic frontier analysis assumes a composite error term consisting of two random variables. The first element in the composite error, v_i, is a symmetric noise term reflecting random noise which influences farmer decisions and can take on both positive and negative values. The asymmetric inefficiency error term, u_i, accounts for technical and managerial constraints and assumes only nonnegative values. A typical specification for the translog stochastic frontier model is

(1)

$$\ln y_i = \alpha_0 + \sum_m \alpha_m \ln x_{mi} + \frac{1}{2}\sum_m \sum_n \beta_{mn} \ln x_{mi} \ln x_{ni} + \sum_q \gamma_q \ln r_{qi} + \sum_m \sum_q \gamma_{mq} \ln x_{mi} \ln r_{qi} + \nu_i - u_i \ ,$$

where y_i represents the observed output measure for the ith farm, and $\mathbf{x_m}$ is the set of farm inputs with farm- and region-specific measures denoted by $\mathbf{r_q}$ and $\beta_{ij} = \beta_{ji}$. The estimated parameters of the stochastic frontier model are identified by α, β, and γ. Producer-specific variables and regional factors that play a primary role in shifting the technical efficiency of cropping systems are identified by $\mathbf{f_g}$ with the estimated parameters λ_g.

The frontier production function for the ith producer is specified using a translog functional form for inputs along with measures of the operational and environmental constraints facing organic producers. The input variables in the model include labor inputs (*LABR*), organic acreage (*ACRE*), the organic soil-improving inputs (*SOILIMP*), and the farm-level organizational and environmental factors ($\mathbf{r_q}$) that directly influence production. The logarithm of total gross income from organic farming (*INCOME*) is the dependent variable in the production frontier, consistent with the specification in Fraser and Horrace (2003), along with logarithms for the labor, organic acreage, and organic soil-improving input variables.

The one-sided error term that represents technical inefficiency must be non-negative. This restriction implies $\hat{u} = \min_i (\hat{u}_i)$, defining the estimate of the frontier intercept across all farms, so that $\hat{u}_i^* = \hat{u}_i - \hat{u} > 0$. Technical efficiency is estimated as $TE_i = \exp(-\hat{u}_i^*)$, where $0 < TE_i \leq 1$, which is implicit in the normalization of $\hat{u}_i^*$. Use of the total value of output measure in the stochastic frontier model has implications for the interpretation of the inefficiency effect, which will be influenced both by pure technical inefficiency and differences in output prices across producers. Following Färe and Zelenyuk (2003), an aggregate measure of technical efficiency is computed with weights based on shares of total value, a measure that is preferred to non-weighted arithmetic average of efficiency scores.

Data and Variable Descriptions

Analysis on a scale broad enough to accurately reflect the production conditions must be drawn from a national survey that is representative of all organic farmers. Since 1993, the private not-for-profit OFRF has conducted biennial surveys of organic farmers in the United States. In its 1997 survey, OFRF queried the entire U.S. certified organic farm population, as identified by organic certifiers. Lohr and Park (2002) established the representativeness of the data by comparing survey response records with production statistics collected by the U.S. Department of Agriculture.

The data represent all crops grown organically, and all regions in which organic crops are produced. Of the 1,192 responses to the OFRF survey, 774 contained enough data to fit the production frontier. Table 1 shows the descriptions and summary statistics for variables in the model we estimate for equation (2). Natural logs of the variables reported in Table 1 were used in estimation where appropriate.

The proposed model considers two cohorts of organic farmers based on years of experience with organic production methods. Newer entrants are classified as farmers with less than five complete years of experience in organic production. The cohort of more experienced farmers consists of producers with more than five years of experience in organic farming. Descriptive statistics for the two cohorts are presented in Table 1, showing information on the 215 newer entrants to organic farming and the set of 559 more experienced farmers. Estimation of the stochastic frontier model initially examines whether the same performance model is appropriate for both the newer and the more experienced farmers. Econometric tests confirm that the factors that influence production performance and technical efficiency differ across the two cohorts of farmers, and separate models are estimated for the two groups.

