FARM SIZE AND DETERMINANTS
OF AGRICULTURAL
PRODUCTIVITY IN UKRAINE

by

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Abstract

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This paper tests the hypothesis of inverse relationship between farm size and productivity for Ukrainian farmers. Several approaches were applied in order to determine which factors, and in particular how land size effect farm productivity. The value of output per hectare and technical efficiency were taken as a measure of farm productivity. Technical efficiency was estimated by two methods – non parametric DEA and parametric SFA. It was found that the relationship between farm size and productivity is nonlinear – productivity rises first and then falls. Ukrainian farms were found to be highly unproductive due to inefficient use of land resources. The calculated optimum size of land plot was determined to be larger than the average actual size of own landholding, and this might be an important argument for canceling of land-selling moratorium in Ukraine.

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Chapter 1

INTRODUCTION

The continuous growth of world's population, urbanization, industrialization and global warming impose an additional burden on agriculture enterprises. As World Bank experts predict, the demand for agriculture products will increase twice by 2030. Therefore, countries that are major in agriculture production should increase their productivity to satisfy future excess demand, taking into account that less land and water resources will be available in the future. Ukraine is one among the minority of countries which have good conditions for the cultivation of plants (temperature, climate, dense net of rivers and lakes and fertile land). In the Soviet Union, it was called the "bread basket" because of the production of large amounts of wheat; however, nowadays the role of agriculture continues to decrease.[1] Therefore, it is of great importance to investigate what are the ways of reviving and increasing the productivity of Ukrainian agriculture and to find out which factors have significant impact on farm productivity.

[1] In 1990 51009 thousands tons of wheat were produced comparing to 34258 thousands of tons in 2006 (in a year, that officially was announced as the year of village). Worth mentioning that areas used for cropping decreased less than by 5%. http://ukrstat.gov.ua/control/uk/localfiles/display/operativ/operativ2006/sg/sg_rik/sg_u/rosl_u.html

This paper investigates one of the most discussed and interesting hypothesis in agriculture literature about the importance of farm scale: that the productivity of a farm increases with the decrease of land holding's size. The concern about this factor of productivity arose in the mid 50ies of the last century when the Indian Farm Management Survey found out that with the increase of farm size the output per acre decreases. This unexpected result provoked researchers to check whether the inevitability of this relationship is really correct. Since that time numerous studies were done for different countries (Sen (1966) and Carter (1984) for India, Helfand (2003) for Brazil, Swinnen (2001) for Germany, Thapa (2007) for Nepalese mid-hills and others), however the debate on this hypothesis is still open. That is mostly due to the fact that earlier studies are severely criticized by some recent works (Sampath (1992), Newell et al (1997), Rios and Shively (2005)) as more advanced methodologies and high-quality data is available nowadays. The fact that farm size and productivity are negatively related which before was taken for granted now has become doubtful. Such research is of particular importance for countries which are major in agriculture because the approval of this hypothesis may give a stimulus to land redistribution among farmers in order to maximize country's productivity.

Nowadays in Ukraine there are approximately 43 thousands farms and about 600 thousands private landowners, which are the members of the Ukrainian Association of Farmers and Landowners. According to statistics, farmers own more than 3 millions ha of agricultural land and rent 2-2,3 millions ha. In developed countries during the last decade the average farm size has being increased annually on average by 1,6% (particularly, in USA – by 1,2%, in Japan – by 2,6%). However due to moratorium on land selling, Ukrainian farmers can't change the size of their own landholdings. Such ambiguous situation with land property rights can substantially influence farms' productivity. Since 2001 this question remains opened because of the deputies' opposite position on whether to permit land selling or not. The Blue Ribbon Commission for Ukraine (2006) suggests that the land assets should be redistributed in favour of more efficient forms of farming.

An alternative to land buying - land renting may not be as good, because the quality of rented land can be lower than the renter believes. Thus, for some crops cultivation, the land has to be unused for particular time. For example, after the sunflower cropping, soil becomes highly exhausted and land has to "rest" for 7-8 years. As usually, land tenants are not interested in renting interruption, so the renter can face low yields of his future crop. Therefore, operation on own land may effect farm's productivity in different way, than in the rented one. That is why, in this study we'll find the impact of own and rented land size on farm's productivity and conclude whether land selling should be acceptable or not.

This paper considers farm's productivity problem, which is solved applying several approaches. As a measure of productivity we take two variables – the value of output per hectare (following the example of many early researches (Sen (1975), Carter (1984), Newell at al (1997)) and technical efficiency (more recent works of Helfand (2003), Rios and Shively (2005)). Technical efficiency is firstly determined by non parametric (econometric) approach– Stochastic Frontier Analysis with imposing a Cobb Douglas specification on production function. Secondly, non-parametric approach of Data Envelopment Analysis (DEA) is applied. These two approaches are usually used together, as they are good supplements of each other (different manner of production function specification and as a result different nature of bias). At the second stage our measures of productivity will be regressed on the set of explanatory variables, employing OLS, fixed effect and RE models.

Many earlier works on this topic (Mazumdar (1965), Rao and Chotigeat (1981), Carter (1984), etc.) had comparatively small number of observations, which were taken from several regions of the country. For our research we use quite representative sample, as information about particular farms characteristics is taken from N 50-сг form (provided by Institute of Economic Research and Policy Consulting). It consists of approximately 2,500 private farms and covers all Ukrainian regions during 5 years: 2001-2005.

The paper will be organized in the following way: in the second chapter the main attainments and shortcomings in the study of this hypothesis are analyzed. Third chapter deals with methodological framework. Data description will be provided in chapter four. In fifth chapter empirical results and policy recommendations about the need to implement land reform will be provided and in the chapter six conclusions will be made.

Chapter 2

LITERATURE REVIEW

The hypothesis about the inverse relationship between farm size and productivity has been tested by many researches in different countries of the world. The debate is still of current importance because no final conclusion has been reached so far. The largest part of the earliest research works has decided it is a 'proven fact', arguing that it should be taken into account by agronomists and farmers who are interested in increasing their productivity. However, starting from the end of 90^{ies} more and more researches began to reject this hypothesis. Therefore, in this chapter I will firstly describe those works, which find the inverse relationship, gathering them in groups that provide particular explanations for it. Secondly, the works that reject this hypothesis will be presented. This category of authors criticizes the first group, pointing out on the necessity of applying other methodologies and adding new explanatory variables.

All studies of the relationship between land holdings and productivity are based on the basic neoclassical model. The farm productivity can be presented as Y= F(A, L, K), where A is characteristics of land holding, L – set of labor characteristics and K- capital used for plant cultivation. Assuming the Cobb – Douglas production function and taking the logarithms of both sides we get the transcendental logarithmic function, which can be estimated by different methods and supplemented by some explanatory variables.

Mazumdar (1965) is one of the pioneers who have determined that with the increase of land holdings of a farm, its productivity decreases. Using the data for two districts in Uttar Pradesh (India) for 1955-1956, he also found that returns to inputs of one acre of land is decreasing, so increasing the input the output per unit of input decreases. Nowadays factors of production substantially differ from those analyzed in this paper: the agriculture developed extensively and bullock labor was one of the most important factors of the plants production. This fact as well as limited number of farms studied were later criticized and attracted many other researches to study this problem.

