The Efficiency of Labor Input in the Tree Nut Growers Industry: A Stochastic Frontier Production Approach Study in Butte County, California

Kuo-Liang Matt Chang[1]
Assistant Professor
Department of Economics
South Dakota State University
Email:

Dr. Todd A. Lone, Lecturer
Department of Agricultural Economics
Jordan College of Agricultural Sciences and Technology
California State University, Fresno
Email: tlone@csufresno.edu

I. Introduction

The shortage of farm labor in specific agricultural production sectors has caught wide attention in recent years. The *Wall Street Journal* claimed "farmers nationwide are facing their most serious labor shortage in years" (*Wall Street Journal*, July 20, 2007). In California, the seasonal labor shortage has been recognized as a major problem among farm communities. According to a grower in Santa Clara County, "Due to shortages, guys go where they get paid the most so they keep moving. Labor contractors are short of people. Harvest scares me to death (*Ag Alert*, August 9, 2006)." In an attempt to solve the problem of the insufficient number of domestic workers who are willing and qualified to fulfill seasonal agricultural jobs, the U.S. government applied the Bracero program of 1942–1964 to permit Mexican laborers to take temporary work in the U.S. agricultural sector. In 1964, this program was replaced by the so-

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called H-2A program, which allowed foreign workers to work in both agricultural and nonagricultural jobs (Homeland Security, 2008).

While reviving the H-2A program in 2007, the Bush Administration also proposed giving broader legal status to millions of currently undocumented immigrants in the United States. The H-2A program originated from the "guest worker" agreement (H-2 program) between the United States and Mexico in 1964. When the Immigration Reform and Control Act of 1986 was enacted, the H-2A program was designed specifically to address the temporary agricultural worker shortage. The goal of the program was to reduce the number of illegal immigrant workers while securing the U.S. border. Immigrant workers have long been linked to U.S. social and economic problems. According to a report submitted to the Subcommittee on Immigration, Citizenship, Refugees, Border Security, and International Law Membership on the Judiciary U.S. House of Representatives by the Congressional Budget Office (CBO), there are 23 million foreign-born workers in the United States—about one in every seven people within the total labor force in 2006. A recently published estimate suggests that the number of unauthorized immigrant workers in the year 2000 was about 6.3 million (Passel, Hook, and Ben, 2004). Currently, the United States has about 30,000 temporary agricultural workers. These immigrant workers, regardless of their legal status, fill the domestic low-skilled, low-paid jobs. The surplus labor force created by immigrant workers causes the stagnation of the wages in those industries, which contributes to serious urban and rural poverty problems (Martin, 2006).

Since the Immigrant Reform and Control Act (IRCA) in 1984, agricultural lobbyists have argued they have developed a special need for, and dependence on, immigrant workers (Farm Labor Alliance, 1986). Because the U.S. agricultural sector is comprised mostly of small, familyowned businesses, most of the need for the immigrant workers is to fill the seasonal labor shortage. The current seasonal farm workers are mainly foreign-born due to the unwillingness of native laborers to apply for such positions because of tough working conditions and relatively low wages.

Less-skilled immigrants (many of them illegal) use traditionally low-wage rate, manual-labor agricultural jobs as their "port of entry" to the United States and hope to get legal status in the long run. Once the earlier immigrant workers earn legal status, they move to other jobs that pay higher wages, leaving the agricultural job vacancies for the newcomers, most of whom are also illegal immigrants. The growth of this new labor supply in the low-skilled sectors depresses the market wage and the total income of the people who are at or below the poverty line. Historically, U.S. immigration law apparently worsens the problem by constantly granting legal status to illegal immigrants once they have lived in the country for a specific period of time or granting it to their offspring who have been born in the United States, at which time their offspring, not the parents, are U.S. citizens. This policy creates a dilemma for the U.S. government. On the one hand, the agricultural sector insists the immigrant workers are essential for their industry's survival. On the other hand, the presence of illegal immigrant workers in the agricultural sector creates a growing negative to the U.S. economy. Thilmany and Blank (1996) conclude that the IRCA has failed to control the increasing flood of illegal immigrants into the United States, forcing farmers to use more farm labor contractors, thus generating more managerial and risk-management problems for farmers.

