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Production efficiency and risks in limited resource farming: The case of Bulgarian peanut industry

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We used a stochastic production frontier and a Tobit model to evaluate technical efficiency and inefficiency of Bulgarian limited resource peanut farms for the period 2000/2002. We used a Just-Pope model to examine risks related to on-farm yield adjustments. Technical efficiency of farms ranged from 77 to 97%, with an average 92%, a median of 93%, mode of 90%, and skewness -1.49. The technical efficiency of these farms are largely influenced by on-farm decisions, the quantity of seeds, phosphate, fungicide, the amount investment capital, hours of manual labor used, and leased mechanized labor. The results indicate that efficiency is more crop specific than farm size dependent. Farm inefficiency was unrelated to size but rather to gender and age of operator. Farmers used less than the optimum levels of seeds and phosphate but there was risk associated with an increase in application rates of these inputs. These findings indicate that limited resource Bulgarian peanut farms are approaching efficiency, and adjustment to attain greater efficiency may be influenced by socio-demographic factors and limited government intervention.

Key words: Production, efficiency, peanuts, Bulgaria.

INTRODUCTION

Agriculture is the backbone of the Bulgarian economy. It employs about 26.2% of the labor force and contributes 17.3% to the gross domestic product (GDP) (Totev and Shahollari, 2001). However, most of the crops are produced on small farms that range in size from 0.9 to 11.3 ha, and a large proportion of the crops produced are consumed by the farm household. The small farm size has been suggested as one of the factors restricting agricultural development in post-adjustment periods since agriculture production fell since 1989. It has also been argued that subsistence agriculture is an impediment to agricultural growth in Central Eastern European (CEE) countries because of its lower technical and economic efficiencies (Hazel, 2004; Brent, 1999). Policy makers and researchers are worried that Bulgaria will not be competitive as a member of the World Trade Organization (WTO) because its small farm sizes limit the commercialization of agriculture. There are advocates who favor policies to expand farm size to enhance production efficiency (Lulcheva and Todolrova, 2005) without prior examination of the technical efficiency and resource substitution at the farm level. We investigate whether technical efficiency of Bulgarian peanut farms is farm-size specific and related to factor substitution or

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exogenous factors. We also examined the related risk associated with attainment of maximum yield efficiency. Peanut is the only crop in Bulgaria experiencing an increase in production over the transition period. Peanut production increased by 52% during the transition period, 1990 to 1999, and most of all the output is concentrated in the Plovdiv region where 73% of the production takes place. In 2000-2003, Bulgaria was responsible for 93% of the peanuts produced in Europe. Peanut seemed to be a logical crop choice for farm income enhancement during the post-transition period (period after 1989 there was a transformation in the society) because the soil and environmental conditions in southern Bulgaria and the Plovdiv region favor its production. The crop is produced by limited resource farmers in Bulgaria and has tremendous market potential. Given that peanut can be produced with limited external inputs and can be grown profitably under large or small scale conditions, it is important to examine the technical efficiency related to its production as new market opportunities open up for Bulgarian farm products, and the government is coerced to adopt new land tenure policies. Economic analyses conducted to measure the technical efficiency of limited resource peanut farms are non-existent. The factors influencing production efficiency and how the efficiency of small and large farms can be improved are yet to be analyzed separately.

Theoretical framework

A production function defines the technological relationship between inputs and output. An estimated production function from empirical data indicates average levels of outputs that can be produced from given levels of inputs. One of the basic assumptions in the estimation of a production function is that all firms are technically efficient and the representative firm defines the production frontier. Variations from the frontier are associated with mis-or un-measured production factors. Another assumption underlying the specification of a production frontier is that the firm engaged in production is applying “best management practices”, and it receives the maximum potential output for a given set of inputs, employing a specific production process. Failure to attain this maximum is deemed inefficient; therefore, based on the observed output of a firm one is able to measure its level of efficiency (Greene, 1993). The measurement of firm specific technical efficiency is based upon deviations of observed output from the best production or efficient production frontier. If a firm’s actual production point lies on the frontier, it is perfectly efficient. If it lies below the frontier then it is technically inefficient, with the ratio of the actual to potential production defining the level of efficiency (Herrero and Pascoe, 2002).

A production frontier is estimated through two distinct approaches, the data envelopment analysis (DEA) which is a non-parametric method whose main weakness is an inability to allow for stochastic shocks to the frontier. The stochastic frontier analysis (SFA), in contrast, is designed to incorporate stochastic disturbances, but requires strong parametric specifications in its implementation (Roy, 2002).