Mazumdar explained the inverse relationship between farm size and productivity by the fact that family labor is used for cropping on small farms and hired labor is used on large farms. It may be clarified by means of incentive economics: the motivation for more productive work is higher for family members rather than for hired workers. The last ones, as a rule, are used by large farms. It may also be true, that families in small farms will use other factors of production more intensively to produce the planned amount of product. This explanation is also supported in works of Sen (1966), Griffin et al. (2002), Benjamin (2002) and others.

Carter (1984) using a small household sample (376 holdings) confirmed the inverse relationship. The data was pooled because of its poor quality, as farmers recorded the required observations not properly. He suggested that the inverse relationship have happened not because of sample selection bias or 'misidentification of village effect', but because of 'capitalistic mode of production'. He cites as an explanation to inverse relationship quite controversial argument the impact of which is decided to be opposite by many researches and will be discussed later in this chapter: 'intra village soil quality difference' partly explains the negative relationship between farm size and its productivity. He completely confides in the empirical part, pointing out that 'overall statistical analysis strongly supports' his beliefs.

The other main reason why the inverse relationship may occur is that a risk-averse farmer tends to redistribute his time-labor efforts between alternative employments. This idea is proposed by Srinivasan (1972), who have suggested that the desire to substitute from risky activity is higher for the landowners of larger farms, as the success of harvest is uncertain. Using the assumption that farmer is risk-averse person of an Arrow - Pratt type (he will become more risk averse if his wealth decreases), the author argues that among two types of income sources, smaller farms will choose less risky self cultivation rather than wage labor.

Two other motivations for large farms division into smaller ones are geographic differences of studied regions and diminishing returns to scale.

However, the last one is not properly studied in empirical literature. Berry and Clinc (1979) have pointed out, that the returns to scale are approximately constant. Newell et al (1997) suggested that if there would be decreasing returns to scale, the land holdings were to decrease continually to the smallest pieces of land.

By the mid 70^{th} approximately twenty works were devoted to study this phenomenon in India agriculture (Sen (1975)). Almost all of them as well as researches of Eastern Europe, Asia and Latin America agreed on negative relationship between size of a farm and productivity (Bardhan, 1973).

The first shortcoming of the earlier works, however, was that they used not complete micro data of FMS which was available only for limited number of Indian districts. Deodalicar (1981) in his literature survey points to three works that first extended the data and got another results. Thus, Rao (1967) failed to find any inverse relationship because he used disaggregated data sources for other Indian districts. Ruda (1968) came up with the same results in his research of 20 villages. Rani (1971) also didn't detect an expected effect of size on yields for seven out of twenty five Indian villages.

The second shortcoming was proposed by Deodalicar (1981), who extended the understanding of this problem by pointing out the importance of technical progress. The negative relationship is preserved only in "traditional agriculture, and it breaks down with technical progress". The fact that small farms are more productive is valid only when level of agriculture technology is low. This paper makes particular contribution to the empirical literature, as it tests the hypothesis that the inverse relationship is valid for all Indian farms and not for separate limited number of villages (using 247 districts during the years after the Green Revolution (1970-1971)). However, later researches have not relied on his explanation, as the inverse relationship is still found even for the recent farm – level data

The misleading results of the authors may also come from the fact that farm size is relative measurement for a large and heterogeneous sample and is expressed in absolute value (acres). However for Indian regions that have different climate it may be the case that for the same absolute square the size classification will be interpreted differently. Thus for arid region Rajasthan 10 acre farm can be considered as a small farm, but for irrigated West Bengal it is a large farm (Patnaik (1972)). Thus Chadha (1978) separated Punjab into three agro-climatic zones. He found out that in the more 'dynamic zones' the negative relationship between firm size and productivity per acre does not hold.

Bhalla and Roy (1988) suggest that the inverse relationship comes from the unobserved difference in land fertility. They argued that in developing countries, once the exogenous land quality variable is accounted, the inverse relationship is 'observed to weaken, and in many cases disappear'. Therefore, one of the most popular hypothesis being discussed in numerous research works may be rejected just controlling for the land fertility factor (dividing it into particular regions). Authors tend to explain fertility differences by Malthusian approach – in more fertile area firms are as a rule smaller and as a result more productive.

Sampath (1992) tried to prove Bhalla and Roy's suggestion. The advantages of his research were such: he used data for entire India (88,046 households) and the period after the green revolution (1975-1976). The author points out that he has used the approach of Cline (1970) and Bharadwaj (1974) – land was divided on net sown area and gross cropped area. The reason for that is obvious – areas at some period of time may be unused, so no outcome is produced. The author's innovation was to use another land characteristic – type of irrigation. However it is closely related to previous innovations - to control for different climatic zones or just dividing farms into particular regions. Thus, he has found out, that controlling for irrigation facilities 'there are no diseconomies of scale in land use'.

Newell et al (1997) also agreed with the assumption of Bhalla and Roy and extended the previous literature both by adding missing explanatory variable costs of cultivation and by dividing farms by the regions on 39 clusters. The hypothesis doesn't hold in neighboring farms, but is proved only across different village. To control for regional differences they included the amount of rainfalls, population density, and dummy variables of crop zones, soil types, altitude categories. Such regional indices as literacy rates, road and railway infrastructure and district electrification are found to be insignificant.

However, shortcomings of the previous works are not only the data specifications and its quality, but also the methodology used. In recent works (Townsend (1998), Mathijs, Swinnen (2001), Helfand (2003) and others) to measure the productivity efficiency the Data Envelopment Analysis (DEA) is used, which was firstly suggested by Farrell (1957). This nonparametric approach allows to measure technical and allocation efficiencies without imposing any functional form on the production function. As it doesn't allow testing direct hypothesis, two steps should be used: to get the inefficiency measures using DEA and then regress it on the set of explanatory (farm specific characteristics). This methodology will be presented in details in the third chapter of this research work.

Townsend et al (1998) claims that he is among the first researchers, who used this new methodological approach (of DEA) and 'recent farm survey data'. The research was conducted for wine producing farms in South Africa. The farm productivity was estimated both as separated partial and total productivity. The author has found out that the inverse relationship is weak and total factor productivity deviates from region to region. Therefore, his empirical research has contributed to the agronomists' world discussion the conclusion that hypothesis of inverse relationship may be invalid.

Helfand (2003) have shown that the relationship between farm size and productivity is more complex than it was earlier believed. Applying Data Envelopment Analysis (DEA), the U-shaped relationship was determined: the productivity first falls (for farms up to 200 hectares) and then rises. He avoided the aggregation bias by using the data from 426 counties, 4 types of land tenure and 15 classes of farm size. However, as he didn't have access to farm level data, the representative farm was introduced for each type of farm characteristics, as a result 237,595 observations were aggregated into 9,304. He followed the approach proposed by Vicente et al (2001), who proposed to measure total factor productivity (TFP) which accounts land, labor and inputs productivity. Worth mentioning, all previous works determined the impact of farm size on land (of one acre) and labor productivity.

For the first stage of DEA estimation Helfand (2003) used several methodologies: to account for spacial heterogeneity - fixed effect, for heteroscedasticity across 426 counties - RE and for spacial correlation in the errors across counties - SUR framework. As explanatory variables of technical efficiency he used 6 types of farm characteristics: farm size, land tenure (type of ownership), composition of cattle, access to institutions and use of public goods, technology and inputs. All of them had statistically significant impact on farm efficiency, however, only high farm specialization, access to institutions (to credit, electricity and technical assistance) and the level of technology had large influence. The author argues that if small farms had at least the same access to institutions, technology and inputs, as large farms did, their efficiency will be higher (than of the last ones).