This paper aims to examine the contribution of the labor input to agricultural production efficiency. If an increase in numbers of labor does not increase production efficiency, we should have reason to question the current quantity-oriented labor policies in terms of solving the labor shortage issue. In addition, we want to examine the marginal rate of technical substitution (MRTS) between the labor input and other inputs. The MRTS will provide a clear idea of how labor can be replaced with other inputs without losing total production. Finally, the influence of farm labor on economies of scale and economies of scope will also be discussed. We will investigate whether the scale and size of the farm has a significant role in determining production efficiency for our target farmers.

It is extremely important to recognize that each agricultural commodity has its own unique production technology with respect to labor demand. We chose to conduct our survey on the tree nut industry due to its relatively stable production and significant seasonal labor demand. In addition, the variable of geographic differences might distort the research results due to the effect of environmental and socio-economic differences. To reduce potential biases, we collected sample data from tree nut growers in Butte County, California that share similar soil, weather, geographical, and environmental characteristics. According to a recent study by the USDA, part-time or seasonable farm workers have become a large proportion of all farm workers in the tree nut industry (Kandel, 2008). Therefore, a careful study of production efficiency with respect to labor in the tree nut industry is warranted.

II. Methodology and Model

This paper adapts the stochastic production frontier regression approach developed by Aigner et al (1977), Meussen, and Van Den Broeck (1977). Traditional econometrics methods incorporate a random error term that can be positive or negative, and consequently the production functions generated from these methods are an average relationship between output and inputs (Alaudddins et al, 1993). The stochastic frontier production model is superior to the traditional econometrics methods because of the way that the parameters are estimated by the "frontier" of the production function, which corresponds to the maximum output assumption held by most economic theory (Kalirajan and Shand, 1999). Several studies have applied the frontier model in the study of agricultural production efficiency and generated results more consistent with theoretical assumptions (Battese and Corra, 1977; Battese and Coelli, 1995; Nahm and Sutummakid, 2005).

An important advantage of the stochastic frontier method is that it allows researchers to specify the error term in two components (Bishop and Brand, 2003). The first part of the error is a standard, random, two-sided component that is similar to the traditional approach. The second part of the error is a non-negative component that identifies the sources of technical inefficiency.

Given the sample size N, the analysis summarized in this paper assumes the production function as follows:

$$Q_i = f(x_i;\beta)\exp(V_i - U_i) \quad i=1,\ldots, \mathrm{N} \qquad (1)$$

Where Q_i is the production of producer i;

x_i is the vector of input quantities of the i-th producer;

β is the vector of the unknown parameters to estimate;

V_i is the random error term which are assumed to be i.i.d. (0, δ_v^2); and

U_i is the non-negative error term to measure technical inefficiency.

The term U_i usually has no theoretical rationale regarding its distribution. This paper adapts the single-stage, maximum likelihood estimation approach developed by Battese and Coelli (1995) to allow us to study possible explanations of production inefficiency. This approach defines

U_i as non-negative random variables that are distributed independently as truncations at zero of the $N(m_i, \delta_u^2)$ distribution.

To be specific

$$m_i = z_i * \delta \qquad (2)$$

Where z_i is a vector of variables that may influence the efficiency of the producer; and

δ is a vector of parameters to be estimated.

Model Specification

We propose three models to study the influence of the labor input on production efficiency. This study assumes the production function is a homogeneous Cobb-Douglas function.

Model I

$$\ln Q_i = \beta_0 + \beta_c * \ln \mathrm{C}_i + \beta_K * \ln \mathrm{K}_i + \beta_w * \ln \mathrm{W}_i + \beta_L * \ln \mathrm{L}_i + (V_i - U_i) \qquad (3)$$

Model II

$$\ln Q_i = \beta_0 + \beta_c * \ln \mathrm{C}_i + \beta_K * \ln \mathrm{K}_i + \beta_w * \ln \mathrm{W}_i + (V_i - U_i) \qquad (4)$$

Model III

$$\ln Q_i = \beta_0 + \beta_L * \ln \mathrm{L}_i + \beta_K * \ln \mathrm{K}_i + (V_i - U_i) \qquad (5)$$

Where C_i is the total chemical usage, which includes all fertilizer, insecticide, and herbicide inputs;

W_i represents ground-water inputs.

