Technical Efficiency of Grain Production in Ukraine

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May 1998

Paper to be presented at the 1998 American Agricultural Economics Association Annual Meeting in Salt Lake City, UT, August 2-5, 1998.

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1. Introduction

Creation of a market-oriented privatized agriculture is an important component of overall economic reforms started in Ukraine in the early 1990s. Unlike for western industrialized countries, Ukraine's agricultural sector traditionally accounted for a prominent share of aggregate output and employment. In 1992, primary agriculture contributed 19% to the Ukrainian net material product, and employed about 20% of the labor force (World Bank, 1994).

Grain is one of Ukraine's most important agricultural products. Ukraine produced on average 47.4 million tons of cereals per year in 1986-1990. Grains were grown on some 14,541 thousand hectares on average over the years 1989-1992, an area which represents 44 to 45 percent of the total Ukrainian area sown. Grains are the key crop for both livestock production and human consumption. Wheat accounts for 49% of the total area cultivated under cereals on average in 1989-1993. Barley, the most important feed grain, accounts for 19%, followed by maize (15%) (World Bank, 1994). The significance of grain comes also from the fact that it is one of the commodities used by Government in barter trade with other former Soviet Union countries (Csaki and Lerman, 1997b). Although state and collective farms were very diversified agricultural enterprises, virtually all of them produced grains.

In pre-reform agriculture, the farming system was an integral part of the centrally planned national economy and farm performance was judged not by the financial results of production, but by how well the centrally planned production targets were met. Artificially low food prices and subsidies left producers with little motivation for improving efficiency and competitiveness (Csáki and Lerman, 1997a).

Although begun in the early 1990s, the restructuring and reorganization of former state and collective farming system has not been genuine, as most collective and state farms reorganized into the new legal form of collective farm enterprise with no internal reorganization. According to World Bank surveys, in 1996, more than 80% of farm managers continue to endorse life-time employment for farm personnel, and 86% former state and collective farms preserved central management responsible for overall production planning (Csaki and Lerman, 1997b). By 1997, some 35,000 private farms were created, but the private sector still accounts for 15% of the country's agricultural land only. In sum, collective forms of organization continue to dominate in Ukrainian agriculture as they control most of the land and remain major employers in rural areas.

In general, the reforms which started with limited price liberalization and introduction of private property have resulted in an initial sharp decline in production and consumption. By 1996, Ukrainian GDP dropped to 43% of its 1990 level, and gross agricultural product dropped to 59% of the 1990 level (Csáki and Lerman, 1997b). The transformation of agriculture has been accompanied by political and legal uncertainty, lack of supportive market environment, and, consequently, high risks for producers. Prices for purchased inputs grew much faster than farm gate prices for agricultural products that were still controlled by the Government. Decreased farm income in the presence of high nominal interest rates, in turn, reduced farm investment. Standard measures of agricultural productivity (i.e., output per worker, crop yields, milk per cow, and animal slaughter weights) clearly deteriorated. Even though areas sown to crops decreased since 1990 by only 5%, the production of main cash crops, cereals and sugar beets, dropped by 30%-40% between 1990 and 1995 (Csaki and Lerman, 1997b).

In order to stabilize farm income and food production, the Government of Ukraine used short-term adjustment policies providing agricultural producers with compensation payments (UIAE, 1996) and farm inputs in the exchange for sales of production to state. In addition to land reform, other important long-term initiatives, like creating of a competitive market environment for agriculture and development of rural financial structures are also essential for the creation of efficient market-oriented agriculture. However, there is relatively little empirical work to support the restructuring and development of new agricultural policies aimed to reverse the decline in productivity and improve efficiency. This paper addresses issues of technical efficiency in grain production.