Rios and Shively (2005) studied the impact of farm size on productivity using the data on coffee farms in two districts of Vietnam. Using the two steps analysis (DEA and Tobit regression) he also disproved the hypothesis of inverse relationship and identified which factors of production influence technical and cost inefficiency (long pipe lines, farmer's level of education). One of the main factors that affect large farms to be more efficient is that they have access to credit and investment.

Therefore, no increasing return to size of small farms was proved both in developing and developed countries by many researches in 70-90th. However, recent works have shown that the larger the land holding – the larger is farm productivity. This conclusion is made for countries with developed agriculture, where the farms are equipped with modern technology and have a free access to credit. It is important to define what is the best land policy for Ukrainian farms at this transition period. Thus, if productivity of farm increases with land holding, a good policy will be the abolition of moratorium. We should also take into account not typical to other countries high ability of Ukrainian farmers to rent land. If productivity will increase with total land, but decrease with increasing the size of rented lend, it will be another argument for allowing selling of the land.

Chapter 3

METHODOLOGY

In order to estimate farm's productivity several approaches will be used in this paper. Firstly, we'll consider a parametric (econometric) approach of estimation the farm productive efficiency (Stochastic Frontier Analysis), secondly we'll use non-parametric (operational) approach - Data Envelopment Analysis (DEA), which will help to find out what are the main determinants of Ukrainian farms efficiency and what the impact of size is. And thirdly we will use an alternative measure of farm's efficiency – value of output per hectare. The combination of two efficiency estimation methods is used in many recent works for different countries, where the hypothesis of inverse relationship between farm size and productivity was tested: Zyl, Miller, Parker (1996) for Poland, Mathijs and Swinnen (2001) for East German agriculture, Helfand (2003) for Brazil, Masterson (2007) for Paraguay agriculture and others.

It is a good tradition to use DEA and SFA techniques together because each of them has its advantages and disadvantages (Felthoven (2000)). They differ in the manner of production frontier generation; as a consequence, the source of the result's bias is different. For the SFA estimation we need to assume a specific form of production function (usually a Cobb-Douglass), therefore actual results can be biased due to incorrect specification. The strong point of SFA is that it is robust to random noise. DEA is used as alternative to SFA when it is difficult to specify the correct SFA model. It constructs a piecewise linear representation of the technology frontier using mathematical programming. A weak point of non-stochastic DEA approach is that it is sensitive to random noise. Such different approaches to production frontier construction can sometimes yield different results and the researcher has to choose analytically which results are more appropriate to the theoretical model.

Efficiency in parametric approach (also called a regression technique) is calculated by comparing the observed output with the optimal (maximum) output for the same input. We describe below a Cobb-Douglas specification of production function, as it is commonly used for stochastic production function estimation.

Consider a farm that operates using a set of inputs: capital K, family and hired labor L and A acres of land (which consists of own and rented land) for producing output Y.

To construct SFA estimation we have to assume that the actual output of a particular farm i at time t is a function F(·) of the set of inputs and error term ε_{it}, which consists of two parts: TE_{it} – technical efficiency and e_{it} – statistical noise, which is purely random variation in output. Assume that these two components of error term enter the function multiplicatively.

$$Y_{it}=F(A_{it}, K_{it}, L_{it}) \cdot TE_{it} \cdot e_{it} \quad (1)$$

Taking the logarithm of both sides and denoting y_{it} = $\log(Y_{it})$, f= log (F), u_{it}=-log (TE_{it}), v_{it}=log(e_{it}) , we get

$$Y_{it}=f(A_{it}, K_{it}, L_{it})-u_{it}+v_{it} \quad (2)$$

To find technical efficiency term u we have to impose functional form on f(·) and to assume the distribution of statistical noise v and efficiency term u. Let's assume Cobb-Douglas production function to estimate the production function frontier

$$F(A_{it},K_{it},L_{it})=A_{it}^{\alpha}K_{it}^{\beta}L_{it}^{\gamma} \quad (3)$$

Taking the logarithm of equation (3), the resulting production function frontier specification with u≥0 can be presented in the form:

$$\ln y_{it}= \alpha_0 + \alpha_1 \ln A_t + \beta_1 \ln K_{1t}+ \beta_2 \ln K_{2t}+\ldots+ \beta_k \ln K_{kt} + \gamma_1 \ln L_{1t} + \gamma_2 \ln L_{2t} + \ldots+\gamma_k \ln L_{kt} + \eta_1 T_{01}+ \eta_2 T_{02}+ \eta_3 T_{03}+ \eta_4 T_{04}+ \eta_5 T_{05} -u_{it}+v_{it}, \quad (4$$

where α_0 is an intercept, y_{it} is the total annual farm output per hectare (deflated by CPI) , A - the size of a farm, T_i- dummy variable for time, α_1, β_k, γ_k are production elasticities for input k.

We assume that u_{it} is half-normally distributed with mean μ and variance σ_v^2 and v_{it} is normally distributed with zero mean and variance σ_u^2.

Estimation of this model will give us the possibility to compare actual and predicted output for each farm, thus to determine its technical inefficiency. We'll do this firstly, by setting u_{it}=0, so if there is technical inefficiency (u_{it}≠0), the level of output is below the frontier (Kumbhaker and Lovell (2000)). Secondly, for panel data we will use time-varying decay model (Battese and Coelli (1992)). Technical efficiency is redefined as

$$u_{it}= \eta_i u_i= u_i \exp(-\eta(t-T_i))$$ (

Where η is decay parameter, T_i – the last time period in the i panel. When $\eta=0$ the degree of inefficiency is constant over time (time invariant model), $\eta>0$ inefficiency decreases with time, $\eta<0$ – inefficiency increases.

Obtained scores of technical efficiency we regress on farm characteristics, farm management set, input set and regional dummies. We will use OLS, fixed effect and random effect approaches and define the effect of farm size on productivity. As farm characteristics we use the amount of own and rented land, as farm management characteristics[2] - technical and marketing assistance.

Secondly, let's estimate the farm productive efficiency using the non parametric approach (DEA). As mentioned above we don't need to impose a functional form on production function, because nonparametric deterministic frontier is determined using linear programming approach. That is, the distance between efficiency frontier and observed input-output combinations gives the value of technical inefficiency.

Total technical efficiency (TTE) can be decomposed into two components: scale efficiency (SE) and pure technical efficiency (PTE) (Mathijs,

[2] Marketing costs and expenditures on leased equipment (Masterson (2007)). However, it is a relative division, as expenditures on leased equipment can also be referred to input set.