L_i is the labor input; and

K_i represents all monetary values of additional custom work and equipment inputs.

The inefficiency effects are estimated by the following equation:

$$m_i = \delta_0 + \delta_1 * \ln Z_{1i} + \delta_2 * \ln Z_{2i} \quad (6)$$

Where Z_{1i} is the amount of land in production; and

Z_{2i} represents the product difference.

We include only two major tree nut products, walnuts and almonds, and Z_{2i} is assigned as a dummy variable to specify this difference. The reasoning behind this method and the measurement of these variables will be discussed in the next section.

Model I is used to investigate the influence of each input on production efficiency. The labor input is removed from the production function in model II as a comparison to study the potential efficiency change. Model III is a general model used to study the relationship between capital and labor without controlling other inputs. Use of these three models will provide a better understanding of the importance of the labor input to the tree nut growers in our sample.

III. Data

Data used for this paper was collected by postal, phone, and personal surveys. The contact information of the local tree nut growers was made available though the assistance of the Butte County Agricultural Commissioner's Office. One hundred growers were randomly selected for the survey from a list of 1,033 local tree nut growers. Potential interviewees were contacted via phone and mail during the first period of the study. To encourage growers to return the questionnaire, a $15.00 gift card for a national home-improvement store was provided. The return rate, however, was surprisingly low at only 12 %. To increase the sample size, on-site visits to growers who were part of the original one hundred names selected but who had not responded to initial contact attempts was conducted. Most growers we encountered were extremely reluctant to share their production and cost information. At completion of the survey, full or partial information from thirty-three of the original one hundred targeted growers was collected. Of these thirty-three, only twenty of the surveys contained all of the key information needed for this study.

The questionnaire was designed to acquire detailed information on production level, crop types, operating costs, approximate harvest revenue, amount of farm land in production, water usage, capital investments, labor inputs, and chemical usage (fertilizer, herbicide, and insecticide) during the 2006/2007 production year.

Total production (Q_i) was identified and measured in pounds. The production inputs measurement, however, was complicated due to the diverse nature of each input. For example, different types of chemical inputs have different levels of optimal usage such that their efficiency cannot be quantified by simply measuring the amount applied. In this study, total monetary cost was measured by the chemical input (C_i). The water input (W_i) was originally designed to record both surface- and ground-water usage. However, the survey results indicated that all the growers in the sample used ground water as their only water input resource. Although most growers did not provide the information of water-usage quantity, the monetary costs from their electric bills for pumping ground water were collected.

A similar difficulty was experienced when collecting information for the labor input (L_i). Most growers were reluctant to specify the type and hours of labor applied in the production process. Therefore, to the data does not identify the proportion of labor input between domestic and immigrant workers. However, the total monetary cost for the labor input was available. According to a cost and efficiency study done by the University of California Cooperative Extension (2006), the hourly wages of skilled and unskilled workers are $14.49 and $10.35, respectively . Although we are able to translate the monetary cost into working hours by applying this information, we chose to use the monetary cost rather than hours to represent the labor input to reduce any unnecessary bias. The capital input (K_i) was limited to include only the direct costs of equipment and additional custom work. All the input values were converted into natural log values before applying them to the model.

In order to measure economies of scale accurately, we control the size of farm land (Z_{1i}) and intend to identify any possible inefficiency due to variations in production scale. Although the sample includes only almond and walnut growers, variable Z_{2i} in equation (6) is purposely designed to examine whether there is a significant effect on production inefficiency between these two commodities.