LITERATURE REVIEW

Studies which examine the technical efficiency of Bulgarian cooperative farms and that of smaller farm households indicate that there have not been clear indications that larger commercial or corporate farms are more efficient. Kopeva and Noev (2002) showed that cooperate farms in Bulgaria are more efficient in the production of vegetables and cereals, while family farms engaged in grape production perform better. They concluded that output was dependent on size of farm and use of inputs, no matter the type of production. Mathijs and Vranken (2001) measure and explain farm-specific technical efficiency of Bulgarian crop and dairy farms applying the Data Envelopment Analysis (DEA). They found that family farms were technically superior to corporate farms in crop farming, but rejected it for dairy farming. Totev and Shahollari (2001) indicated that even with small sized family holdings that Bulgaria had a revealed comparative advantage in most of its export crops when compared to its neighbors, Macedonia and Albania.

Empirical findings do not support the proposition that small-sized farms are generally inefficient. Mathijs and Swinnen (2001) argue that family size farms in Germany were technically more efficient than large scale successor organizations. They claimed that the difference in technical efficiency, however, declined during transition mainly due to structural changes in Agriculture. Mathijs et al. (1999) also used DEA to confirm that family farms in Czech and Slovak were technically efficient after transition.

In spite of the existing technical information, some researchers believe that the small-sized farms serve as an impediment to agricultural development in Bulgaria, and clearly emphasized that the major problem of agricultural commercialization in Bulgaria is embedded in fragmented land holdings (Lulcheva and Todorova, 2005). Todorova and Lulcheva (2005) are of the opinion that rural development and agricultural sustainability can be achieved through land consolidation and territorial planning. Some policy makers suggest that unless Bulgaria modernizes its agriculture there will be a continuous exodus of people from the rural sector. Policy discussions are to limit the growth of these small farms in order that Bulgaria becomes competitive on the global market (OECD, 1999).

Kostov and Lingard (2002) defended subsistence agriculture by stating that even with lower technical efficiency small-scale subsistence agriculture has positive economic effects both in terms of production and consumption.

They also indicated that in spite of low technical efficiency exhibited by small-scale farms, they display economic efficiency at the aggregate level as regards to their utility function. Limited resource farms that generate large marketable surpluses during the transition period of CEE countries are likely to engage in factor substitution in order to improve their technical efficiency. To evaluate the technical efficiency of limited resource farms in Bulgaria we employ a stochastic production frontier function. We evaluate whether farm characteristics, management decisions and resource use affect farm efficiency. We also investigate whether risks is a factor determining levels of input use.

Stochastic production frontier

The stochastic production frontier model was developed independently by Aigner et al. (1977), and Meeusen and van den Broeck (1977) to estimate the technical efficiency of the production process. Since then it has been employed to measure the production efficiency of various agricultural areas, such as factor productivity of industry, farms, crops and livestock. The technical efficiency of the UK potato industry was examined by Wilson et al. (1998). The technical production frontier was used by Coelli et al. (2003) to measure the total factor productivity for crop husbandry in Bangladesh for the period 1961 to 1992. Tzouvelekas et al. (2002) used the stochastic production frontier to examine the efficiency levels of organic and conventional farms in Greece. Karagiannis and Tzouvelekas (2001) also used the stochastic production function to look at efficiency of olive-growing farms in Greece. Seyoum et al. (1998) studied the technical efficiency and productivity of maize producers in Eastern Ethiopia. Yao and Liu (1998) used the same technique to examine the efficiency of grain production in China.

The stochastic production frontier model has also been widely used to study animal production efficiency. The technical efficiency of Dutch dairy farms was studied by Reinhard et al. (1999); the swine industry in Hawaii was evaluated by Sharma et al. (1997). Dey et al. (2000) used the production frontier to evaluate the technical efficiency of tilapia grow-out operations in the Philippines. Sharma and Leung (2000) used the production frontier to measure the technical efficiency of carp production in India.

Ali and Byerlee (1991) did an intensive literature review of studies that have focused on the economic efficiency of small farmers in developing countries. They summarized the studies by the method used, the countries where the studies were conducted, existing environmental factors, and the other factors that have resulted in farm inefficiencies. Bravo-Ureta and Pinheiro (1993) also did an intensive review of literature of the deterministic and stochastic production frontier approaches that have been employed in studies dealing with developing country agriculture. They organized the studies by the type of data used, the different countries, the different crops and the socio-economic factors that were applied in the different models.