Swinnen (2001)). Mathematically, total technical efficiency under CRS can be presented in terms of minimizing inputs per unit of outputs

$$TTE\ (y^j, x^j) = \min \theta$$

$$s.t.\ \Sigma z^k y^k_m \geq y_m^j,\quad m=1,\dots,M$$

$$\Sigma z^k x_i^k \leq \theta x_i^j \quad i=1,\dots,N$$

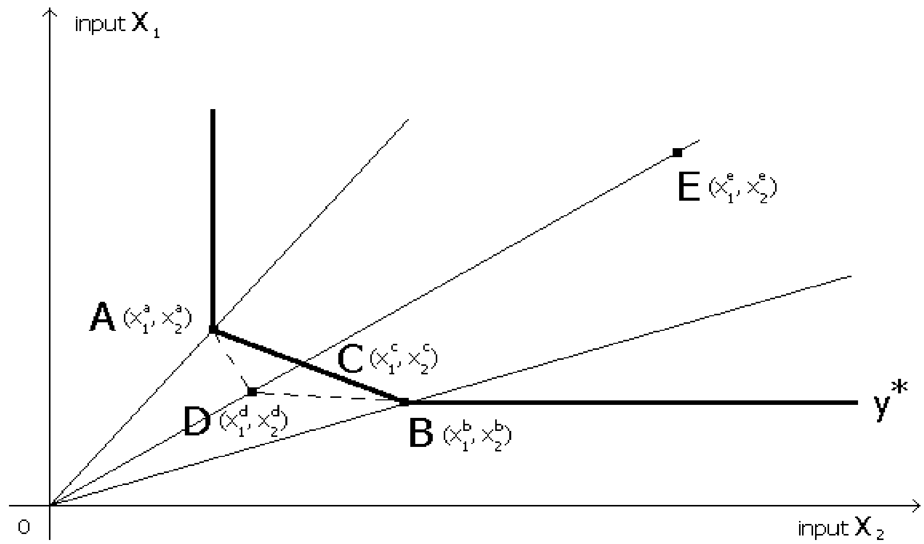
$$\theta \geq 0,\ z^k \geq 0$$

where θ is the ratio of observed to the maximum (efficient) vector of inputs, y^j_m is the output of activity m of farm j, x_i^j – the vector of inputs, z – intensity of each activity (the arbitrary positive scalar which reflects radial expansion / contraction of observation k).

Thus, assuming that proportionate expansion or contraction of vectors of inputs and outputs will remain in the technology set T, and that intensity z of each farm is non negative, the linear programming model finds the minimum value of θ.

Graphically the DEA - estimator of Farrell input oriented technical efficiency can be presented as a locus of the efficient points[3]:

[3] For simplicity, we depict two-input case.



The frontier is determined by the linear combination of the most efficient farms. Thus, if we have two efficient farms A and B, the efficient frontier Y* will connect them with a straight line, thus point C will be on the efficient frontier. However, if there appears a farm with the same inputs proportions as farm C, but with less real quantities used in production, point D will be included to the efficient frontier, combining linearly A,D and B points. The efficiency of inefficient farms (point E) is equal to the ratio of the efficient and actual inputs quantity combinations (OC/OE).

To find PTE the other assumption should be added to the previous case with TTE: both constant and nonconstant returns to scale are possible.

$$PTE\ (y^j, x^j) = \min \theta$$

$$\text{s.t. } \Sigma z^k y^k_m \geq y_m^j, \quad m=1,\ldots,M$$

$$\Sigma z^k x_i^k \leq \theta x_i^j \quad i=1,\ldots,N$$

$$\theta \geq 0,\ z^k \geq 0$$

$$\Sigma z^k = 1$$

Finally, scale efficiency is obtained dividing TTE by PTE. The scale inefficient farm is identified by solving the following linear program:

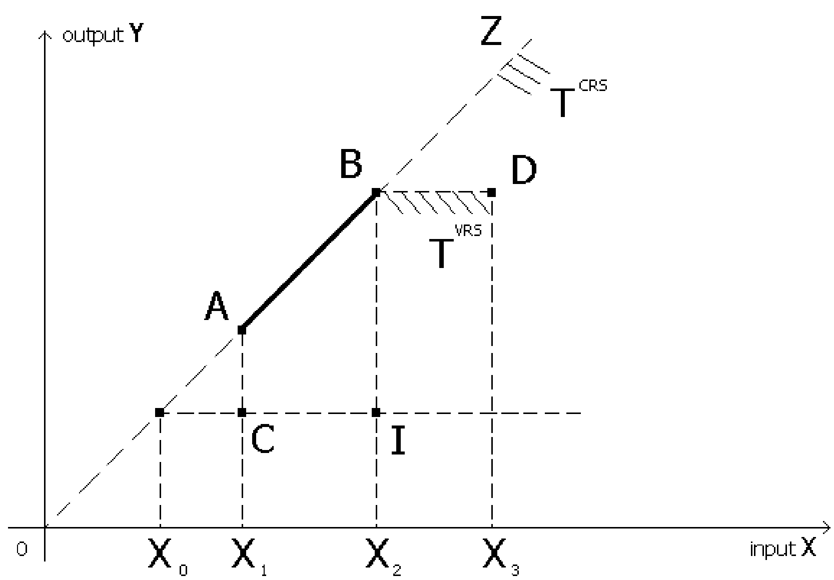
$$SE\ (y^j, x^j) = \min \theta$$

$$\text{s.t. } \Sigma z^k y^k_m \geq y^j_m, \quad m=1,\ldots,M$$

$$\Sigma z^k x^k_i \leq \theta x^j_i \quad i=1,\ldots,N$$

$$\Sigma z^k \leq 1$$

The relationship between the farm size and its efficiency can be illustrated on the following graph



On the dotted line OZ, which shows CRT technology, we have two efficient farms A and B. Farms which are below OZ line (CRS) are inefficient:

farms C and D. Points A, B, C, D become technically efficient (form the efficient frontier) when non constant returns to scale is assumed. Scale efficiency is received after the extracting pure technical efficiency from total technical efficiency. Thus, small farm C and large farm D are technically efficient, but are not scale efficient. The value of scale inefficiency for the farm C is OX_0/OX_1, and for D is OX_2/OX_3. Farm, such as I are both technically (by OX_1/OX_2) and scale inefficient (OX_0/OX_1), so the total level of inefficiency is equal to OX_0/OX_2.

It is important to note that the term "inefficiency" is used to denote the distance between the actual output and the efficient frontier. "Inefficient" farm behavior can be explained by a lot of other reasons that are not related to X-inefficiency: market failures, quality of rented land, credit market constraint and others. For our second stage we regress obtained technical efficiency scores as well as output per hectare (using pooled OLS, fixed effect and random effect approaches) on farm size, land tenure (the impact of own and rented landholdings), composition of output (wheat, corn, sunflower, barley and horticultures), access to institutions/ public goods (electricity, technical assistance, leased equipment and property), inputs (labor, machines, fertilizer, fuel spent) to determine how they effect technical efficiency.

Pooled OLS can be not a good approach to find the impact of different factors on farm productivity as it does not account for the unobserved characteristics of the farms. As a result we will have omitted variables bias. To coupe with this problem we will use fixed effect and random effect approaches. Fixed effect will be used in order to get rid of the variation in farms constant with time, however if there is no correlation between unobserved fixed characteristics and explicative variables – we will use random effect.

There can arise several problems which are related to the second stage estimation. We will briefly discuss those, which are more likely to happen. First of all, there can be a problem of multicollinearity, because as we have panel data, in all variables there can be presented the same trend, e. g. farmers with larger land holdings use more humus and fertiliser than those with smaller ones. If dependent variables are highly collinear, OLS estimators will have larger variance and covariance and as a result estimates will be not precise. To account for correlations in standard error of each farm over time we will use clustering by farms.