Dependent Variable

The logarithm of total organic farming gross income (*INCOME*) is the dependent variable. Mean gross organic income for the farmers was \$51,534. Farmers in the high experience group generally report higher incomes (averaging about \$54,727), exceeding earnings of the more recent entrants to

Table 1. Variable Descriptions and Summary Statistics (N = 774 farms)

Variable	Description	New Organic Farmers [a]	Experienced Organic Farmers [a]
INCOME	Total gross organic farming income, U.S. dollars (US$)	43,233 (69,752)	54,727 (84,109)
LABR	Managers, full-time employees, and part-time employees	10.52 (33.41)	7.50 (13.93)
ACRE	Acreage farmed organically, 1 to 6,000 acres	128.16 (303.54)	128.22 (357.48)
TOTSRCS	Soil-improving inputs used on-farm, 0 to 5 inputs	2.96 (1.64)	3.35 (1.42)
REGSRCS	Soil-improving inputs acquired completely from on-farm or local sources, 0 to 5 inputs	2.08 (1.55)	2.38 (1.35)
ONLYORG	Only organic production on-farm, 1 if yes	0.62	0.80
PCTRENT	Land leased for organic production, percentage of total	31.7 (41.5)	25.8 (38.1)
PCTVEG	Share of organic acreage in vegetables, percentage of total	26.6 (39.6)	29.1 (38.8)
MANGMETH	Sustainable agricultural experts available in the organic farmer's geographic area	4.96 (13.4)	8.10 (17.0)
WEST	Farm is in SARE [b] Region 1, percentage of sample	34.9	33.1
SOUTH	Farm is in SARE [b] Region 3, percentage of sample	7.0	6.4
NOREAST	Farm is in SARE [b] Region 4, percentage of sample	23.2	25.2
NORCENT	Farm is in SARE [b] Region 2, percentage of sample	34.9	35.3
YRFRM	Years of farming experience	12.3 (11.5)	19.5 (11.8)
Observations		215	559

[a] New organic farmers have less than 5 years of experience in organic farming. Experienced organic farmers have more than 5 years of experience in organic farming.
[b] Sustainable Agriculture Research and Education.

Note: Numbers in parentheses are standard deviations.

organic farming farmers by about $11,494. Diversification is a hallmark of organic farming. Vegetable crops, including herbs, were grown by about 28 percent of the farmers in the sample, with a typical crop mix of at least four different vegetable crops. Fruit, nut, and tree crops were produced by about 21 percent of the sample, with a lower degree of diversification, averaging two crops in this category. Field crops were the predominant production category, with 51 percent of farmers allocating acreage across an average of two field crops.

Production Inputs and Soil Improvements

The two inputs given in equation (2) are labor and acreage, which are assumed to be entirely under the control of the producer and can be changed annually depending on the planned output for that season. The labor input (*LABR*) is the sum of managers, other full-time employees, and part-time employees. 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 61 percent hired only part-time workers and 26 percent hired no workers.

The mean farm size in the sample was about 128 acres for both groups of farmers, with the largest farm in the sample being 6,000 acres. Organic farm size is most strongly related to production of field crops with a correlation coefficient of 0.73, followed by vegetable production at 0.61, and fruit, nut, and tree crop production at 0.40. Larger farms tend to include field crop production and vegetable production.

Acquiring and managing soil materials constitute critical management decisions for organic farmers. Soil improvement plans must be submitted to obtain organic certification, and soil organic matter enhancement is perhaps the most important factor in eliminating the synthetic nutrients and pest controls that are prohibited under organic regulations. Major constraints for organic farmers are difficulty in obtaining legally acceptable soil inputs and long distances to suppliers for these inputs (Walz 1999). Since soil improvement is a process, requiring years to achieve optimum organic efficiency, these inputs are both relevant to annual crop decisions and to long-run farm productivity. Soil-improving inputs have both a direct effect on the annual output and an indirect effect on future output.

Respondents to the OFRF survey identified their sources for organic soil-improving inputs and amendments, including farm-derived and local sources. Local sources include neighboring farms or farm suppliers within 50 miles of the producer. Five soil-improving inputs were reported, comprising animal manures for compost, green waste for compost, finished compost, mineral soil amendments, and biological soil fertilizers. The sustainability index developed by Rigby et al. (2001) assigned more weight to farmer self-reliance in inputs as well as to methods for acquiring inputs that support local economies. Organic farmers frequently use regional sources (on-farm or local farms) for acquiring reprocessed wastes, and particularly rely on these sources in producing and processing composting materials. About 69 percent of the farmers acquire all their animal manures for compost from regional sources, with green wastes for compost (54 percent) and finished compost (60 percent) registering slightly lower levels of regional self-sufficiency among farmers. Mineral soil amendments were used by 74 percent of farmers in the sample and biological fertilizers by 49 percent, but the reliance on regional supply sources for these highly specialized inputs was lower, at 30 percent and 16 percent, respectively.