METHODOLOGY

A stochastic production frontier model developed concurrently by Aigner et al. (1977) and Meeusen and van den Broeck (1977) and based on econometric specification of a production frontier is developed for peanut production in Bulgaria. The model can be written as:

$$Y = f(X_i;\beta) + \varepsilon \qquad (1)$$

where Y is the output, X_i is ith input, and β is a vector of unknown parameters. The stochastic frontier model is based on the idea that the error term ε in Equation 1 is composed of two independent elements:

$$\varepsilon = v - u \qquad (2)$$

The random factors outside the farmer's control (e.g. weather, disease, topography, luck etc.), measurement errors on the dependent variable, and other statistical noise are captured by v which is symmetric. This error is assumed to be independently, identically, and normally distributed as $N(0,\sigma_v^2)$. The term u, on the other hand, is a one-sided component ($u_i \geq 0$), and represents the technical efficiency relative to the stochastic frontier, and is independently and identically distributed, and it follows a half-normal distribution $|N(0,\sigma_u^2)|$. Thus u measures the deviation in the output Y from the maximum output given by the stochastic frontier $f(X_i;\beta)+v$. When a farm output lies on the frontier, u is equal to zero, and when a farm output is below the frontier, u is greater than zero.

The use of the maximum likelihood (ML) to estimate Equation (1) results in consistent estimators for β, λ and σ^2, where β is a vector of unknown parameters; $\lambda = \sigma_u / \sigma_v$ and $\sigma^2 = \sigma_u^2 + \sigma_v^2$ (Bravo-Ureta and Pinheiro, 1997). Inferences about the technical inefficiency for individual farmers can be made by using the conditional distribution of u, given the error term ε from Equation 1 (Jondrow et al., 1982). The formula for calculating the technical inefficiency for individual farmers is given in Equation (3).

$$E[u_i \mid \varepsilon_i] = \frac{\sigma_u \sigma_v}{\sigma}\left[\frac{f(\varepsilon_i \lambda/\sigma)}{1 - F(\varepsilon_i \lambda/\sigma)} - \frac{\varepsilon_i \lambda}{\sigma}\right] \qquad (3)$$

where $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\lambda = \sigma_u / \sigma_v$. F(.) and f(.)are the standard normal distribution and the standard normal density function, respectively, and are evaluated at $\varepsilon_i \lambda / \sigma$. Thus the technical efficiency TE_i for each individual farm is given by:

$$TE_i = \exp(-E[u_i \mid \varepsilon_i]) \qquad (4)$$

The technical efficiency TE_i will be a number between zero and one (inclusive). A TE_i of one indicates that the farm is producing maximum output given the level of inputs. The coefficient $\lambda = \sigma_u / \sigma_v$ shows the relative variation of the standard error of u to the standard error of v. When λ is zero the symmetric error, v dominates the one-sided error u which is an indication that the difference between the observed output and the frontier output is due to factors outside the farmers control. When λ is large the one-sided error, u dominates the symmetric error v, and this implies that the difference between the observed and the frontier output is the consequence of technical inefficiency. Battese and Corra (1977) used γ, which is defined in Equation 5 as the ratio of variability of u to the total variability ($u + v$), to measure the difference in the observed output and the frontier output.

$$\gamma = \frac{\sigma_u^2}{\sigma^2} \tag{5}$$

where $\sigma^2 = \sigma_v^2 + \sigma_u^2$. The coefficient of γ gives the difference between the observed output and the frontier output due to the technical inefficiency. The mean technical efficiency for the population is given by Equation 6.

$$E[\exp(-u)] = 2\exp\left(\sigma_u^2 / 2\right)[1 - F(\sigma_u)] \tag{6}$$

Where $F(.)$ is the standard normal distribution function elevated at σ_u.

Production inefficiency

Production inefficiency is an unobserved variable. Hence to determine the level of inefficiency we employ a Tobit model. The Tobit model supposes that there is a latent (that is, unobservable) variable Y_i^*. This variable linearly depends on x_i. Under the Tobit model the relationship between the latent and observed variables for the $_ith$ farm is y^* if y is >0; otherwise 0. The inefficiency of peanut farms is described as:

$$Y = f(X_i; \beta) + \varepsilon \tag{7}$$

where $\varepsilon_i \sim N(0, d), x,$

Production risk

While farmers may adjust farm inputs to increase farm efficiency there are risks associated with resource adjustments on a farm. A Just-Pope (J-P) production function is used to estimate the risk effects of a production function, since it relaxes the second moment of the production restrictions (Just and Pope, 1979; Traxler et al. 1995). The J-P function used in this study is given by:

$$Y_i = f(X_i, \beta) + g(X_i, \alpha) + \varepsilon_i \tag{8}$$

where Y_i is the yield or mean response output, $f(X_i, \beta)$ is the function of the explanatory variables, $g(X_i, \alpha)\varepsilon_i$ is the variance of output related to the explanatory variables, X_i is a vector of explanatory variables, β and α are parameter vectors, and ε_i is a random variable with zero mean. The J-P production function implies a multiplicative heteroskedastic model even if the production variances are the independent variables (Judge et al., 1985; Harvey, 1976). Therefore, the three-stage estimation method described by Judge et al. (1985) is used in this study. When the variance is an exponential function of K explanatory variables, the heteroskedastic error of the general model is expressed as:

$$Y_i = X_i' \beta + e_i, \text{ where } i = 1, 2, \ldots. N \tag{9}$$

$E(e_i^2) = \sigma_i^2 = \exp[Z_i' \alpha]$ (10)

where $Z_i' = (z_{1i}, z_{2i}, \ldots\ldots. z_{ki})$ is a vector of observations for K explanatory variables; $\alpha = (\alpha_1\ \alpha_1\ \alpha_1 \ldots.. \alpha_k)$ is a (K x 1) vector of unknown coefficients, and $E(e_i) = 0$, $E(e_i e_s) = 0$ for $i \neq s$. Using the natural log transformation, Equation (10) can be rewritten as

$\ln \sigma_i^2 = Z_i' \alpha$.

Since σ_i^2 is unknown, the least square residuals from Equation (10) can be used to replace σ_i^2 in Equation (10) which then become

$$\ln e_i^{*2} = Z_i' \alpha^* + u_i \tag{11}$$

where $u_i = \ln(e_i^{*2} / \sigma_i^2)$

According to Harvey (1976) the u_i will be asymptotically independent with a mean of $E[u_i] = -1.2704$, and with an asymptotic covariance matrix $\Gamma = 4.9348\ (Z'Z)^{-1}$. This result is asymptotically valid in hypothesis tests for the risk effects. To obtain efficient coefficients the predicted values of Equation (11) are used as weights for Equation (8).

Empirical model specification

A semi log model is used to estimate the stochastic production function given in Equation 1:

$$\begin{aligned} \ln Y_i = {} & \beta_0 + \beta_1 X_1 + \beta_2 X_1^2 + \beta_3 X_2 + \beta_4 X_2^2 + \beta_5 X_3 + \beta_6 X_3^2 + \beta_7 X_4 + \beta_8 X_4^2 + \\ & \beta_9 X_5 + \beta_{10} X_5^2 + \beta_{11} X_6 + \beta_{12} X_6^2 + \beta_{13} X_7 + \beta_{14} X_7^2 + \varepsilon_i \end{aligned} \tag{12}$$

where $\ln Y_i$ is the log of yield in kg per ha for the i^{th} farm. The explanatory variables for this model are, quantity of seed per hectare (X_1), quantity of seed per hectare squared $(X_1)^2$, quantity of phosphate per hectare (X_2), quantity of phosphate per hectare squared $(X_2)^2$, quantity of nitrogen per hectare (X_3), quantity of nitrogen per hectare squared $(X_3)^2$, quantity of fungicide per hectare (X_4), quantity of fungicide per hectare squared $(X_4)^2$, fixed investment costs per hectare (X_5), fixed investment costs per hectare squared $(X_5)^2$, amount of manual labor per hectare (X_6), amount of manual labor per hectare squared $(X_6)^2$, amount of mechanized labor per hectare (X_7) and amount of mechanized labor per hectare squared $(X_7)^2$. The semi-log model was considered superior after a likelihood test of the OLS, Cobb-Douglas, and the Quadratic functional forms, the semi-log was considered appropriate for model estimation. Maximum likelihood estimation is used to develop the model because of the low mean square error.

The inefficiencies in peanut production were calculated by subtracting the estimated technical efficiency from one. The inefficiencies are then regressed on the different explanatory variables. Since the inefficiencies are values that ranged from zero to one, a Tobit model is used. The advantages of a Tobit model are that it allows the dependent variable to be constrained between certain values; in this study between zero and one (Greene, 1993; Hossain, 1988; Bravo-Ureta and Pinheiro, 1997). The agriculture inefficiency model is given in Equation (13)

$$\delta_i = \alpha_0 + \sum_{j=1}^{6} \alpha_j Z_{ji} \tag{13}$$

Table 1. Number of farms and peanut area for the different villages in Bulgaria.

Village	Number of peanut farms	Peanut area (acres)	Peanut area (%)	Average size of peanut farm (acres)
Asenovgrad	21	49.50	8.70	2.4
P. Evtimovo	12	11.25	2.00	0.9
Kozanovo	11	41.25	7.30	3.8
Muldava	10	9.00	1.60	0.9
D.Voden	10	112.88	19.90	11.3
Zlatovrah	10	10.50	1.80	1.1
Konush	11	63.50	11.20	5.8
Izbegli	15	32.00	5.60	2.1
Karadzhovo	11	41.50	7.30	3.8
Hr. Milevo	10	8.75	1.50	0.9
Katunitsa	2	8.00	1.40	4.0
Kochevo	10	19.50	3.40	2.0
Popovitsa	10	19.50	3.40	2.0
Mominsko	14	32.25	5.70	2.3
Boljrtsi	10	36.75	6.50	3.7
D. Izvor	14	43.75	7.70	3.1
Debar	10	12.50	2.20	1.3
Gradina	14	15.50	2.70	1.1
Total	205	567.88	100.00	