Secondly, there can be a problem of heteroscedasticity which may happen due to several reasons: presence of outliers, incorrect specification of regression model and the so called "error-learning model", which means that farmers get experience in cropping with time, and their behavior errors become smaller. Though heteroscedasicity does not bias the coefficients, it biases the standard errors, and this may lead to the incorrect specification of our results. We will use Breush - Pagan test to detect its presence and estimate robust standard errors (Huber/White estimators) to deal with it.

Finally, we want to draw attention to another possible problem - endogeneity of productivity. This may happen because not the land holdings influence the farm productivity, but the past farmer's experience influences his choice to choose the proper land holdings in order to maximize productivity. If we have this problem, estimated results will be biased. To test the validity of the assumption of no endogeneity Durbin-Wu-Hausman test will be used. In case of endogeneity we should use instrumental variables, however as we haven't found no appropriate ones used in the literature, and because we have micro-level data with limited number of explanatory variables, we can only use lags of land holdings.

As Ukrainian farmers operate on the land market only by renting the land, this may influence their efficiency. The reason for that may be due to imperfect knowledge of the quality of rented land, which can be lower than they believe (e.g. due to uninterrupted use) and they have less motive to invest in land. Akerlof (1970) shows that market with imperfect information (when sellers are better informed than buyers) can shrink or even disappear. Therefore, it is important to determine both how the total land holding and the use of rented land influences the farm productivity.

C h a p t e r 4

DATA DESCRIPTION

The empirical analysis is based on the balanced data sample of 1170 Ukrainian private farms during the 2001-2005 years. Because of not full and proper initial data set, in which we had some missing farms for some years, we had to deleted them in order to create balanced data sample (which is needed for DEA and SFA approaches).

We have compared results, obtained by the parametric approach for balanced and unbalanced panel data (see Table A.5) and concluded that there is no difference if we drop some observations. The particular farm characteristics are taken from N 50-сг form, which was collected by State Committee of Statistics (Derzhkomstat) and provided by the Institute for Economic Research and Policy consulting (IER). To control for specific climate conditions and original land fertility the territory of Ukraine the regional dummy variable was used.

The data set allows using for the empirical analysis such information (the descriptive statistics is presented in the table below):

- For every specific crop: production (in metric centners), the cost of production (thd. UAH), number of workers, the cost of sold products, sales revenue (thd. UAH).[4]

- Costs of: labor (wage bill), mineral fertilizers, fuel, electricity, repairs, depreciation, payments for rented land, payments for rented property, the use of an input for production, total (thd UAH), the use of an input in crop production

-Farms' financial results: from selling agricultural products: profit(thd UAH), loss (thd UAH), other revenue (thd. UAH), other losses (thd. UAH), net profits (thd. UAH), net loss (thd. UAH), farm profitability, average annual value of fixed and variable (floating) assets (thd. UAH), average annual number of workers employed in production, administrative costs, marketing costs.

- Land use: total, leased, agricultural land, total including arable land, hayfield, pastures.

Data set also allows us to control for farm specialization in a particular year. Therefore, dummy variables for crop, grain, sunflower, sugar-beet, animal and multi crop specialization will be included into the regression.

We should control for these factors as they may have an important effect on the farms productivity.

According to our statistics Ukrainian farmer on average has 45,7 hectares of own land and can rent up to 5000 hectares (some large farmers, with a large

4 All the monetary values are corrected for CPI with 2001 as a base year.

number of hired labor). As the farm's size has a wide range of variations, we can have problems because of heteroscedasticity.

Table 1. Summary statistics of explanatory variables

Variable	**Obs**	**Mean**	**Median**	**Std. Dev.**	**Min**	**Max**
Rented land	5850	1547.31	1153	1018.633	0	19800
Own Land	5850	32.21	21.2	229.89	0	5593
Depreciation	5850	46.61	14.84	88.67	0	1198
Labor	5850	63.14	46	81.29	1	2593.01
Seed	5850	126.88	83.5	143.91	0	2593
Fertilizer	5850	103.13	34.68	218.36	0	5069
Fuel	5850	130.7453	102.9	146.5103	0	2976.029
Electricity	5850	10.07017	5.35	24.02753	0	1109.018
Repairs	5850	57.48587	31.9	90.47008	0	1902.042
Leased property	5850	4.935297	1	19.38936	0	828.002

According to statistics [13], the largest number of farms are located in Odessa (14,5%), Nikolayev (10,6%), Dnepropetrovsk (8%), Kirovograd (6,1%) and Kherson (5,7%) regions. The smaller number is in Ivano-Frankovsk (1,4%), Rovno (1,1%) and Chernigov (1%) regions.

The average farm size depends both on the region and specialization. The largest land area in average for one farm is located in Lugansk (173 ha), Kharkov (166 ha), Kyrovograd (148 ha), Sumy (138 ha) and Dnepropetrovsk (129,6 ha) regions. The smallest size of the average farm is in Zakarpatska (7,9 ha) and Chernovtsy (21 hf) regions. This may happen due to Malthusian approach (difference in climate and land fertility) and the farm specialization. [5] Our statistics differs from the official statistics, because our sample includes only limited number of observations (as mentioned above, there are 43 thousands farmers in Ukraine, but we have about 2500). Unfortunately, the smallest farms don't have to submit any statistical reports; therefore we can have a problem with sample selection bias. However, As Ukrainian farmers can't buy land, but only rent it, we are particularly interested in those farmers that can afford to rent land and to hire labor to work on that land. To determine the impact of the rented land size on it's productivity, we have to use data of those farmers that rent land.

As can be seen from the TableA.1, we have a quite representative sample, as the size of own land holdings are comparatively similar to the official statistics. Worth mentioning, that although the size of own land can not be changed by the law, still there are some small changes in its value (as seen from the table below).

Table 2. The change of own land holding by years:

Year	Own land, ha
2001	64.14667
2002	37.29914
2003	19.98718
2004	16.21026
2005	23.44017

[5] For example, a farmer who crops wheat or sugar beet needs 300 ha of land and 40-50 ha is sufficient for farmer who crops vegetables (however more labor is required).

As some analysts mention there are some possibilities to overcome low – and the land can “move” between land owner and middlemen. The descriptive statistics by the year shows that the maximum land holdings were in 2001, than they decreased by 2004 and in 2005 they again started to grow.

Chapter 5

ESTIMATION RESULTS

We will start discussion of our results from presenting the values of technical efficiencies, obtained first, by SFA approach, and second, by DEA method. Then, more important for testing our hypotheses results will be presented: which factors effect farm productivity. As mentioned above, for this second stage we'll use three dependent variables: value of output per hectare and technical efficiencies, estimated in the first stage by two approaches.

For obtaining the scores of technical efficiency by SFA approach we used Stata 10 and by DEA method - program DEAP; for our second stage estimations we applied Stata 9. Worth mentioning that for DEA estimation other software can be used, in particular Matlab.

Since we are interested in the estimates of technical efficiency and not in the frontier per se, we will present the results of the first stage estimation of stochastic frontier in the Appendix (Table A.2) and skip the discussion of the coefficients. Worth mentioning, that the majority of coefficients are statistically significant at least at 1% level of significance (due to individual t-tests).

To estimate technical efficiency by DEA approach we used 1-output-4 inputs model (total crop production as unknown function of labor, land size, purchased inputs and technical expenses). Inputs were assumed to be free disposable. Purchased input variable was created based on the expenditures on seed, fertilizer, humus and services provided by other organizations. Technical expenses include expenditures on leased property, fuel, electricity and repairs.