The influence of organic soil-improving inputs on production efficiency is evaluated along two dimensions—number of inputs used and the number of inputs produced completely on-farm. Soil inputs can be classified as those that are produced entirely on-farm or acquired from neighboring farm sources (*REGSRCS*) and those that are partially acquired from more distant sources (*DISTSRCS*), so the total number of organic soil materials that the farmer uses can be measured as *TOTSRCS* = *REGSRCS* + *DISTSRCS*. After appropriate substitution, the soil-improving input variables in the stochastic frontier model can be written as

$$(2)\quad \begin{aligned} SOILIMP &= \phi_f REGSRCS + DISTSRCS \\ SOILIMP &= TOTSRCS\left[1+(\phi_f-1)\frac{REGSRCS}{TOTSRCS}\right], \end{aligned}$$

where φ_f measures differences in productivity of soil inputs that are acquired or produced completely from on-farm or neighboring farms. The redefined measure for organic soil materials in equation (2) is substituted into equation (1) and respecified as

$$(3)\quad \alpha_3 \ln(SOILIMP) = \alpha_{31}\ln(TOTSRCS) + \alpha_{32}\frac{REGSRCS}{TOTSRCS},$$

where $\alpha_{32} = \alpha_{31}(\varphi_f - 1)$. Estimates of α_{32}, α_{31}, and the implied value for φ_f were obtained from the stochastic frontier using farm-level data on gross organic income, labor, acreage, and organic soil materials. The long-term effects of the soil-improving inputs are captured as indirect effects on technical efficiency of the production system through the error term in the stochastic frontier. The soil-improving measures along with years of farming experience appear as explanatory variables in the error term, as the components of $\mathbf{f_g}$ in u_i. This is consistent with the approach used by Morrison-Paul, Johnston, and Frengley (2000) incorporating factors that influence both the technological structure of production and technical efficiency at the farm level. The average number of organic soil materials per farm (*TOTSRCS*) was about three for the new organic farmers, with an average of two soil inputs acquired or sourced completely on-farm or from nearby farms (*REGSRCS*). About 45 percent of these farmers use four or more of the five inputs listed in the survey, while only 20 percent use two or fewer inputs. Over 50 percent of new organic entrants were self-sufficient in two inputs—animal manures for compost and finished compost.

Experienced organic farmers show very similar patterns in the use of soil-improving inputs, with slightly higher adoption levels as 53 percent of experienced farmers use four or more of the inputs. Over 50 percent of experienced organic farmers achieved regional self-sufficiency in three inputs—animal manures for compost, green waste for compost, or finished compost. The on-farm production variable showed a slight negative correlation with acreage (correlation coefficients for both groups of farmers was below -0.20), indicating that increases in farm size do not severely constrain the ability to produce soil-improving inputs from on-farm or regional sources.

Farm and Regional Fixed Effects

The fixed effects in our example are farm and regional factors that influence individual producer efficiency. These variables influence the ability of the farmer to respond optimally to production constraints. Under the U.S. organic regulation, farmers may certify as organic less acreage than they farm, resulting in the possibility of parallel organic and conventional systems being managed by the same operator. About 80 percent of experienced farmers have committed the whole farm to organic production (*ONLYORG*), a percentage that is significantly higher than that for young farmers (62 percent). Producers who farm only organically can focus time and resources to learning about the full complement of organic practices available and are more financially dependent on finding optimal systems for their conditions.

Organic farmers may expand acreage by renting additional land certified for organic production, a flexible management strategy for scaling up the enterprise without large investment costs. The percentage of farmed organic acreage rented for production (*PCTRENT*) is included in the model, averaging 32 percent for young farmers, with a slightly lower share for the older cohort. Skillful farmers may lease land to implement newly developed techniques and to take advantage of expected shifts in market demand.

Direct marketing of vegetables, especially through farmer markets and subscription farming, is an entry point for new organic farmers. Addition of vegetable acreage is a common strategy to diversify crop mix that may influence organic farm incomes. In 2001, farmers in 47 states raised nearly 72,000 acres of organic vegetables, up 15 percent from the previous year (Greene and Kremen 2003). The percentage of acreage allocated to vegetable production (*PCTVEG*) is below 30 percent for both cohorts of farmers in the sample.

