MODELLING FARMS' PRODUCTION DECISIONS UNDER EXPENDITURE CONSTRAINTS

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Abstract

Limited budget for the purchase of variable inputs might adversely affect producer's input use decisions and might result in a non-optimal input usage. If expenditure constrains are present and binding, unconstrained profit-maximization is not valid for modelling producers' input use decisions. In this paper we apply the indirect production function approach which describes output maximization subject to a given technology, a set of quasi-fixed inputs and a given budget for the purchase of variable inputs. By employing the indirect production function in the stochastic frontier framework we can estimate producer's output loss due to both expenditure constraints and technical inefficiency. Our estimation results show that most of the study farms were expenditure constrained during the considered period. Expenditure constraints have caused on average a potential output loss of 11 percent. Output loss due to technical inefficiency is quite moderate and averages 18 percent.

Key words: Indirect production function, SFA, expenditure constraints, technical efficiency, Russian agriculture.

1 Introduction

The input use decisions and production efficiency of Russian farms have been subject of many investigations in the past decade (Sotnikov, 1998; Osborne and Trueblood, 2002; Bokusheva and Hockmann, 2006). These studies were primarily sought to evaluate the effect of economic transformation on the allocation of productive resources. Under the central plan economy, farm production inputs were delivered according to the governmental plans and thus were not necessarily the subject of farmers' decision making. However, producers' input allocation decisions, particularly input adjustments have gained importance in the transitional context, primarily due to need to increase efficiency in input use. At the same time, low liquidity of farms and an only limited access to external finance due to financial market imperfections seriously limited producers' space for input decisions during transition. Hence, limited budget for the purchase of variable inputs might have induced a non-optimal input usage, which in turn resulted in productivity and efficiency losses.

If expenditure constrains are present and binding, then the assumption of a profit-maximizing firms is highly questionable, because it presupposes that farms face no constraints in their input-allocation decisions. On the other hand, in the cost-minimizing formulation, farmers are assumed to minimize the cost of a pre-determined level of output. Although this formulation incorporates some constraints on producers' behaviour, the exact nature of the constraint seems to be misspecified. That is the constraint is not in terms of output. Indeed, in the transitional context farms are constrained by the availability of funds required for purchase of variable inputs. This type of constraint can not be sufficiently represented in the cost-minimizing formulation. In particular, if the farm has limited budget for purchase of variable inputs, then profit maximization is equivalent to revenue/output maximization, given the availability of funds. This is especially true when the markets (inputs and output) are competitive. Lee and Chambers (1986) develop the theory of expenditure-constrained profit maximization. They derive the expenditure-constrained supply by differentiating expenditure-constrained profit function and show that profit-maximizing output supply under expenditure constraints equals to revenue-maximizing supply evaluated at the optimal input level.

In this paper we apply the indirect production function approach which describes output maximization subject to a given technology, a set of quasi-fixed inputs and a given budget for the purchase of variable inputs. Apart from being a more appropriate characterization of producers' behaviour, the indirect production function approach has the advantage that it allows for the direct computation of the output or the budget effect (the production analogue of the income effect) resulting from a change in input price.

In addition to facing a budget constraint, a farm may be technically inefficient. That is, it might not be able to operate on the production function (we define it as the frontier) given the input quantities. We use the stochastic frontier approach to model technical inefficiency. The presence of technical inefficiency might also affect allocation of inputs, and given the presence of budget constraint the impact on output loss will be more. Here output loss is defined in potential sense by comparing profit maximizing output levels with and without budget constraints and technical inefficiency.

Empirically the analysis uses survey data for 90 farms from three different regions in Central, South and Volga Russia for the period from 1999 to 2003. The data contains results of structured interviews with farm managers conducted in 2004, as well as farm accounting data from 1999 to 2003. In this paper, we utilise the farm bookkeeping data and the data which is related to basic characteristics of the farm, enterprise organisation, managerial characteristics, production-related characteristics, farm business environment.

The paper is organized as follows. The next section presents the general concept the indirect production function without and with technical inefficiency. In section 3, we derive the econometric specification of the indirect production function in the stochastic frontier framework. In section 4 we specify the empirical model and describe estimation procedure. The data employed in this study is presented in Section 5. We proceed with the discussion of model estimation results in Section 6. We finish by drawing conclusions.