Table 3. Summary statistics of technical efficiencies

	Mean	Std. Deviation	Min	Max
SFA	0,342	0,23	0,0051	0,962
DEA	0,4024	0,304	0,0002	1

From the table above we can see that the efficiency of farms is very low: by SFA estimation they are efficient only on 34%, and due to DEA approach – on 40%. However, these scores can come due to different reasons. Therefore we found the correlation between the efficiency scores (Table4). We also want to point out that the maximum values of technical efficiencies are different in SFA and DEA not occasionally – any observations that are close to frontier are attributed to efficient in DEA approach (the most efficient farms get technical efficiency equal to 1), and to random error in SFA (therefore maximum efficiency can not reach1).

Table 4. Correlation between the technical efficiency scores

	SFA	**DEA**
SFA	1	0,63
DEA	0,63	1

Although, there is correlation between the efficiencies of SFA and DEA approaches (as can be seen from the table and from the test, which proved it's significance) we need to present results of the second stage for both of this methods. This is necessary because due to different source of bias, technical efficiencies estimated by SFA and DEA approaches can give different results, and as we are not able to determine which bias is larger we can't choose which method is better.

To determine the sources of such high inefficiency we precede with more detailed discussion of the second stage results. In Appendix we present tables with results for SFA, DEA and the alternative measure of farm productivity – value of output per hectare (Table A.3, Table A.4 and Table A.5 respectively). For parametric estimation with output per hectare as dependent variable, we present results for both balanced and unbalanced panel data. From the Table A.5 we see that the results are very similar, therefore we can conclude that balancing the data, by dropping missing farms does not lead to bias.

As was mentioned in chapter 3, three methods are used to test our hypothesis: pooled OLS, fixed effect and random effect. We can include into OLS regression dummy variable of regions in order to capture unobserved regional characteristics, however this regression (LSDV) will give us the same results as FE, therefore we don't present it in this paper. To account for correlation in error terms of each farm over time, T statistics for pooled OLS regressions in all three approaches reflect robust standard errors and are calculated by farms clustering.

For all three approaches both test between pooled OLS and fixed effect (simple F-test) and test between pooled OLS and random effect (Breush - Pagan test) have shown, that pooled OLS is not preferential approach. To test fixed effect versus random we applied Hausman test.

In SFA approach some assumptions of Hausman test were violated, so test didn't show us which method is better to use. However, as the differences in coefficients in these methods are not very large, we tend to believe in random effect estimation (as can be seen from the TableA.3. results from fixed and random effects are very similar).

In DEA and parametric approach (with value of output per hectare as dependent variable) Hausman test showed in favour of fixed effect estimation. We have combined the results for the efficient methods for these three approaches in the Table5.

Table 5. Second stage estimation

Variable	**SFA** (RE)	**DEA** (FE)	**Parametric** (FE)
Farm size			
Own land	0,0081***	0,0080*	0,0426***
Rented land	0,1186***	0,1866***	4,5347***
$(\text{Own land})^2$	-0,0042**	0,0007	-0,0221***
$(\text{Rented land})^2$	-0,0733***	-0,1153***	-2,7709***
Specialization			
Corn	0,0568	0,0155	0,0923
Sugar beet	-0,005	0,001779	0,0650
Sunflower	-0,0236	-0,1926***	-0,0622**

Grain	-0,0181***	-0,0761***	-0,0596***
Animal	-0,0374***	0,0595***	-0,1761***
Expenses on inputs			
Labor	-0,0126***	0,0172***	0,00356***
Seed	00028	0,0226***	0,1008***
Fertilizer	-0,0022***	-0,0055***	-0,0038
Humus	-0,0018	-0,0102***	0,0163**
Services by other organization	-0,0017***	-0,0023**	0,0008*
Leased property	-0,0015**	-0,0055***	-0,0097***
Repairs	-0,0056***	-0,0092***	-0,0085*
Depreciation	0,0028***	0,0029***	0,0027
Fuel	-0,0031***	-0,0101***	-0,0057
Electricity	-0,0005	-0,0005	0,0081*
			5850
Adjusted R^2	0,756	0,10	0,59

***- coefficients are significant at least at 1% level of significance; ** - significant at least at 5%; *- significant at least at 10%; without mark – not statistically significant.

As can be seen from the table above, the impact of size is statistically significant in all three approaches, but is not as easy as was explained in many previous works. Our results support the hypothesis of Helfand (2003), that the relationship between the farm size and productivity is non-linear – first productivity rises and then falls. Thus, up to some point farmer increases the productivity of his farm by renting more land, but then productivity decreases.

We have calculated the intervals of optimal land holdings (both for own and rented land) based on the coefficients from the above regressions. Even though the squared of own land is not significant in DEA approach, the optimum size, calculated for three methods is very similar. Farmer has high technical efficiency (up to 90%) if the size of own land holding is up to 100 hectares. However, the optimum size of rented land should not exceed 20 hectares, as technical efficiency is very sensitive to changes in rented land.

High sensitivity to rented land change may come due to different reasons of land inefficient use. On the one hand, farmer can rent land of lower quality than expected (e.g. because it is exhausted by previous cropping of sunflower). On the other, he can rent more land than is optimal to profit maximization because of spurious expectations about the land policy[6].

Next, we proceed the discussion of our results with interpreting the coefficients of other explanatory variables. First of all, we want to point out that labor elasticity is statistically significant in all three approaches. We draw attention to this result, because in many research works on the micro-level data (Battese and Coelli (1992), Felthoven (2000), Alvarez and Arias (2004)) authors found that the impact of labor on farm productivity is not significant. From our estimation, we can see that an increase in labor on 1% causes productivity to increase on 1,7% (according to DEA approach), on 0,3% (according to parametric approach with output per hectare as a dependant variable) and to decrease on 1,2% according to SFA approach. The magnitude and the sign of labor elasticity are different in all three methods, because as was mentioned in chapter 3 all approaches may give different source of bias.

[6] Politicians in 2004-2005 suggested, that land which is rented by farmers, can be bought by them in the future by oversimplified procedures. Later this suggestion was canceled.

The specialization of farmers can also influence productivity. Thus, we have found out that the specialization in grain, sunflower and animal production has negative impact on farm's productivity. It's a typical situation for Ukraine (and for the majority of other countries) that farms specialized in animal production are inefficient. Therefore, government provides special benefits for these producers in order to stimulate production. The negative impact of specialization in grain and sunflower can be explained by the fact, that these cultures are very "fastidious", sensitive to weather changes and require a lot of farmer's efforts and knowledge.

Many other explanatory variables have quite evident influence on productivity. Thus, expenses on repairs negatively affect farm productivity, seed, electricity, humus and leased property – positive (however the signs of these explanatory variables sometimes differ depending on the method of estimation).

Summing up the results, we can conclude that there are large inefficiencies in agriculture production of Ukraine. On average farms have 66% (according to SFA) and 60% (to DEA) margin of actions to improve their productivity either by increasing the efficiency of factors used or by adjusting size of land. All specifications, used in this paper, have shown that the size of a farm has significant impact on farm productivity, and the relationship is not linear. The impact of other factors in general is also very similar, but sometimes their can be some differences, which can be explained by different source of bias.