Two fundamental problems are inherent in the nature of the data collected for this study that suggest certain implications of our study results need to be carefully examined. First, growers who chose to respond to the survey might be more motivated to improve their farm's productivity than those not responding. This creates a bias of data toward the group with higher efficiency goals. Second, the inability of differentiating the types of labor input was domestic or immigrant reduces the power of explaining the influence of seasonal workers on farm productivity in this study. According to a study published by the USDA, approximately one third of the farm laborers are hired workers and 60 percent of these workers are noncitizens (Kandel, 2008). This information is used when discussing the study results in the upcoming section; however, the potential problem of overgeneralization should be treated with caution.

IV. Results and Discussion

General descriptive statistics for the data are summarized in table 1. The sample distribution of output is skewed to the right and peaks toward the mean, which reflects the fact that most of the growers in the sample have very similar output levels with only a few exceptions. The kurtosis values for the usages of chemicals, water, capital, and land size suggest a wide range of differences in the scale of production exists in the sample.

The distribution of the labor input in the sample is "peaky" with a relatively high kurtosis value. The distribution skews to the right, which implies an inconsistent relationship between the labor input and the scale of production. A significant amount of input cost is spent on chemicals and labor in our sample. The small percentage of capital input cost stems from the fact that only equipment and custom work costs were included in this category.

The FRONTIER 4.1 program developed by Coelli (1996) was applied to perform the efficiency study. Table 2 lists the results of the log likelihood function (LLF)values and the likelihood ratio (LR) tests among the three models. The log likelihood function values for models I, II, and III are -9.10, -9.56, and -15.10. The LR test is a "goodness-of-fit" test to determine if adding more independent variables would improve the fit of the model to the data. In this study, Models I and II differ by the inclusion of the labor variable in Model I, Models I and III by the inclusion of the chemical and water variables in Model I, and Models II and III by including only labor and capital in Model III. The null hypothesis (H_0) for all the LR tests is that adding more independent variables will not increase the level of goodness-of-fit.

Table 1: Descriptive Statistics

	Output (lbs)	**Chemical ($)**	**Water ($)**	**Labor ($)**	**Capital ($)**	**Land size (acres)**
Mean	134,001	20,552	5,487	12,628	585	55
Standard error	27,349	4,487	898	3,725	130	8
Kurtosis	3.05	0.27	-0.68	4.80	1.36	0.20
Skewness	1.71	1.23	0.79	2.25	1.34	1.13

Minimum	27,300	2,599	1,080	500	1	16.8
Maximum	502,512	63,247	13,284	63,384	2122	152
Percentage to total cost	N/A	52.3 %	14.0 %	32.2%	1.5 %	N/A

Table 2 results indicate there is no significant difference between model I and model II as previously specified in equations (3) and (4), which implies that adding labor to the model cannot improve the goodness-of-fit for our sample. On the other hand, both models I and II are significantly better than model III when both chemical and water inputs are extracted from the production function. In addition, the difference between Models II and III is the water input, which LR test result indicates that creates the difference in the goodness of fit between these two models. Therefore, it is reasonable to conclude that water is more important than labor in terms of improving the goodness-of-fit of our model.

Table 2: Likelihood Ratio Test for the Production Functions

	LR Test	Decision
Model I /Model II	0.92	Don't reject H_0
Model I/Model III	12***	Reject H_0
Model II/Model III	11***	Reject H_0

Note: *** means significant at 99 % confidence level.

The estimation of parameters for all of the models is summarized in Table 3.

Models I and II have very similar results except for the variable γ. The chemical and capital inputs are significant at the 1% level in both models. The positive sign of chemical usage implies a positive relationship between increased chemical input and output. The capital input for equipment and custom work has a negative relationship with output. A possible explanation is that farmers who sell their products directly to the processors do not spend large amounts of money on equipment and custom work. Instead, these farmers may focus their energy on improving the efficiency of nut production. The water input is significant at the 10 percent level and has the expected positive sign. The absolute values of the estimated coefficients for chemical, water, and capital inputs are all less than 1, indicating that output is inelastic with respect to these inputs. The labor input is not significant in Model I, and its negative value implies that mismanagement of labor may actually reduce production efficiency. The summations of β_c , β_w , β_L , and β_K are less than 1 in both models I and II, implying our sample growers are at the production stage of decreasing returns to scale.