where δ_i is the inefficiency in peanut production for the i^{th} farm and Z_{ji} is the value of the j^{th} explanatory variable associated with the technical inefficiency effect of farm i. The risk of related to peanut production is estimated using the yield variance of peanut production. After the specification of a parametric form for $f(X_i, \beta)$, the model can be consistently and efficiently estimated using a three step process. First the $Y_i = X_i'\beta + e_i$, expressed in Equation (8) is estimated , second the residuals $E(e_i^2) = \sigma_i^2 = \exp[Z_i'\alpha]$ as stated in Equation (9), and third the model is efficiently estimated taking into consideration the heteroscedasticity reflected by the estimated variance. The functional form for the mean yield is given as:

$$\ln Y_i = \beta_1 X_1 + \beta_2 X_1^2 + \beta_3 X_2 + \beta_4 X_2^2 + \beta_5 X_3 + \beta_6 X_3^2 + \beta_7 X_4 + \beta_8 X_4^2 + \beta_9 X_5 + \beta_{10} X_5^2 + \beta_{11} X_6 + \beta_{12} X_6^2 + \beta_{13} X_7 + \beta_{14} X_7^2 \tag{14}$$

While the functional form for the variance of the yield is given as:

$$\ln e_i^2 = \alpha_1 X_1 + \alpha_2 X_1^2 + \alpha_3 X_2 + \alpha_4 X_2^2 + \alpha_5 X_3 + \alpha_6 X_3^2 + \alpha_7 X_4 + \alpha_8 X_4^2 + \alpha_9 X_5 + \alpha_{10} X_5^2 + \alpha_{11} X_6 + \alpha_{12} X_6^2 + \alpha_{13} X_7 + \alpha_{14} X_7^2 \tag{15}$$

Data

The data for this study were gathered from 205 farmers from 18 villages during the period 2001 to 2002. Demographic, farm, crop production systems and marketing data were collected. Information on peanut production was also solicited from farmers. The data on the peanut farmers are summarized in Tables 1 and 2. The age distribution of farmers is skewed towards the age beyond retirement, with 24% belonging to this group. The education level is low with a majority of head of farm households only attaining a primary education level. A large portion of farmers depend on their experience in farming because most farmers have owned and managed their farms for over 20 years. The survey data show that about 95% of the household members participate in peanut growing activities. Of those who participate, about 50% work part-time of up to 4 h per day.

The average size of the peanut farms ranged from 0.9 to 11.3 ha. The peanut yield for the Bulgarian farmers ranged from 550 to 1690 kg/ha, with an average yield of 952 kg/ha. The average amount of seed used is 45 kg/ha, ranging from 32 to 76.8 kg/ha. The recommended quantity of seeds for Bulgarian farmers is 120 kg/ha, but given the factor price of $1.38 per kg, the optimal level is 130 kg/ha. This means that some farmers are using less than the recommended quantity of seeds. The average quantity of phosphate used by farmers is 35.71 kg/ha, with a minimum of 0 and a maximum of 200 kg/ha. The average quantity of fungicide used is 0.10 kg/ha, with a minimum of 0.00 and a maximum of 1.37 kg/ha. The statistical analytical software (SAS) and STATA were used for data analysis. The data on peanut production were used to examine the technical efficiency of peanut farmers by comparing the results of a stochastic production frontier using a maximum likelihood (ML) function and the average production function obtained through ordinary least squares function (OLS).

RESULTS

The estimated results for the mean response function for peanut production (average yield) in Bulgaria are given in Table 3. The factors affecting yield are quantity of seeds, quantity of seeds squared, quantity of phosphate squared, quantity of fungicide squared, investment capital, investment capital squared, mechanized labor, and mechanized labor squared. Farmers can increase yield by increasing the quantity of seeds used to a given

Table 2. Descriptive statistics for the factors use in the production functions.

Variable	Mean	Min	Max	CV (%)
Yield (kg/Acre)	952.14	550.00	1689.83	17.73
Seed (kg)	45.51	32.00	76.80	9.26
Qty. Phosphate (kg)	35.71	0.00	200.00	136.10
Qty. Nitrogen (kg)	169.76	48.00	400.00	25.07
Qty. Fungicide (kg)	0.10	0.00	1.37	171.85
Investment capital ($)	8.42	0.00	108.70	265.69
Manual labor (Hours)	37.45	4.00	126.00	31.77
Leased mechanized labor (Hours)	32.62	9.60	75.43	30.57
Peanut acreage	2.77	0.25	100.00	262.00

Table 3. The ordinarily least square (OLS) and maximum likelihood (ML) estimates for the semi-log model based on a sample of 205 farmers in Bulgaria.