CONCLUSION

The goal of our research work was to test the relationship between farm size and its productivity in order to provide arguments whether the moratorium on land selling in Ukraine should be canceled or not. Using the data for 1170 Ukrainian farms during the 5 years (2001-2005) we applied several approaches to determine which factors, and in particular how land size affect farm productivity. As a measure of farm productivity, we took the value of output per hectare and technical efficiency. The last one was estimated by two methods – non parametric DEA and parametric SFA approaches.

We found out that the relationship between farm size and productivity is non-linear. This means that up to some point productivity increases (for farms with total land size up to 120 ha) and then decreases. We have estimated that elasticity of rented land is higher than of own land. This means that if the amount of land used for cropping exceeds optimum amount, productivity decreases in a greater extent if more rented land is used.

According to our estimations, optimum size of own land is 100 hectares, which exceeds the average own holdings of Ukrainian farmers. However, the amount of optimum rented land (20 hectares) is significantly lower than the actual average size of rented plots. There can be different reasons to this "over-renting" effect. We suggest that farmers rent large plots of land, and thus deliberately reduce their productivity (and agricultural productivity of the country as a whole) because of political spurious promises. One of them – farmer has ability to buy all the land, which he currently rents.

Therefore, the main argument for moratorium cancelling is the fact, that average size of own land holding is less than the optimum for efficient production. Renting of needed land is not a good alternative, as productivity of this land is lower (rented land may be of lower quality (exhausted by previous cultivation) and farmer has less incentive to invest in this land).

However, we should take into account the possibility that farmers may want to increase their holdings of rented land in order to purchase this land in the future (to get additional profit by reselling it). Therefore, several restrictions should be made in the land law before the moratorium will be canceled. Thus, one way of improving the situation on the Ukrainian land market, can be providing a restriction on buying large sizes of land (more than 120 hectares) or establishing a particular range for each farmer on which he can change his land plot. This is a policy implication for the first stage – coming from moratorium – to free market. In order to achieve maximum efficiency in agriculture production, the access to land market should not be restricted by government.

In addition we want to present other typical fact for Ukrainian economy - in spite of moratorium on land selling, holdings of own land of some farmers changed from year to year. As experts comment, there are different ways to overcome Ukrainian low, so those who have such possibility can buy / sell land in small amounts. Therefore such restrictions are not only the sources of inefficiency, but additional corruption. This may be another argument for moratorium canceling.

BIBLIOGRAPHY

1. Akerlof (1970). The market for "Lemos": Quality Uncertainty and the Market Mechanism/ The Quarterly Journal of Economics, Vol. 84, # 3, pp. 488-500.

2. Alvarez A., Arias C., 2004. Technical efficiency and farm size: a conditional analysis. Agricultural Economics 241, pp 241-250.

3. Battese, Coelli (1992). Frontier production function, technical efficiency and panel data: With application to paddy farmers in India. Journal of productivity analysis. 3:153-69.

4. Bardhan, P., K., (1973). Size Productivity, and Returns to Scale: An Analysis of Farm- Level Data in Indian Agriculture. The Journal of Political Economy, Vol. 81, No. 6, pp. 1370-1386.

5. Benjamin, D., and Brand, L., (2002). Property Rights, Labor Markets, and Efficiency in a Transition Economy: The Case of Rural China. The Canadian Journal of Economics, Vol. 35, No. 4, pp. 689-716.

6. Berry, A., W., Cline (1979). Agrarian Structure and Productivity in Developing Countries. Baltimore, Johns Hopkins University Press.

7. Bhalla, S., S., and Roy, P., (1988). Mis-Specification in Farm Productivity Analysis: The Role of Land Quality. Oxford Economic Papers, New Series, Vol. 40, No.1. pp. 55-73.

8. Carter M. (1984) Identification of the inverse relationship between farm Size and productivity: an empirical analysis of peasant agricultural production. Oxford Economic paper, New series, Vol. 36, No.1, pp. 131-145.

9. Chadha GK (1978). Farm Size and Productivity Revisited: Some Notes from Recent Experience of Punjab - Economic and Political Weekly.

10. Deolalikar A. B. (1981) "The Inverse Relationship between Productivity and Farm Size: A Test

Using Regional Data from India" American Journal of Agricultural Economics, Vol. 63, No. 2, pp. 275-279. doi:10.2307/123956534.

11. Farrell M. J., (1957). The measurment of productive efficiency, Journal of the Royal Statistical Society Series A, 120: 253-81.

12. Felthoven (2000). Measuring fishing capacity: an Application to in North Pacific Groundfish Fisheries. Draft submitted for the American Agricultural Association annual meeting, Florida.

13. Griffin, K., A., R., Khan and A., Ickowitz, (2002)."Poverty and Distribution of land". Journal of Agrarian Change, Vol 2 (3):279 .330.

14. Helfand S. (2003), Farm size and the determinants of productive efficiency in the Brazilian Center-West, 25th International Conference of Agriculture Economists (IAAE), ISBN Number: 0-958-46098-1.

15. "Komentarii" (2006), #45 (56). http://comments.com.ua/?spec=116 4299801

16. Kumbhakar, Lovell (2000). Statistical Frontier Analysis. Cambridge: Cambridge University press.

17. Masterson (2007) Productivity, Technical Efficiency, and Farm Size in Paraguayan Agriculture. Working Paper No. 490.

18. Mathijs, Swinnen (2001). Production organization and efficiency during transition: an Empirical Analysis of East German Agriculture. The review of economics and statistics, Vol.83, No.1, pp.100-107

19. Mazumdar (1965). Size of Farm and Productivity: A Problem of Indian Peasant Agriculture. Economica, New Series, Vol. 32, No. 126, pp. 161-173 doi:10.2307/2552546

20. Rao V, Chotigeat T (1981) "The Inverse Relationship between Size of Land Holdings and Agricultural Productivity", American Journal of Agricultural Economics, Vol. 63, No.3, pp. 571-574. doi:10.2307/1240551

21. Rios AR, Shively GE. (2005). Farm Size and Nonparametric Efficiency Measurements for Coffee Farms in Vietnam - American Agricultural Economics Association annual meeting.

22. Sampath R (1992). Farm size and land use intensivity in Indian agriculture, Oxford Economic Papers, New series, Vol. 44, No.3, pp. 494-501.

23. Sen, A. K. (1966). "Peasants and Dualism with ir without surplus labor, Jornal of political Economy 7: 425-450.

24. Sen, (1975).AK Employment, Technology and Development. Oxford: Clarendon Press.

25. Srinivasan, T N. (1972). "Farm Size and Productivity: Implications of Choice Under Uncertainty." Sankhya Series B, Vol. 34, Part 4: 409-418.

26. Townsend, R.F., Kirsten, J.F. & Vink, N. (1998). Farm size, productivity and returns to scale in agriculture revisited: a case study of wine producers in South Africa. Agricultural Economics, 19(1-2), 175-180.

27. Patnaik U (1972). Development of Capitalism in Agriculture: II.. Social Scientist, Vol. 1, No. 3, 3-19.

28. Thapa (2007). The relationship between farm size and productivity: empirical evidence from the Nepalese mid-hills.

29. Zelenyuk, V., Fare, R. (2003): "On Aggregate Farrell Efficiencies", European Journal of Operational Research, 146:3, pp. 615-621.

30. Zyl, Miller, Parker (1996). Agrarian structure in Poland: The Myth of Large-Farm Superiority. The World Bank, Policy research working paper 1596.