Indicator variables representing the four USDA Sustainable Agriculture Research and Education (SARE) regions are included in the model. These regions reflect the U.S. government's demarcation of sustainable agriculture extension-research support. A dichotomous variable was created for each region, equal to one if the respondent's farm was in that region, and zero otherwise. Overall, 33.6 percent of farmers were in the SARE 1 region (*WEST*), 35.1 percent in the SARE 2 region (*NORCENT*), 6.6 percent in the SARE 3 region (*SOUTH*), and 24.7 percent in the SARE 4 region (*NOREAST*). Regional shares were quite similar for the two sets of experience levels.

Geographic effects are evident in the number of organic soil materials applied by farmers and soil inputs produced completely on-farm. Farms in the West region used 3.1 types of soil materials and developed local self-sufficiency networks for an average of 2.2 soil inputs. Organic farms in the South and Northeast employ an expanded set of organic soil materials, exceeding 3.6 inputs on average. Farms in these two regions also show more success in accessing local supply networks for their soil input needs, on average exceeding 2.5 inputs.

The West region has historically received the strongest institutional support for organic agriculture and is home to 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. Thus, the locality-specific research needed for successful organic farming emerged sooner in the West than in the other regions.

Sunding and Zilberman (2001) emphasized the key role of technical support and expertise along with extension training in fostering the adoption of agricultural technologies and management systems. Expertise may be clustered more heavily in specific geographic regions and may play a role in the technical efficiency achieved by farmers in that region. To assess the institutional support and information available for organic production and marketing systems, we gather data on the geographic distribution of experts in sustainable agriculture. The *Sustainable Agriculture Directory of Expertise* (Sustainable Agriculture Network 1996) provides information on nearly 1,000 individuals and over 200 organizations, along with their areas of technical expertise and geographic location, including town, state, and zip code. The directory profiles information from university researchers, cooperative extension, farmers, and ranchers, along with farm consultants, agribusiness firms, and nonprofit research and education organizations. The information was aggregated into 25 major areas of expertise defined in the directory, including such categories as farm management, nutrient management, soil management, and pest management. The geographic location of each expert was matched with the location of each producer. The resulting variable (*MANGMETH*) is an indicator of the diverse fields of expertise that are available when organic producers seek technical and management advice from local sources.

Geographic effects appear in the institutional support for organic agriculture as measured by available expertise. Farms in the West region have the most experts available for each farmer, with an average of 9.8 areas of expertise reported for each farmer. Organic farmers in the South face the most constraints in locating experts to provide technical and management assistance, with about 4.4 experts available per farmer.

Estimation Results

The specification of the stochastic frontier highlights the link between technical efficiency and management strategies of producers in acquiring soil inputs from regional sources. The model considers whether a pooled stochastic frontier is appropriate that combines the cohort of newer entrants (less than 5 years of organic experience) and the more experienced cohort of organic farmers (more than 5 years). The restrictions that the estimated coefficients are equal across the two groups of farmers is rejected, as the calculated value of the F-statistic ($F_{15,\,744} = 1.835$) exceeds the critical value at the 95 percent confidence level. We proceed by estimating separate models for the two groups, with the coefficient estimates and asymptotic t-ratios presented in Table 2.

A statistical test for including the interaction terms of the soil-improving inputs with the land and labor variables confirmed that these variables were not significant, as the calculated χ^2 value of 4.49 was below the critical value χ^2_6 of 12.59 at the 95 percent confidence level. Consequently these variables were excluded from the model. The restrictions consistent with a Cobb-Douglas functional form which would omit the quadratic and interaction terms for the land and labor input were also rejected. The calculated χ^2 value of 28.26 exceeds that critical value of χ^2_3 of 7.82 at any reasonable confidence level.

In the translog model estimated, the coefficient estimates for the natural logs of the inputs are interpreted as output elasticities, calculated by taking the derivatives with respect to the logarithms of each input measure incorporating the coefficients on both linear and quadratic terms. The output elasticities measure the change in gross organic farm income due to a specified change in the use level of an input and are evaluated at the means of explanatory variables. The resulting output elasticities indicate that a one percent increase in labor used increases organic farm income by 0.35 percent for the recent entrants, less than the 0.40 percent expansion attained by the older cohort. The output elasticity for labor is statistically higher for the more experienced organic farmers. For organic farmers with less than five years experience, the first and third quartiles of the labor elasticities range from 0.30 to 0.75, and for more experienced farmers from 0.39 to 0.50.