2 Model

2.1 The indirect production function

The concept of the indirect production function (IPF) is relevant in the context of maximization of output subject to a given technology, a set of quasi-fixed inputs and a given budget for the purchase of variable inputs. Underlying this function, there is the familiar formulation of production function that relates inputs and output:

$$y_i = f(\mathbf{x}_i;\mathbf{z}_i) \tag{1}$$

where y_i is the output of producer i $(i \in I)$, $\boldsymbol{x_i}$ denotes a vector of N variable inputs used by producer i, $\mathbf{z_i}$ denotes the quasi-fixed input vector of order M. The budget constraint faced by the producer i can be written as:

$$C_i = \mathbf{w}_i'\mathbf{x}_i \tag{2}$$

where $\boldsymbol{w_i}$ denotes the vector of variable input prices faced by producer i and C_i represents the budget available to producer i for the purchase of variable inputs.

If the producers maximize output, given by (1), subject to the constraint in (2), the Lagrangean for the problem is:

$$L = f(\cdot) + \lambda(C - \mathbf{w}'\mathbf{x}) \tag{3}$$

where λ denotes the Lagrange multiplier associated with the constraint in (2), and the choice variables are the inputs, $\mathbf{x}$. The exogenous variables are the elements in vectors $\boldsymbol{z}$, $\boldsymbol{w}$ and the total budget of the producer, C, while the input vector $\boldsymbol{x}$ and λ are determined endogenously. Solving the first-order conditions ($f_j = \lambda w_j \ \forall\, j$ and $C - \mathbf{w}'\mathbf{x} = 0$), we get the solution of the endogenous variables in terms of the exogenous variables, viz.,

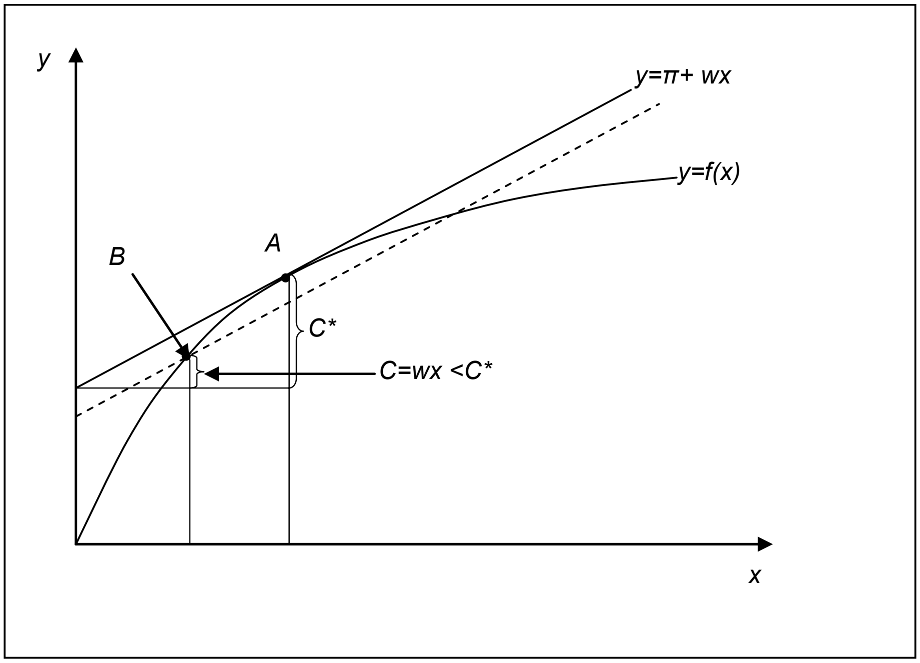
$$x_j^* = g_j(\mathbf{w};C;\mathbf{z}) \qquad \forall\, j = 1,\dots,N \tag{4a}$$

$$\lambda^* = h(\mathbf{w};C;\mathbf{z}) \tag{4b}$$

Substituting the optimal values of x_j^* from (4a) in (1) we get the optimal value of the objective function:

$$y_i = \psi(\mathbf{w}_i; C_i; \mathbf{z}_i) \quad (5)$$

Equation (5) represents the indirect production function (IPF), which expresses the maximum attainable output for producer *i* in a specified period as a function of the availability of funds, the price of variable inputs, the quantity of fixed inputs.



Source: Authors' own representation.