Production factor		OLS	ML
Constant	β_0	5.414 (3.173) ***	5.793(19.156)***
Seed	β_1	0.0409(0.609)	0.034(2.938)**
Seed squared	β_2	-0.000382(-0.561)	-0.000316(-2.595)***
Qty. Phosphate	β_3	0.000555(0.228)	0.000375(0.953)
Qty. Phosphate squared	β_4	0.0000051(0.281)	0.00000651(2.283)***
Qty. Nitrogen	β_5	0.00092(0.260)	0.000262(0.218)
Qty. Nitrogen squared	β_6	-0.00000673(-0.665)	-0.0000039(-1.021)
Qty. fungicide	β_7	-0.283(-1.067)	0.299(2.108)**
Qty. Fungicide squared	β_8	0.429(3.800)***	-0.651(-4.302)***
Investment capital	β_9	-0.00263 (-0.378)	-0.0028(-2.182)*
Investment capital squared	β_{10}	0.0000355(0.394)	0.0000375(2.232)**
Manual labor	β_{11}	0.00956(1.053)	0.0104(3.112)***
Manual labor squared	β_{12}	-0.0000406(-0.484)	-0.0000564(-1.157)
Leased mechanized labor	β_{13}	1.479(0.638)	-0.0111(-2.950)***
Leased mechanized labor squared	β_{14}	0.000080(0.658)	0.000277(4.747)***
σ_u^2			0.0111
σ_v^2			0.01135
σ^2			0.02245(3.956)***
$\lambda = \sigma_u / \sigma_v$			0.99
$\gamma = \sigma_u^2 / \sigma^2$			0.496*** (2.14)
Log. Likelihood			-1280.3

*Significance level 10%; ** Significance level 5%; *** Significance level 1%; Values in brackets are t-statistics.

Table 4. Frequency distribution of farm's level technical efficiency for semi-log model.

Technical efficiency level	Number of farms	Percentage
0.00-0.10	0	0.00
0.10-0.20	0	0.00
0.20-0.30	0	0.00
0.30-0.40	0	0.00
0.40-0.50	0	0.00
0.50-0.60	0	0.00
0.60-0.70	0	0.00
0.70-0.80	1	0.49
0.80-0.90	32	15.61
0.90-1.00	172	83.90
Total number of farms and total percentage	205	100.00

Table 5. Descriptive statistics of the technical efficiency of the individual farms for semi-log model.

Statistical parameter	Value
Mean	92%
Median	93%
Mode	90%
Standard deviation	3%
Minimum	77%
Maximum	97%
Range	20%
First quartile	92%
Third quartile	94%
1st percentile	84%
5th percentile	87%
10th percentile	89%
90th percentile	95%
95th percentile	96%
99th percentile	97%
Skewness	-1.49

level. However, there is a point at which the optimum level is attained after which further increases in input may engender a decline in output. Farmers can also increase yield, manual labor, and reduce the amounts of fungicide, whereas increasing the investment level may have a decreasing effect on yield.

The quantity of seed used had a significant and positive effect on yield. An increase in the quantity of seed by 1% would increase yield by 1.6%. An increase in capital investment has a negative effect on yield suggesting that peanut producing farms in Bulgaria may be overcapitalized, or the available set of equipment may be incongruous to the farm sizes.

The total variability, (σ^2) for the stochastic model is 0.02245, while variability for *u,* (σ_u^2) is 0.0101 and the variability for *v*, (σ_v^2) is 0.01135. The coefficient λ is 0.99 indicating that the one sided error term dominates, and therefore, it is appropriate to use the stochastic frontier model to estimate the production function. The coefficient γ is 0.496, and is significantly different from zero. It shows that about 50% of the discrepancy between the production frontier and the observed output is due to the technical inefficiency at the farm level and this can be controlled by farmer decision. A frequency distribution of the individual farm's level of efficiency is given in Table 4, and shows that none of the 205 farms in this study are producing on the production frontier. Although none of the farms are producing the maximum output, 204 of the farms had technical efficiency that varied from 80 to 97%, and only one farm had technical efficiency that ranged from 70 to 80%. Table 5 gives the descriptive statistics of the technical efficiency of the farms in this study. The average technical efficiency of the farms is 92%. The mode of the technical efficiency for these farms is 90%. The minimum and maximum level of technical efficiency is 77 and 97%, respectively. The standard deviation is 3.0%. The skewness coefficient for the technical efficiency is -1.49.

The 4.0% inefficiency can be explained by gender and age of farmer. Increasing women managed farms increased the level of inefficiency. Increasing the ages of farm managers beyond 45 or below 30 years old increased inefficiency for farms employing more than 35 h of manual labor per ha. Physical farm size was not an issue in terms of farm inefficiency but the number of manual labor hours employed (Table 6).