There have been considerable applications of frontier methods in agriculture (see Battese, 1992; Bravo-Ureta and Pinheiro, 1993; Coelli, 1995). However, little research exists on the efficiency of agriculture in the formerly planned economies. Data have been limited, especially at the farm level, and much of the work on efficiency in agriculture has been limited to analysis of highly aggregated data (Johnson and Brooks, 1983; Boyd, 1987). A few recent studies exist that use more disaggregated data to study production efficiency (e.g., Brada and King, 1993; Johnson et al., 1994; Brock, 1994; Piesse et al., 1996.)

The examination of the previous literature suggests that an analysis of trends in production efficiency and the factors affecting technical efficiency could be very beneficial for agricultural policy questions. Farm-specific variables, such as characteristics of the farm manager and farm management system, experience of managers and distance from supply and distribution points, can enhance the understanding of farm production efficiency (Battese and Coelli, 1995; Brock, 1994). Since farms continue to bear the main responsibility for most social services in the village it is also important to evaluate the impact of farm involvement into social services provision on its overall economic performance. We focus on one part of the overall farm performance, technical efficiency: the ability of a production unit to achieve maximum possible output given the technology and quantities of inputs available.

In this study of Ukrainian grain producing farms, we estimate a frontier production function and evaluate the relationship between technical efficiency and farm workforce composition. The analysis includes quantifying the changes of production, input use, and the efficiency over time in order to obtain estimates of the effects of factors associated with technical inefficiency and the elasticities of grain production with respect to the different inputs and returns-to-scale. The paper is organized as follows: in Section 2, data and farm structure are described together with productivity indicators. In Section 3 a stochastic frontier production model is presented, followed by the results of estimation discussed in Section 4. Finally, in Section 5, we summarize our findings with some concluding remarks.

2. Data

For our analysis we employ data coming from a random survey of 49 state and collective farms in Ukraine during 1989-92. Since little internal restructuring has occurred over the period after the years available, the clear advantage of the detailed input and output data reported in physical units well overweighs the possible disadvantage of using six year old data.

The data were collected in 1992 retrospectively for 1989-1991. The survey was designed as a random sample of state and collective farms across agro-climatic zones and was stratified by farm size. The Ukrainian Institute for Agrarian Economics (UIAE) supervised the administration of the survey. The data come from farm-kept written records that are the source for standard statistical questionnaires filled out at the end of each year. Of the original 80 farms surveyed, data for 49 from two administrative regions, Kyivska oblast and Cherkaska oblast of the mixed soil-climatic zone were complete and used for the analysis. The mixed soil-climatic zone has average annual precipitation is 450 to 600 mm and predominantly highly favorable black soils. This zone takes up about one third total Ukrainian agricultural land. The comparison of sample means with those of census confirms that the sample is representative for the mixed soil-climatic zone of Ukraine.

Descriptive Statistics. Descriptive statistics show changes over 1989-1992 typical for Ukraine's agricultural sector as large collectivist farms started to downsize. The average farm size in 1989 was 2,403 hectares of agricultural land with 384 farm workers, 327 of whom were engaged in agricultural production. The average decline in the land holdings of the farms over the period was 7.6 percent, as a result of obligatory transfer of land to state reserves. The reserves serve as a source of land for subsidiary household plots of state and collective farm members and for independent private farms (Csaki and Lerman, 1997b). The average decline in the total number of farm and agricultural workers was 13 percent and 11 percent, respectively. On average, the number of pensioners per worker increased by 17 percent over the period. The decrease in the working population on the farms can be attributed to young people leaving farms and going into cities and retired workers remaining on the farms (World Bank, 1994; UIAE, 1992). The UIAE (1992) reports specifically that the rural population of the two administrative regions represented in the data declined by more than 22 percent from 1970 to 1990. On average, the share of farm resources devoted to activities other than agricultural production declined 8 percent, as measured by the share of workers not involved in the main production. In 1992, about 13 percent of farm employees were social, maintenance, repair, construction, or processing workers. The share of non-agricultural production expenditures in total farm expenditures increased from less than 5 percent in 1989 to almost 20 percent in 1992. However, because of complex system of subsidies, bonuses, and other price distortions, it is not clear whether there was an increase in this measure in real terms. Also, a part of this increase might be attributed to problems of keeping adequate financial accounting in the situation of high inflation as prices doubled from 1990 to 1991, and increased almost 20 fold from 1991 to 1992. To avoid the considerable error that might be introduced while relying on the data in rubles, we employ the data in physical units only for our analysis.