Table 3: Estimated Parameter Values of the Cobb-Douglas Production Function

Parameter	Model I	Model II	Model III
β_0	3.51***	3.71**	10.77***
β_c	0.87***	0.77***	N/A
β_w	0.29**	0.25*	N/A
β_L	-0.05	N/A	0.16
β_K	-0.23***	-0.20***	-0.03
δ_0	0.16	0.10	1.40***
δ_1	0.01***	0.01*	-0.03***
δ_2	0.25	0.22	0.38
σ^2	0.19***	0.17***	0.31

γ	0.99***	0.54	0.28

Note: 1. Log likelihood function for model I = -9.1038.
Log likelihood function for model II = -9.5578.
Log likelihood function for model III = -15.1023.
2. Significance levels are indicated as follow: *: 90 %; **: 95 %; ***: 99 %

The β values for the labor and capital inputs are not significant at any confidence level for model III. Compared with models I and II, the result from model III suggests that both chemical and capital inputs are not significant without the inclusion of water in the production process. But the exclusion of labor between model I and model II does not change the significance of chemical, capital, and water inputs. As a result, it may be that water management, not labor, needs more attention for our sample tree nut growers, if improving production efficiency is their goal.

The coefficient for the size of farmland (δ_1) is significant in all three models. The positive sign for models I and II implies that as farmland size increases, the production efficiency actually decreases. Given that most growers included in this sample are middle- or small-sized producers, we are surprised to see that their production scale is at the level of diseconomies of scale, as indicated by the summations of $\beta' s$ values as shown in Table 3. Therefore, it is possible that the inefficiency may simply result from managerial problems that have nothing to do with the size of the farm. In other words, to take advantage of economies of scale, growers need to utilize their available land in a more efficient way. The insignificance of parameter δ_2 suggests that the type of commodity does not affect production efficiency.

The parameter γ is defined as $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$ by Battese and Corra (1977). This value lies between 0 and 1 as an indicator of the proportion of the total variation that results from the inefficiency effects in the model. For example, the γ value in model I indicates that 99 percent of the variation can actually be explained by the inefficiency effects. However, once the labor input in model II is taken out, γ is no longer significant and the value is reduced to 54 percent. This difference in γ between the two models suggests that the labor input contributes directly to production inefficiency for the growers.

The marginal rates of technical substitution (MRTS) between labor and chemical, water, and capital inputs at the mean are -10.69, -13.34, and 99.00, respectively. The cost of replacing labor with capital is extremely high at a 1/99 ratio, thus it will be economically inefficient for small- or medium-scale growers to try to reduce the seasonal labor problems by investing in machinery. Instead of purchasing more machinery to replace labor, our study results suggest it will be more economically efficient for tree nut growers to concentrate on improving the chemical and water usage as indicated by the negative value of the MRTSs.

An important advantage of applying the FRONTIER 4.1 program is that it provides estimations of the average and individual technical efficiencies for the sample. Table 4 summarizes the estimation results of production efficiency for models I and II, along with their relationship with farm size. Model I has smaller average efficiency because more growers are clustered in the low efficiency coefficient intervals; there are 4 growers in the 0.00–0.19 interval in model I but no growers in this interval for model II. In addition, model II contains more growers in the 0.40–0.79 efficiency intervals. Since labor is included in model I only, it is concluded that adding more labor input actually contributes to lower production efficiency.

Table 4 also suggests a strong negative relationship between efficiency and farm size. Relatively larger growers in the sample seem to have less efficiency. Due to the fact that the efficiency shown in table 4 is based solely on the quantity of product, we hesitate to make any further explanation of this result beyond stating that most growers in the sample do not enjoy the benefit of economies of scale.