APPENDIX

Table A1. The size of own land holdings by regions

Region(oblast)	Own Land size, ha
Crimea Autonomy	73.2
Vinnytsa oblast	11.83
Volyn oblast	0.2
Dnipropetrivsk oblast	45.88
Donetsk oblast	94.52
Zhytomyr oblast	57.18
Transcarpathian oblast	0.54
Zaporizzya oblast	36
Ivano-Frankivsk oblast	2.7
Kyiv oblast	9.77
Kirovograd oblast	90
Lugansk oblast	25
Lviv oblast	3.98
Mykolaiv oblast	42
Odessa oblast	71.2
Poltava oblast	18.93
Rivne oblast	1.14
Sumy oblast	70
Ternopil oblast	69
Kharkiv oblast	117
Kherson oblast	45
Khmelnitska oblast	4.41
Cherkasy oblast	35
Chernivtsa oblast	56

Table A.2. First stage: Stochastic frontier estimation

	Dependent variable: crop output
Variable	**Estimation**
Own land	-0,014 (-1,05)
Rented land	-0,2974 (-4,23)***
$(\text{Own land})^2$	0,010

	(1,10)
(Rented land)^2	0,183 (4,25)***
Corn	0,175 (0,98)
Sugar beet	0,097 (1,28)
Sunflower	0,035 (0,32)
Grain	-0,059 (-2,38)**
Animal	-0,309 (-13,62)***
Labor	-0,001 (-0,15)
Seed	0,051 (4,72)***
Fertilizer	0,008 (2,18)**
Humus	0,0448 (5,72)
Services by other organization	0,012 (4,34)***
Leased property	0,002 (0,67)
Repairs	0,007 (1,34)
Depreciation	0,006 (1,93)*
Fuel	0,021 (3,96)***
Electricity	0,012 (2,57)**

***- coefficients are significant at least at 1% level of significance; ** - significant at least at 5%; *- significant at least at 10%; without mark – not statistically significant.

Table A.3. Second stage estimation by SFA

Variable	OLS (1)	FE (2)	RE (3)
Farm size			
Own land	-0,0031	0,0083***	0,0081***
Rented land	-0,7839***	0,1417***	0,1186***
$(\text{Own land})^2$	0,0055	-0,0043***	-0,0042**
$(\text{Rented land})^2$	0,4784**	-0,0874***	-0,0733***
Specialization			
Corn	0,1302	0,0574*	0,0568
Sugar beet	0,0918	-0,0018	-0,005
Sunflower	-6,941***	-0,0060	-0,0236
Grain	-0,4070***	-0,0064	-0,0181***
Animal	-0,1641***	-0,0327***	-0,0374***
Expenses on inputs			
Labor	0,0579***	-0,0141***	-0,0126***
Seed	0,0320**	0,0026	00028
Fertilizer	0,0407***	-0,0033***	-0,0022***
Humus	-0,0006	-0,00194	-0,0018
Services by other organization	0,0039	-0,0018***	-0,0017***
Leased property	0,0010	-0,0016***	-0,0015**
Repairs	0,0087	-0,0059***	-0,0056***
Depreciation	0,0077**	0,0028***	0,0028***
Fuel	0,0060	-0,0034***	-0,0031***
Electricity	0,0172***	-0,0011	-0,0005
Adjusted R^2	0,522	0,757	0,756

***- coefficients are significant at least at 1% level of significance; ** - significant at least at 5%; *- significant at least at 10%; without mark – not statistically significant.

Table A.4. Second stage estimation by DEA

Variable	OLS (1)	FE (3)	RE (4)
Farm size			
Own land	0,0251	0,0080*	0,0082***

Rented land	-0,1721	0,1866***	0,1186***
(Own land) ^{2}	0,0041	0,0007	-0,0042**
(Rented land) ^{2}	0,0821	-0,1153***	-0,0733***
Specialization			
Corn	0,7618***	0,0155	0,0568
Sugar beet	O,1524	0,001779	-0,0005
Sunflower	-0,5524***	-0,1926***	-0,0236
Grain	-0,7283***	-0,0761***	-0,0181***
Animal	0,1697***	0,0595***	-0,0374***
Expenses on inputs			
Labor	0,1342***	0,0172***	-0,0126***
Seed	0,1000***	0,0226***	0,0028
Fertilizer	-0,0014	-0,0055***	-0,0022***
Humus	-0,0365**	-0,0102***	-0,0018
Services by other organization	-0,0001	-0,0023**	-0,0017***
Leased property	-0,0221***	-0,0055***	-0,0015**
Repairs	-0,0210*	-0,0092***	-0,0056***
Depreciation	0,0052	0,0029***	0,0028***
Fuel	-0,02478**	-0,0101***	-0,0031***
Electricity	0,0137	-0,0005	-0,0005
Adjusted R^2	0,15	0,10	0,319

***- coefficients are significant at least at 1% level of significance; ** - significant at least at 5%; *- significant at least at 10%; without mark – not statistically significant.

Table A.5. Estimation of farm productivity, measured by the value of output per hectare

	Unbalanced panel data			Balanced panel data		
Variable	OLS (1)	FE (2)	RE (3)	OLS (1)	FE (2)	RE (3)
Farm size						
Own land	0,0367***	0,0536***	0,0508***	0,0290*	0,0426***	0,03906***
Rented land	2,9625***	3,8158***	3,417***	3,2626***	4,5347***	3,9051***
(Own land) ^{2}	-0,02488***	-0,0356***	-0,034***	-0,0205*	-0,0221***	-0,02528***

(Rented land)^2	-1,8233***	-2,354***	-2,1039***	-2,0064***	-2,7709***	-2,3914***
Specialization						
Corn	0,2731**	-0,0705	-0,3279***	0,2055	0,0923	0,1617
Sugar beet	0,1731**	0,0875	0,1114	0,1695	0,0650	0,0944
Sunflower	-0,640**	-0,2717***	-0,3547***	-0,06531***	-0,0622**	-0,2676**
Grain	-0,4707**	-0,1045***	-0,2725***	-0,5034***	-0,0596***	-0,3018***
Animal	-0,4448***	-0,2118***	-0,3279***	-0,4232***	-0,1761***	-0,3351***
Expenses on inputs						
Labor	0,1402***	-0,0068	0,04398***	0,0918***	0,00356***	0,05019***
Seed	0,0720***	0,0679***	0,0618***	0,0944***	0,1008***	0,0863***
Fertilizer	0,0502***	0,0094***	0,0259***	0,0439***	-0,0038	0,01931***
Humus	0,0403***	0,0034**	0,01777***	0,0364***	0,0163**	0,0278***
Services by other organization	0,0128***	-0,0003	0,0034*	0,0130***	0,0008	0,0067**
Leased property	0,0050**	-0,0054**	0,0004	-0,0015	-0,0097***	-0,0034
Repairs	0,0205***	0,0008	0,0090**	0,0104	-0,0085*	0,0006
Depreciation	0,0089***	0,0031	0,0036*	0,0097**	0,0027	0,0058*
Fuel	0,0278***	-0,0016	0,0081**	0,0273***	-0,0057	0,01226**
Electricity	0,0278***	0,0082**	0,0208***	0,0248***	0,0081*	0,0184***
Number of observations	12134	12134	12134	5850	5850	5850
Adjusted R^2	0,36	0,59	0,55	0,40	0,59	0,35

***- coefficients are significant at least at 1% level of significance; ** - significant at least at 5%; *- significant at least at 10%; without mark – not statistically significant.