Partial Productivity Indicators. Table 1 shows the grain production and input use based on the survey results. On average, total grain production declined by 35 percent over the four years, although the area under grains declined by only 12 percent. A part of the decline in yield can be attributed to poor weather in 1991 and moderately inferior weather in1992 (prolonged drought during the summer combined with high temperatures), although input shortages aggravated the situation. Application of inputs changed dramatically, as application of chemicals per hectare went down 19 percent, organic fertilizer per hectare dropped 16 percent, and labor use per hectare increased more than 90 percent on average over the four years. The decline in chemicals application must be contributed to sharp increase in the prices of agricultural inputs relative to prices on agricultural output. The decrease in the amount of organic fertilizer comes from the downsizing of livestock operations (Csaki and Lerman, 1997b). In this situation the farms substituted the inputs that were readily available (labor and land) for more expensive and relatively scarce (chemicals, fertilizer). Reported diesel fuel used per hectare, a proxy for machinery services, did not change over time.

3. Method

In this study, a translog stochastic frontier production function is assumed to be the appropriate model for the analysis of the state and collective farm data for the Kyivs'ka and Cherkas'ka oblast of Ukraine. The model to be estimated is defined by

$$Y_{it} = \beta_0 + d_{91} + \sum_{j=1}^{5} \beta_j x_{ijt} + \sum_{j \le k}^{5} \sum_{=1}^{5} \beta_{jk} x_{jit} x_{kit} + V_{it} - U_{it} \ , \qquad (1)$$

where the subscript, *i*, indicates the observation for the *i*-th farm in the survey (*i* = 1,2,…,41), and the subscript, *t*, indicates the observation for the *t*-th year (*t* = 1,2,3,4).Y represents the logarithm of the total grain production (in metric tons) on the given farm in the given year; β_i, β_{jk} , (*i* = 0,1,…,5; *j*, *k* = 1,2,…,5) represent the unknown parameters, associated with the explanatory variables in the production function; d_{91} is a dummy variable, which has value 1 if *t* = 3, and value 0 otherwise; and x_is (*i* = 1,2,…,5) represent the logarithms of the total amounts of land under grain production (in hectares), labor in grain production (in 1,000 hours), organic fertilizer applied for grain production (in 100 tons), chemicals applied for grain production (in tons), and diesel fuel used in grain production (in 1,000 liters) respectively. The V_{it}s are assumed to be iid N(0, σ_V^2) random errors, independently distributed of the U_{it}s. The U_{it}s are non-negative random variables, associated with technical inefficiency of production, which are assumed to be independently distributed, such that U_{it} is obtained by truncation (at zero) of the normal distribution with variance σ_u^2, and mean, μ_{it}, where the mean is defined by

$$\mu_{it} = \delta_0 + \delta_1 (nonagw_{it} \ / \ totw_{it}) + \delta_2 (agw_{it} \ / \ totland_{it}) + \delta_3 dis_i + \delta_4 t \quad , \qquad (2)$$

where δ is a (5 x 1) vector of unknown parameters to be estimated. The variable $nonagw_{it} / totw_{it}$ is the ratio of the number of workers on the farm that are not involved in agricultural production to the total number of the workers on the farm; $agw_{it} / totland_{it}$ is the number of agricultural workers on the farm per hectare of the total farm land; dis_i is the distance from a given farm to a nearest city in kilometers; and t is the year of observation (t = 1,2,3,4).