Figure 1: Output and profit with and without expenditure constraints

Unfortunately, from the preceding analysis, we cannot determine which farms are expenditure constrained and what is the potential output loss due to the presence of budget constraint. To do so, we assume that the desired budget for farm *i* (is consistent with maximum profit, for example) is C_i^*, which by definition can not be lower than the actual expenditure (C_i). That is, $C_i^* \geq C_i$ where the strict inequality means that the farm in question is expenditure constrained. The presence of constraints means that the farm in question can only spend C_i and not C_i^* and because $C_i^* \geq C_i$ output will be lower and so is profit. That is, output (profit) associated with C_i^* (say $y_i^* = \psi(\mathbf{w}_i; C_i^*; \mathbf{z}_i)$) will be higher than y_i which is associated with the budget C_i (given in (5)). This can be shown graphically, where the expression for profit is rewritten as $y = \pi + wx$ with output price used as a numeriare (Figure 1). Thus the vertical intercept of the line $y = \pi + wx$ measures profit. Profit without constraint is measured by the intercept of the solid line and profit associated with expenditure constraint is measured by the intercept of the dotted line that is associated with lower expenditure.

The optimization problem with budget constraint can be expressed as maximization of (1) subject to $C^* \geq C \Rightarrow C^* e^{-\eta} = C \;= \mathbf{w}'\mathbf{x}, \eta \geq 0$. The Lagrangean of the problem is

$$L = f(\cdot) + \lambda(C^* e^{-\eta} - \mathbf{w}'\mathbf{x}) = f(\cdot) + \lambda(C - \mathbf{w}'\mathbf{x}) \tag{6}$$

which is not different from the one we discussed before (3). Thus, the IPF is exactly the same. Since we do not observe C^* the corresponding output level y^* cannot be observed. In other words, one can not directly observe which producer is expenditure constrained and the extent of such constraints from the IPF.

However, there is a way to get the necessary information. It is through the Lagrange multiplier λ. Since at the optimum $\lambda = \partial L / \partial C = \partial y / \partial C$, one can get an estimate of λ by differentiating the estimated IPF with respect to the observed expenditure C. If a farm is not constrained its output will be the same as the profit maximizing level and the value of λ will be unity, if the output is measured in value terms. That is, at the optimum the return from spending an additional euro has to be matched by a return of one euro in additional output. If not, its profit can be increased by spending more (less) and the farm is not operating at the optimum. If the farm faces an expenditure constraint (i.e., $C_i^* \geq C_i$) the value of λ will exceed unity. It follows from the fact that the production function is concave in ***x***. Since we can estimate λ for each farm (once the IPF is estimated), we can easily find out which farms are expenditure constrained.

Since the value of λ for an unconstrained profit maximizing farm is unity, we can obtain C^* as a solution of C from the equation: $\partial y / \partial C = 1$. C^* can then be plugged into the IPF to get the optimum (unconstrained) output level, y^*. The deviation of actual (predicted) output from the optimal output can then be viewed as output loss due to expenditure constraint.

2.2 The IPF with technical inefficiency

So far we assumed that all farms are technically efficient. That is, given the inputs the produced output is the maximum from the technological point of view. If farms fail to produce the technically maximum level of output, the production function can be expressed as

$$y_i = f(\mathbf{x}_i; \mathbf{z}_i) e^{-u_i}, u_i \geq 0 \tag{7}$$

where u_i is a measure of technical inefficiency. Alternatively, $e^{-u_i} \leq 1$ is defined as technical efficiency. We can interpret $100.u$ as the percentage loss of output for being technically inefficient.

Since technical inefficiency in (7) is neutral, it does not affect marginal rate of technical substitution (the ratio of marginal product of inputs) between two inputs. Thus, input allocation is not affected by the presence of technical inefficiency. In other words, the solution of x_j in (4a) is not affected by the presence of technical inefficiency.[1] However, the solution of λ and y will be affected in the following fashion,

$$\lambda^* = e^{-u}\, h(\mathbf{w};C;\mathbf{z}) \tag{8}$$

$$y_i = e^{-u}\, \psi(\mathbf{w}_i;C_i;\mathbf{z}_i) \tag{9}$$

Since $e^{-u_i} \leq 1$, marginal return to the euro ($\partial y / \partial C$) is lower. More specifically, the return is only 90% if technical efficiency is 0.9.

To find out which farms are expenditure constrained and by how much (or the affect of it on output) as well as the impact of inefficiency on output, we need to estimate $\lambda^* = e^{-u}\, h(\mathbf{w};C;\mathbf{z})$ in which the $e^{-u_i} \leq 1$ term shows the effect on output due to inefficiency. The effect of credit constraint on output can be examined as before (the case without inefficiency).