El-Hage Scialabba and Hattam (2002) mentioned that organic agricultural enterprises often require more labor inputs than conventional farming and that labor demand is a constraining factor in converting to organic production. Descriptive statistics from the OFRF sample indicate

Table 2. Stochastic Frontier Parameter Estimates for Organic Producers (N = 774 farms)

Parameter	Variable	New Organic Farmers Estimate[a]	Experienced Organic Farmers Estimate[a]
α_0	Constant	7.810* (23.743)	7.771* (34.477)
α_1	ln(*LABR*)	0.074 (0.458)	0.327* (2.987)
α_2	ln(*ACRE*)	0.219 (1.866)	0.152 (1.857)
α_{31}	ln(*TOTSRCS*)	0.098 (0.958)	0.078 (1.091)
α_{32}	$\frac{REGSRCS}{TOTSRCS}$	-0.002 (1.395)	-0.0009 (-0.886)
β_{11}	ln(*LABRSQ*)	0.069* (2.381)	0.018 (0.717)
β_{22}	ln(*ACRESQ*)	0.031* (1.988)	0.046* (4.230)
β_{12}	ln(*LABR*) × ln(*ACRE*)	0.021 (0.598)	0.006 (0.279)
γ_1	*ONLYORG*	0.365* (3.116)	0.142 (1.626)
γ_2	*PCTRENT*	0.073 (0.548)	0.286* (3.072)
γ_3	*PCTVEG*	0.268 (1.610)	0.452* (4.459)
γ_4	*MANGMETH*	0.0004 (0.114)	0.003 (1.687)
γ_5	*WEST*	0.006 (0.079)	0.322* (4.733)
γ_6	*SOUTH*	-0.187 (-0.905)	-0.194 (-1.398)
γ_7	*NOREAST*	0.207* (1.966)	0.052 (0.707)
γ_8	*NORCENT*	-0.077 (-1.093)	-0.116* (-3.492)
λ_0	*CONSTANT*	0.120 (0.876)	0.178 (1.378)
λ_1	ln(*TOTSRCS*)	0.057 (0.565)	0.045 (0.652)
λ_2	$\frac{REGSRCS}{TOTSRCS}$	-0.002 (-1.476)	-0.001 (-1.165)
λ_3	*YRFRM*	-0.007 (-1.413)	-0.006* (-2.094)
R-squared		0.63	0.60

[a] New organic farmers have less than 5 years of experience in organic farming. Experienced organic farmers have more than 5 years of experience in organic farming.

Note: Asymptotic t-values in parentheses with significance at $\alpha = 0.05$ level denoted by asterisk.

that more experienced organic farmers use fewer employees than the recent entrants, suggesting caution in viewing labor as an input limiting the efficiency of the organic farm enterprise. The output elasticity for the labor input shows that labor employed by experienced organic farmers is more productive in contributing to output. The average farm size was approximately the same across the groups of farmers, suggesting that the scale of the farm operation is not driving this difference. The result that more experienced farmers are able to generate a greater shift in output for each unit of labor employed has not been noted in previous studies. The acreage elasticity is essentially the same for both groups (0.47 and 0.48). The quartiles of the acreage elasticities for newer farmers are 0.35 to 0.62, and for more experienced farmers 0.36 to 0.77.

The all-organic variable had a positive, significant coefficient for the set of recent entrants but was not statistically significant for the more experienced group. Looking at newer entrants only, the results show that producers with all organic operations have farm incomes that are about 30 percent higher than producers with mixed operations. Methods to diversify organic farming acreage and retain flexibility in farm size through use of rented acreage are statistically significant predictors of higher income for more experienced farmers. These factors do not influence organic income levels for the less experienced group. Examining the more experienced cohort, a one percent increase in rented land increases gross organic income by 0.28 percent, while a one percent expansion of vegetable acreage increases it by 0.45 percent. Farmers who rent more land as well as operators relying on higher percentages of vegetable acreage generate higher gross organic income among the experienced cohort of farmers.