The *nonagw/totw* ratio is expected to have a negative effect on the size of the technical inefficiency effects, i.e., as the relative share of nonagricultural activities on the farm increases, so is the infrastructure quality on the farm, which in turn, increases the technical efficiency of the farming operations. The *agw/totland* ratio is included into the model to control for the relative labor abundance of the farm. The distance to the nearest city is expected to have a negative effect on the technical inefficiency as the further the farm is located from the alternative sources of employment, the better are the chances of keeping the most productive labor on the farm. The time variable is used to estimate how the inefficiency effects change over time. We have included dummy variable d_{91} to account for poor weather conditions in 1991. The descriptive statistics of the variables used in estimation are presented in Table 2.

The model defined by equations (1) and (2) was proposed by Battese and Coelli(1995). The parameters of the model, i.e. the β's, the δ 's, and the variance parameters $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ are simultaneously estimated using the method of maximum likelihood. We used program FRONTIER 4.1 developed by Coelli (Coelli, 1994) that computes the parameter estimates by iteratively maximizing a nonlinear function of the unknown parameters in the model subject to the constraints.

4. Results

Table 3 reports maximum likelihood estimation results. Several generalized likelihood-ratio tests pertaining stochastic frontier coefficients, inefficiency model, and variance parameters, are presented in Table 4. The generalized likelihood-ratio statistic is computed as $\lambda \equiv -2\log\left[L(H_0) / L(H_1)\right]$, where $L(H_0)$ and $L(H_1)$ are the likelihood functions evaluated at the restricted and unrestricted maximum-likelihood estimator for the parameters of the model. If the null hypothesis, H_0 , is true, then the statistic has approximately chi-squared distribution with parameter equal to the number of restrictions imposed by H_0.

The estimated standard errors of some of the coefficients in the stochastic frontier are large relative to their estimates, which indicates that the individual coefficients may not be statistically significant. However, the generalized likelihood-ratio test rejects the composite hypothesis that second order variables in the translog model are zero. That means that given the assumption of translog specification, a Cobb-Douglas function is not an adequate representation of the stochastic frontier function.

Using the maximum-likelihood estimates for the parameters of the frontier, the elasticities of frontier output with respect to land, labor, organic fertilizer, chemicals, and fuel, were estimated at the means of the input variables to be 0.70, 0.13, 0.08, 0.06, and 0.03, respectively. The high land elasticity practically coincides with the value 0.71 found by Johnson et al., 1994 who used a different model and relied on data in rubles for several inputs. The returns to scale parameter was found to be 1.01, implying constant returns to scale for grain production on the state and collective farms. This result is consistent with earlier studies for Ukraine (Johnson et al., 1994) and Russia (Skold and Popov, 1990).

The major interest of our study are the coefficients for the inefficiency model. The second null hypothesis tested that inefficiency effects are absent from the model is strongly rejected at the 5 percent level of significance, and so is the third null hypotheses that the explanatory variables in the model for the technical inefficiency effects have zero coefficients. Because the generalized likelihood-ratio tests of the hypotheses are preferred to the asymptotic t-tests in maximum likelihood estimation, the null hypotheses that individual effects of the explanatory variables in the model for the technical inefficiency effects are zeros were tested as well. The results presented in Table 4 indicate that all four null hypotheses were rejected.

The estimated coefficient of year is positive which means that technical efficiency declined over time, a result that is consistent with earlier findings obtained with a different model and a different Ukrainian farm data set (Johnson et al., 1994). The results illustrate that the economic reforms are costly in terms of technical efficiency, probably because the old production ties, like state input distribution system, severely deteriorated with the start of economic reforms, while new production intermediaries have not emerged yet. In this situation, declining precision of inputs availability timing not captured by the quantities of inputs applied to production might have been reflected in the estimated negative effect of the coefficient of year on efficiency.