Output variance response

The results of the variance response function estimation are given in Table 5. The R^2 for this model was 0.83. The joint F-test was used to test the hypothesis that each production factor did not affect the variance (Table 5). The F-test that the coefficients of quantity of seed and

Table 6. Tobit regression results for the technical inefficiency model for farms that use more than 35 h of manual labor per acre for the semi-log model.

Parameter		Coefficient	t-value	P>t
Constant	α_0	0.0679516***	11.92	0.000
Gender (0=male; 1=female)	α_1	0.013941***	2.51	0.014
Age (1= between 30 and 45 years; 0 = older than 45 years)	α_2	-0.0172938***	-2.95	0.004
Education (1= elementary School; 0 = secondary school)	α_3	-0.0039389	-0.83	0.409
Peanut area in acres	α_4	-0.0010011	-1.16	0.248
Number of observations		200[1]		
Log likelihood		242.72		

*Significance level 10%; **Significance level 5%; ***Significance level 1%; [1]The sample was divided into two; Farmers who use more than 35 h of manual labor=1 and those who use less=0. Two extreme observations were excluded.

quantity of seed squared are equal to zero shows that ($\beta_1 = \beta_2 = 0$) was rejected with an F-value of 4.43, indicating that quantity of seeds affected the variance of peanut yield. This means that increasing the quantity of seeds used increases the risk of the peanut farmers in Bulgaria. The F-test that the coefficients manual labor and phosphate squared were equal to zero ($\beta_3 = \beta_4 = 0$) was rejected with a F-value of 2.27; this implies increasing the quantity of manual labor employed increases the risk of peanut yield in Bulgaria. The F-tests for the other production factors are not rejected implying that they were not affecting the variance of the peanut yield and the risk of producing peanuts in Bulgaria (Table 7).

DISCUSSION

The results show that peanut production in Bulgaria is approaching full efficiency and that factors leading to efficiency may vary. Due to changes in farm structure during the transition period, there may be excess capacity at the farm level as farmers search for the optimum levels of input to produce a given quantity of peanuts. A study by Kopeva and Noev (2002) showed that cereal, vegetables and grape farms had average efficiency levels less than that of peanuts for both family and corporate farms. The mean efficiency levels obtained for cereal, vegetable and grape farms were 63.2, 42.9, and 43.1%, respectively, compared to the 92% for peanuts found in this study. Kopeva and Noev attributed the inefficiencies obtained for cereal, vegetables and grapes to the negative effects of the ongoing land, and structural reforms in Bulgarian agriculture. They stated that the loss of efficiency may be due to necessary changes resulting from shifts in the state agricultural policies. The technical efficiencies obtained from peanut farms in Bulgaria are also larger than that for small, medium and large rice farms in the Myanmar. The mean levels of efficiency for the small, medium and large rice farms were 81, 73 and 80%, respectively (Kyi and von Oppen, 1999). The results show, however, that the factors influencing efficiency may be crop specific, and about 50% of 8.0% (4.0%) of farmers considered technical inefficient can be reduced by government supportive programs and farmers adoption of best management practices.

The quantity of seeds used affected the levels of efficiency. Hence farmers can increase the quantity of seeds used to improve yields. The response of yield to quantity of seed used is elastic and a one percent increase in seed application results in a 1.17% increase in yield, *ceteris paribus*. Kyi and von Oppen (1999) found that seeds significantly influenced technical efficiency of small farms in the Myanmar. The average quantity of seeds used per hectare by Bulgarian farmers is 45.5 kg per ha whereas the recommended quantities in the US may vary from 65 to 180 kg/ha based on plant spacing, and that recommended for Bulgaria is 120 kg/ha. Therefore, there may be room for improving peanut yield by increasing the seeding rate, especially as farmers are using less than the optimal quantity of seeds. Feder (1980) indicated that farmers may be using less than the optimal quantity of input if they are risk averse. The results show that increasing seeding rate poses the greatest risk, and even if the seed cost shares are relatively small, the total seed cost and variation in quality are important budget items to limited resource farmers who are already financially constrained. In our case, the price of the seed to the farmer is the opportunity cost of consumption since farmers save their own planting materials.

Other factors that can be manipulated are pesticide treatment, investment and the use of manual labor. Additional amounts off manual labor may increase farm efficiency. However, increasing number of manual labor may increase yield risk.

Investment capital and mechanized labor are negatively related to yield, and there will be a reduction in yield if additional amount of inputs are employed. The negative relationship between investment capital and yield indicates that farms are overcapitalized and farmers may seek to make farm adjustments in the long run. An estimation of cross production elasticities would suggest that the present situation in peanut farming encourages

Table 7. Estimated coefficients for the mean and the variance of the peanut yield for the semi-log model based on a sample of 205 farmers in Bulgaria.