The geographic variable estimates compare regional organic farm income with the average for all U.S. organic farms. These measures are independent of any arbitrarily chosen base region (avoiding the dummy variable trap) and provide a clearer interpretation of how the complete set of regional effects influence organic farm income. The null hypothesis that the regional effects are jointly equal to zero is rejected at $\alpha = 0.05$ for the more experienced farmers only. For these farmers the positive coefficient for the West region and the negative coefficient for the North Central region are statistically significant. Farms located in the West region have gross organic farm incomes 32 percent higher than the average U.S. organic farm, consistent with the early and continuing institutional support for organic agriculture in this region. Those farms in the North Central region have gross organic farm incomes 11 percent below the average U.S. organic farm. This may be due to emphasis on field crop production in the region, which tends to return lower gross income per acre than vegetable and fruit crops.

Technical Efficiency in Soil-Improving Inputs

Table 3 shows the overall technical efficiency for the stochastic frontier model with fixed effects for the newer entrants and the more experienced organic farmers. Values of the technical efficiency estimates are bounded between 0 and 1, with 1 indicating a fully efficient organic farm which attains the maximum level of output (organic farm income) given its level of inputs. Our discussion of results focuses on the general patterns of technical efficiency across new organic farmers and experienced organic farmers, recognizing the substantial variability inherent in efficiency estimates. The estimated mean technical efficiency score is 0.760 for recent entrants to organic farming, which is slightly higher than the value of 0.713 attained by the farmers with more experience in organic production. Tzouvelekas, Pantzios, and Fotopoulos (2001a, 2001b) 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. Oude Lansink, Pietola, and Backman (2002) document a technical efficiency measure of 0.95 under variable returns to scale for organic farmers in Finland, which is slightly higher than the value estimated here.

The stochastic frontier model is used to assess the technical efficiency of organic producers in acquiring soil-improving inputs from local sources. The parameter φ_f from the stochastic frontier measures the relative marginal contribution to revenue for farmers who rely completely on regional sources in acquiring soil organic materials. Focusing on the newer entrants, a value of φ_f equal to 0.965 (-0.002/0.057 + 1) implies that producers who attain regional self-sufficiency in soil inputs are slightly less productive in generating organic farming gross income than farmers who do not develop self-sufficiency in acquiring inputs. The estimated value suggests that income is at most

Table 3. Overall Efficiency and Decomposition by Experience and Soil-Improving Inputs

	Observations	Overall Efficiency [a]	Minimum	Maximum
New organic farmers [b]	215	0.760	0.617	1.000
Overall farming experience				
Fewer than 5 years	97	0.713	0.617	0.818
5 to 10 years	30	0.722	0.633	0.828
10 to 20 years	33	0.789	0.681	0.913
More than 20 years	55	0.847	0.719	1.000
Use of soil-improving inputs				
No inputs	51	0.709	0.617	0.849
1 or more inputs	164	0.776	0.650	1.000
100% reliance	77	0.828	0.742	1.000
Experienced organic farmers [b]	559	0.713	0.598	1.000
Overall farming experience				
5 to 10 years	151	0.660	0.598	0.732
10 to 20 years	195	0.698	0.620	0.779
More than 20 years	213	0.765	0.668	1.000
Use of soil-improving inputs				
No inputs	66	0.700	0.598	0.942
1 or more inputs	493	0.714	0.612	1.000
100% reliance	202	0.745	0.660	1.000

[a] Overall efficiency computed using value shares following Färe and Zelenyuk (2003).
[b] New organic farmers have less than 5 years experience in organic farming. Experienced organic farmers have more than 5 years in organic farming. Total sample size is 774.

3.5 percent lower when less experienced organic farmers develop strong linkages to local suppliers of soil materials. Similarly, income effects for the more experienced cohort are even smaller, at 2.2 percent, when these managers pursue a policy of relying on local sources for soil organic inputs. Finally, the difference in the income effects across the experience groups is quite small, indicating that knowledge about acquiring and managing soil inputs from local sources diffuses quickly to new entrants and is incorporated into their production plans.

Overall efficiency measures for the newer entrants and the more experienced farmers are also calculated by grouping producers by years of farming experience. Newer entrants have less than five years in organic production but show a range of experience levels in conventional production agriculture. The largest component of the recent organic entrants (45 percent) have less than five years' experience in farming, indicating that they began farming with organic techniques. A second large component of the newer entrants have extensive experience in agricultural production, as over 25 percent have farmed for more than twenty years.