The number of agricultural workers per hectare was found to have positive effect on technical efficiency what suggests that abundance of labor resources for production is important for achieving effective utilization of inputs. The model employed by Johnson et al., 1994, did not estimate impact of farm-specific variables on inefficiency simultaneously with estimation of the stochastic frontier, but a similar relationship was found by comparing the means of the number of agricultural workers per hectare for the fifty least and fifty most efficient farms (the number of farms in the sample was 3,798).

The coefficient of the share of non-agricultural in total number of farm workers is negative, and indicates that technical inefficiency in grain production decreases with an increase of this share, and, presumably, with an increase of infrastructure quality of the farm. This result suggests that in the absence of an adequate market environment, the agricultural production units that invest relatively more (in terms of labor force) into farm infrastructure achieve higher levels of technical efficiency in agricultural production.

Unfortunately, the data used do not discriminate between different types of farm non-agricultural production activities. These activities might mean investment into other production (eg., production facilities construction, processing, marketing), or improvement in farm living conditions (eg., catering, child care provision, road maintenance). Improved farm living conditions are likely to increase quality of available labor resources directly as workers can get better recreation and rest, are pushed into less shirking and absenteeism caused by health and child care problems.

The average quality of labor resources might be affected indirectly through prevention of quits of productive workers as well. Since the potential loss of farm provided social benefits is considered as one of the main reasons for farm employee decision to remain in collective farm as opposed to starting own private farm (Csaki and Lerman, 1997b), investment into farm social infrastructure might be a valuable tool used by farm managers to retain workers from leaving the farms. The decrease in the number of workers might be undesirable because those who leave, on average, possess above average skills, both general and agriculture specific. According to the official statistics the share of rural in total working age population remains stable around 28.4 percent over the past years; therefore the major alternative to the former state or collective farm employment seems to be private farming. The finding of Csaki and Lerman, 1997b, p.76, that private farmers are on average better educated than collectivist farm employees suggests that departure of farm workers toward private farming lowers average level of education of collectivist farm workers. In addition to the well documented fact that better educated labor is more productive, the level of education, as Schultz, 1975, argued, is positively related to an ability to deal successfully with economic disequilibria. Thus, workers leave leads to lower productivity in collectivist farms as education and experience became increasingly important in successfulness of adjustment to rapidly changing economic environment of Ukraine.

Independently of whether increase in the share of farm non-agricultural production activities means more production or social workers, the increase in the share means that the farm provided jobs that not only enhance farm production and/or general infrastructure, but also acquire additional income to rural population. The importance of this additional income is amplified by shrinking scale of main production as outlined above, and consequently, lower farm revenues and wage bill. Moreover, the state, the major buyer of the farms' output, was consistently late with payments for produce, and wage arrears started to distress agricultural enterprises. The World Bank surveys showed that more then half the farms were unable to meet the payroll on time at least once in 1993. The additional non-agricultural production jobs might have provided greater income security for farm families thus reducing further the possibility of leaving collectivist farms. In sum, farm non-agricultural production activities in addition to improving farm infrastructure may have made collectivist farms more attractive for living keeping this way average skill level of workers from declining. Because of this argument, another inefficiency model explanatory variable, the number of agricultural workers per hectare might have captured a part of the effect of the share of non-agricultural in total number of farm workers on inefficiency. The further separation of the effects of these two explanatory variables on technical inefficiency requires, however, specification of a labor mobility model, what is not permitted by data available and is beyond the scope of our study.

The effect of distance to the nearest city on technical efficiency was found to be positive, i.e. *ceteris paribus*, the farms located further from the cities are less technically inefficient. This result may have productive labor-keeping effect explanation as well: the advantage in location may have allowed the farms to compete better with cities for workers. More energetic workers from rural farms located closer to cities could commute to jobs in these cities, thus lowering the average skill/effort level of the available labor on these farms. In addition, the farms located closer to cities had easier access to the less productive (in agricultural tasks) city workers and students recruited for harvest time. In this way, relative efficiency would be related to the distance to city through its effect on the quality of the farm's productive labor even if workers don't leave the rural area permanently. Unfortunately, lack of additional data on commuters and temporary urban labor does not allow us to investigate this argument further and the explanation offered remains a hypothesis.