Production factor		**Mean of yield**	**Variance of yield**
Constant	β_0	5.414(3.173)***	-
Seed	β_1	0.0409(0.609)	-0.124(-2.25)**
Seed squared	β_2	-0.000382(-0.561)	0.00097(1.11)
Qty. Phosphate	β_3	0.000555(0.228)	-0.01011(-1.07)
Qty. Phosphate squared	β_4	0.0000051(0.281)	0.000125(1.79)*
Qty. Nitrogen	β_5	0.00092(0.260)	0.01026(0.657)
Qty. Nitrogen squared	β_6	-0.00000673(-0.665)	-0.000055(-0.76)
Qty. Fungicide	β_7	-0.283(-1.067)	0.1681(0.15)
Qty. Fungicide squared	β_8	0.429(3.800)***	-
Investment capital	β_9	-0.00263 (-0.378)	0.0259 (0.97)
Investment capital squared	β_{10}	0.0000355(0.394)	-0.00035(-1.01)
Manual labor	β_{11}	0.00956(1.053)	-0.0945(-1.64)*
Manual labor squared	β_{12}	-0.0000406(-0.484)	0.00093(1.52)
Leased mechanized labor	β_{13}	1.479(0.638)	-0.0256(-0.43)
Leased mechanized labor squared	β_{14}	0.000080(0.658)	0.00059(0.68)
R-squared		0.41	0.87
N		205	205

*Significance level 10%; ** Significance level 5%; *** Significance level 1%; values in brackets are t-statistics.

capital labor substitution in order to improve efficiency. The results show that manual labor can be increased while investment capital can be reduced to increase efficiency in yield, other factors remaining constant. Substitution of labor input for capital may encounter difficulty since Bulgaria and other CEE countries are facing a situation where the number of farm hands per hectare of cultivated land is decreasing as more employment opportunities open up in other sectors (Brent, 1999).

Peanut yield is also negatively influenced by fungicide use. Only a small number of farmers used fungicide in peanut production in Bulgaria. Fungicide use is not recommended for Bulgarian peanut farmers (Pan and AGROLINK, 2004). Hence the application of fungicide in peanut production may increase cost but not yield.

The need to improve farm efficiency through on-farm resource reallocation is imperative and can be accomplished at little or no cost to the public sector. The method of improvement of peanut production efficiency can be examined within a framework of modifying efficiency of other less efficient production enterprises at limited costs to the sector on a whole. In fact, there may be savings to be captured by the substitution of cheaper inputs for more costly factors of production while increasing economic efficiency of production in the agricultural sector.

Inefficiency was influenced by age. A large percentage of the farmers were above 45, and more farmers who are beyond this age, the greater the levels of inefficiency. As is observed in the survey results 69% of the farmers are older than 45 years old, and 1.9% were less than 30 years old. Draganova (2005) indicated there are large numbers of retired farmers beyond the ages of 70 who are involved in agricultural production, and it is difficult to recruit younger farmers. An increase in the number of farmers younger than 30 years old also increased the level of inefficiency while the opposite is true for farmers between 30 and 45 years. Hence, the government should implement policies that encourage farmers between the ages of 30 to 45 to remain in agriculture, while improving farm sizes as older farmers leave production agriculture.

Gender participation in farm operation and ownership influenced inefficiency. More women operators enhanced inefficiency. This seems contrary to the current literature on the efficiency of female farm operators. During the transition period women were less prepared educationally and had less experience in management of enterprises (Meurs, 1998, Mathijs and Vranken, 2001). Hence, this lack of experience is manifested in lower efficiency in farm management activities. Bulgarian women seem to have less access to farm investment capital and this may influence the level of farm efficiency. Farm operators in Bulgaria work on the average four hours per day out off farm to earn more money. However, women operators with their families may not have the opportunity to work outside and this may limit the non-agricultural resources they are able to transfer to on-farm activities. Also women farm operators have fewer avenues to obtain government assistance to improve their farm activities.

The results show that limited resource Bulgarian peanut farmers are approaching full efficiency. Efficiency is more crop-specific and is less dependent on farm size or levels of investment. Hence, the Bulgarian government, like all other CEE governments, should not rapidly merge farms to improve efficiency without technical information on the crop land requirements and the cropping system. To attain full efficiency farmers must be able to absorb risk and to make minor farm adjustments. The government can facilitate a drive towards full efficiency by putting into place policies that would target farmers between the ages of 30 to 45 to remain into peanut farming and provide farmers with a safety net. Assistance should be directed to women farm operators in terms of education and access towards government programs.

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