Previous farming experience does impact the efficiency ratings of recent adopters of organic techniques. Table 3 shows that technical efficiency for the newer entrants is highest (0.847) among farmers with more than 20 years of farm experience. Technical efficiency for recent organic entrepreneurs with little farming experience is slightly lower than the levels achieved by all recent entrants to the organic sector.

The results highlight two points. First, farmers who have more general experience in farming and greater knowledge of their local soil conditions are more efficient at matching inputs to farm needs and are able to achieve the highest levels of efficiency among the new entrants. The results align with findings reported by Foster and Rosenzweig (1995), who note that experience effects augment the "ability of farmers to make appropriate decisions about input use for new technologies" (p. 1205). Second, new producers entering farming utilizing organic production methods suffer very slight declines in efficiency (0.713 for farmers with less than 5 years' farming experience) and match the overall efficiency of experienced conventional farmers who convert to organic production (0.713).

The technical efficiency estimates confirm that overall farming experience contributes to farm performance, as experienced farmers show higher efficiency scores and use a given set of inputs to produce closer to the frontier of maximum achievable output. There are slight differences in the efficiency scores across years of overall farming experience, with a slight upward trend apparent in the results. Huffman (2001) found that active years of experience had no significant effect on the efficiency of reduced tillage adoption, in contrast to the impact of farming experience identified here. The results demonstrate that conventional farmers who convert to organic methods are able to adapt their production and input acquisition techniques to achieve high levels of technical efficiency using alternative production methods.

Implications of the Results

Organic farmers must be concerned with soil quality. The U.S. organic standard requires explicit planning for soil improvement. As implementation of the Conservation Security Program began in 2004, payment levels will depend on sustainability of farm practices with respect to soil and water resources. Investments in soil improvements do generate long-term economic gains to the farm, but the linkage between organic farm revenues and farm management strategies that promote regional self-sufficiency in soil-improving inputs has not previously been identified.

Our findings align with recent work by de Koeijer et al. (2003), who suggest that efficiency improvements can be achieved by demonstrating the economic effects associated with specific farm-management practices. These relationships are difficult for farmers to estimate and evaluate effectively, highlighting the value of survey research integrated with economic efficiency analysis. The results presented here demonstrate that organic farms can maintain high productivity and farm income levels even while relying on local sources for acquiring natural soil inputs. Research and extension efforts to increase farm and local self-sufficiency in soil-improving inputs and to provide systematic information on matching these inputs to farm needs should generate more uniform productivity gains, raising technical efficiency for the entire organic crop production sector.

The technical efficiency estimates confirm that experience in organic production methods contributes to farm performance. There are modest differences in the efficiency scores across years of overall farming experience, with a slight upward trend apparent in the results for both new and experienced organic farmers. New organic farmers are able to achieve levels of technical efficiency that are comparable to more experienced organic farmers. For new organic farmers in the Northeast, farming experience contributes to an even steeper profile of technical efficiency scores compared to the pattern for all new U.S. organic farmers. Technical efficiency rises from 0.713 for farmers with fewer than 5 years and reaches 0.847 for farmers with more than 20 years of farm experience.

The stochastic frontier model is useful in identifying the best performers among each cohort of farmers (new entrants and experienced organic growers), providing role models who can disseminate successful farm management techniques to other producers. Identifying the most efficient producers and observing and testing their methods are the first steps in developing the information needed to assist new farmers and less successful current farmers. To the extent it is possible to transfer this knowledge and implement technologies, the productivity of the entire organic production sector can be improved.

Management specialization, represented by farmers who have committed the whole farm to organic production, has a significant positive impact on organic farm income. Acreage flexibility and crop diversification are also important. The effects of these variables do depend on the farmer's previous level of experience with organic production methods. From the farmer's standpoint, the least controllable of these three factors is acreage flexibility. The model suggests that a higher percentage of rented acreage among experienced farmers leads to higher gross farm income. Maximum flexibility occurs when certified organic land is available for rent. However, since the U.S. regulation requires that acreage be managed using approved practices for three growing seasons prior to the one in which organic certification is granted, farmers often rent available land and then attempt to certify it. Given the strong effect of percentage of rented acreage on income, there is likely to be an emerging premium market for already certified land that is available for rent. The economic benefits of working with farmers on tactical farm-level decisions about production techniques and acquisition and use of soil-improving inputs to improve technical efficiency can be integrated into extension programs and targeted to cohorts of organic farmers.

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