The estimate for the variance parameter, γ, is estimated to be close to one. If this parameter is zero, then σ_u^2 in (1)-(2) is zero, and the model reduces to a traditional production function with the variables *nonagw/totw* , *agw/totland* , *dis*, and *t* all included in the production function meaning that inefficiency effects are not stochastic. The last null hypothesis H_0: $\gamma = 0$, which specifies that the explanatory variables in the model for the technical inefficiency effects are not stochastic, is rejected by the data. In this case the parameter δ_0 is not identified, and consequently, the number of degrees of freedom for the test statistic is 2.

5. Concluding Remarks

Grain production and input use data in physical units together with overall farm operations information were used to estimate a stochastic frontier model in which inefficiency effects are modeled as a function of farm-specific variables and time. The magnitudes of the production function and efficiency estimates do not differ much from other findings obtained with a different model and a different Ukrainian farm data set. Our results indicate that the traditional production function model is likely to be inadequate for the farm-level analysis of grain production. The results illustrate that the process of transformation of

Ukrainian agriculture started in 1990 is costly in terms of technical efficiency; efficiency declined over the 1989-1992 period. The relative labor abundancy and distance to a nearest city were both found to have a positive effect on technical efficiency. The estimation suggests that investment of farm labor resources into infrastructure improves technical efficiency as technical efficiency in grain production increases with an increase of the share of farm non-agricultural workers. The lack of data did not allow us to separate the effect of different types of farm non-agricultural activities on technical efficiency. Further research is needed on how different types of the non-agricultural production activities affect agricultural production efficiency in Ukraine, and other countries in economic transition. The results highlight the importance of analysis of production at the farm level because production efficiency varies across farms and this should be taken into account for both research and policy considerations.

Endnote

We acknowledge the help of the Ukrainian Institute of Agrarian Economics in collection and interpretation of the data used in this study.

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Table 1. Partial Productivity and Input Use Indicators[a]

Indicator	units	1989	1990	1991	1992	Avg. change per farm 1989-92
Yield	tons per hectare	4.27	4.00	2.88	3.18	-25.4%
		(0.79)	(0.73)	(0.60)	(0.74)	(8.5%)
Production	tons	4936	4562	3205	3183	-35%
		(2690)	(2558)	(1796)	(1778)	(10%)
Area planted	hectares	1173	1149	1104	1020	-12%
		(550)	(542)	(510)	(469)	(10%)
Labor per hectare planted	hours	24	27	28	35	93%
		(12)	(13)	(15)	(17)	(184%)
Fertilizer per hectare planted	kilograms	7603	7624	6598	6385	-16%
		(5952)	(5950)	(5264)	(5556)	(23%)
Chemicals per hectare planted	kilograms	6.5	6.3	5.7	5.2	-19%
		(1.5)	(1.6)	(1.4)	(1.4)	(15%)
Fuel per hectare planted	liters	83	83	82	82	-0.9%
		(14)	(14)	(13)	(12)	(5.7%)

[a]All the indicators reported are average per farm, the numbers in parentheses are the standard deviations

Source: UIAE Survey of Ukrainian farms

Table 2. Summary Statistics for Variables in the Stochastic Frontier Production Function[a]

Variable	Units	Sample Mean	Sample St. Dev.	Minimum	Maximum
Production	tons	3972	2361	1219	18574
Land	hectares	1112	517	268	2850
Labor	1,000 hours	32	29	6	219
Fertilizer	100 tons	79	78	14	596
Chemicals	tons	6.6	3.7	1.6	21.4
Fuel	1,000 liters	93	51	24	285
Ratio of non-agricultural to total workers	number	0.143	0.053	0.041	0.317
Agricultural workers per agricultural land	number per hectare	0.141	0.031	0.081	0.245
Distance to city	km	35	16	10	85