Table 4: Efficiency Effects and the Connection to the Farm Size

Model I		Model II	
Efficiency coefficient		Efficiency coefficient	
Interval	Frequency	Interval	Frequency
0.00–0.19	4	0.00–0.19	0
0.20–0.39	7	0.20–0.39	5
0.40–0.59	4	0.40–0.59	7
0.60–0.79	4	0.60–0.79	7
0.80–1.00	1	0.80–1.00	1
Total	20	Total	85
Average efficiency	0.445	Average efficiency	0.552
Coefficient with the farm size		Coefficient with the farm size	
-0.52		-0.73	

V. Conclusion

The labor shortage in the U.S. agricultural sector has been an ongoing issue for decades, and politicians and farmers tend to solve this problem simply by recruiting seasonal workers from abroad. The history of past decades has proven that the socio-economic cost of satisfying short-term labor demand by hiring immigrant workers—many of them illegal—can be enormous. Rising poverty in rural areas (O'Hare, 1988), the long-debated wage-repression issue, and rural government budget deficits are just a few of the most serious problems related to the current immigration policy in the United States. This paper aims to provide an alternative solution to the labor shortage issue by examining the contribution of the labor input to farm production. Instead of focusing on the quantity side of the labor input, attention was diverted to the quality side of the issue, that is, labor productivity.

To avoid the problem of overgeneralization, a survey study was conducted to collect production and input information from Butte County tree nut growers who share similar soil, weather, geographical, environmental, and product characteristics. The stochastic production frontier regression approach was adopted due to its advantage over other econometric techniques in allowing the researchers to specify the error term as two components—a standardized random term and a technical inefficiency component. The values of the parameters are estimated by the "frontier" of the production function, which corresponds to the maximum output assumption held by most economic theory. Applying the stochastic production frontier model allows analysis of productivity inefficiencies along with information about the importance of each input, the marginal rate of substitution between inputs, and economies of scale regarding the labor input.

We proposed three models based on the same homogeneous Cobb-Douglas production function framework with different combinations of inputs to examine the data. To our surprise, the labor input is not significant in deciding production efficiency in this study. The results in table 2 and table 3 suggest that extracting labor from the model does not change the overall results of goodness-of-fit or the significance of parameter estimate. Although there is not enough information to separate the full-time and part-time labor inputs in our sample, we are able to conclude that labor, in general, does not play a key role in improving tree nut growers' production efficiency. On the other hand, inputs such as chemical, capital, and most importantly, water are all significant in farm productivity. However, when water is removed from the model, all inputs become insignificant. This underscores the important role that water management in production efficiency improvement in this sample.

The stochastic production frontier model enables us to expand this analysis to investigate the possible reasons for inefficiency in production. Table 3 suggests that the selection of products between almonds and walnuts does not contribute to the production inefficiency since the estimate value of δ_2 is insignificant. The size of operation, in contrast, has a significant negative impact on production efficiency. The output elasticity analysis in our study also suggests that growers cannot simply expect to double their output by doubling the inputs. This finding is very important because, although most growers tend to believe expanding farm size is crucial to utilizing the advantage of economies of scale, our analysis result suggests it is the quality of available resources that really matter.

Our suggestion regarding the shortage of labor is not to merely recruit more short-term labor for existing production levels. Instead, improving the logistics of farm management and the quality of work are the keys in finding the long-term sustainable solution for the labor shortage problem. Simply trying to replace labor with machines—as suggested by many factory-oriented farm managers—to improve total productivity can be extremely costly, as verified by our marginal rate of technological substitution analysis.

We cannot deny that the seasonal labor shortage is an economic condition that needs both short-term and long-term policy adjustments to accommodate many small- and medium-sized tree nut growers in Butte County. The problem is rooted in the quality of farm management that requires growers to re-examine everything in their operations such as product selection, density of planting, input combinations, production practices, etc. On the other hand, several dominant U.S. government agricultural policies such as couple or decouple payments, commodity subsidies, marketing loans, etc., seem to encourage growers to put more emphasis on the quantity perspective of production management. According to the results of our study, a long-term, sustainable direction of agricultural policies should emphasize assisting farmers to utilize available resources in more efficient ways. Instead of blindly seeking expansion of the scale of production, farm policies ought to focus on the concepts of economies of scope, marginal analysis, and production efficiency.

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