[a]41 farms, 4 years, 164 observations in total

Table 3. Maximum -Likelihood Estimates for Parameters of the Stochastic Frontier Production Model for Farms of Kyivs'ka and Cherkas'ka oblast

Variable	Parameter	Estimate	St. Error of Estimator[a]
Stochastic Frontier			
Constant	β_0	16.2	1.8
Year 1991 Dummy	d_{91}	-0.178	0.024
ln (land)	β_1	-7.0	1.0
ln (labor)	β_2	0.75	0.71
ln (fertilizer)	β_3	0.54	0.88
ln (chemicals)	β_4	0.92	0.90
ln (fuel)	β_5	4.7	1.1
(ln (land))^2	β_{11}	1.275	0.080
(ln (labor))^2	β_{22}	0.021	0.041
(ln (fertilizer))^2	β_{33}	-0.029	0.035
(ln (chemicals))^2	β_{44}	-0.181	0.085
(ln (fuel))^2	β_{55}	0.54	0.27
ln (land) x ln(labor)	β_{12}	-0.25	0.25
ln (land) x ln(fertilizer)	β_{13}	-0.30	0.24
ln (land) x ln(chemicals)	β_{14}	-0.29	0.27
ln (land) x ln(fuel)	β_{15}	-1.65	0.45
ln (labor) x ln(fertilizer)	β_{23}	0.087	0.063
ln (labor) x ln(chemicals)	β_{24}	0.085	0.023
ln (labor) x ln(fuel)	β_{25}	0.092	0.091
ln (fertilizer) x ln(chemicals)	β_{34}	0.12	0.11
ln (fertilizer) x ln(fuel)	β_{35}	0.30	0.18
ln (chemicals) x ln(fuel)	β_{45}	0.22	0.19
Inefficiency Model			
Constant	δ_0	0.490	0.039
Non-ag./Total Workers	δ_1	-0.61	0.28
Ag.Workers/Total Land	δ_2	-1.88	0.45
Distance to City	δ_3	-0.00194	0.00090
Year	δ_4	0.105	0.011
Variance Parameters			
	σ^2	0.0165	0.0026
	γ	1.000	0.040
ln (Likelihood)		121.16	

[a]The standard errors for the estimators are obtained by the computer programm Frontier 4.1; they are correct to two significant digits

Table 4. Generalised-likelihood Ratio Tests of Hypotheses Involving Parameters of the Stochastic Frontier Inefficiency Model for Grain Production[a]

Null Hypothesis	Meaning of Hypothesis	ln (H_0)	λ	D.F.	Critical Value	Decision
Stochastic Frontier						
H_0: $\beta_{ij} = 0$	Frontier is of Cobb-Douglas form	107.676	26.97	15	25.00	Reject H_0
Inefficiency Model						
H_0: $\gamma = \delta_0 = \delta_1 = \ldots = \delta_4 = 0$	Inefficiency effects are absent from the model	72.812	96.69	6	12.59	Reject H_0
H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$	Inefficiency effects are not a linear function of the explanatory variables	74.792	92.73	4	9.49	Reject H_0
H_0: $\delta_1 = 0$	*nonagw/totw* does not affect inefficiency linearly	118.672	4.97	1	3.84	Reject H_0
H_0: $\delta_2 = 0$	*agw/totland* does not affect inefficiency linearly	114.332	13.65	1	3.84	Reject H_0
H_0: $\delta_3 = 0$	*dis* does not affect inefficiency linearly	119.097	4.12	1	3.84	Reject H_0
H_0: $\delta_4 = 0$	Inefficiency does not change linearly with time	90.974	60.37	1	3.84	Reject H_0
H_0: $\gamma = 0$	Inefficiency effects are not stochastic	117.743	6.83	2	5.99	Reject H_0

[a]The critical values correspond to 5 percent level of significance