3. Stochastic indirect production frontier model

Econometrically, the IPF is specified as follows:

$$y = \varphi(\mathbf{w}_i;C_i;\mathbf{z}_i)\exp(v_i - u_i), \tag{10}$$

where $\varphi(\cdot)$ represents the indirect production frontier, v is a producer specific random noise component and $u_i \geq 0$ represents technical inefficiency. Accordingly, the production frontier is defined as a maximum feasible output for producer i considering his fixed inputs' endowment, variable input prices and budget for the purchase of variable inputs. Thus, IPF allows explaining differences in the producers' input use by both factors - budget constraints as well as technical inefficiencies.

To impose minimum a priori restrictions on the underlying production technology we use a parametric flexible functional form to approximate the IPF in (5). The translog functional form is chosen because it imposes no a priori restrictions on any of the elasticities. After introducing the firm, fixed and variable input subscripts, i ($i \in I$), m ($m \in M$) and j ($j \in J$), respectively, the IPF specification of the stochastic frontier gets the following form:

[1] Here we implicitly assume that farms are allocatively efficient. We capture allocative inefficiency in a somewhat ad hoc fashion in the error terms in the share equations.

$$\ln y_i = \alpha_0 + \sum_{j=1}^{J} \alpha_j \ln w_{ji} + \sum_{m=1}^{M} \phi_m \ln z_{mi} + \alpha_C \ln C_i$$
$$+ \frac{1}{2}\left\{ \sum_{k=1}^{J}\sum_{j=1}^{J} \beta_{jk} \ln w_{ji} \ln w_{ki} + \beta_{CC} (\ln C_{it})^2 + \sum_{n=1}^{M}\sum_{m=1}^{M} \mu_{mn} \ln z_{mi} \ln z_{ni} \right\} \tag{11}$$
$$+ \sum_{m=1}^{M}\sum_{j=1}^{J} \gamma_{jm} \ln w_{ji} \ln z_{mi} + \sum_{j=1}^{J} \gamma_{jC} \ln w_{ji} \ln C_i + \sum_{m=1}^{F} \theta_{mC} \ln z_{mi} \ln C_i + v_i - u_i$$

In addition to the usual symmetry restrictions on the coefficients, β_{jk}, μ_{ml}, γ_{jm}, economic theory tells that the IPF is homogeneous of degree zero in input prices and C. This gives rise to the following set of restrictions on the parameters of the model:

$$\sum_{j=1}^{J} \alpha_j + \alpha_C = 0\,; \tag{12}$$

$$\sum_{j=1}^{J} \beta_{jk} + \gamma_{jC} = 0\,,\ \forall j = 1,...,J\,; \tag{13}$$

$$\sum_{j=1}^{J} \gamma_{jm} + \theta_{mC} = 0\,,\ \forall m = 1,...,M\,; \tag{14}$$

$$\sum_{j=1}^{J} \gamma_{jC} + \beta_{CC} = 0\,. \tag{15}$$

These homogeneity conditions can be easily imposed by scaling (dividing) input prices and expenditure by one of the input price. That is, all prices and C are to be normalized in terms of one input price.

The constant-cost demand function for the jth variable input can be derived from the IPF by using Roy's identity:

$$x_j = \frac{\partial y}{\partial w_j} / \frac{\partial y}{\partial C} \tag{16}$$

Using this equation the share of the jth input in total variable cost can be determined as following:

$$S_j = \frac{\partial \ln y}{\partial \ln w_j} / \frac{\partial \ln y}{\partial \ln C} = -\frac{e_{yj}}{e_{yC}}. \tag{17}$$

where e_{yC} denotes the output elasticity with respect to a change in the producer's budget and e_{yj} denotes the output elasticity with respect to a change in the price of input j.

4 Empirical specification and estimation procedure

4.1 The econometric model

The econometric model consists of the indirect production function and (*J-1*) cost share equations. To accommodate panel data we amend equation (11) by introducing time variable t and change the i subscript with subscripts i and t. This results in the following IPF system:

$$\ln y_{it} = \alpha_0 + \sum_{j=1}^{j} \alpha_j \ln w_{jit} + \sum_{m=1}^{M} \phi_m \ln Z_{mit} + \alpha_C \ln C_{it} + t + t^2 + \sum_{j=1}^{J} \tau_{jt} \ln w_{jit} t + \sum_{m=1}^{M} \tau_{mt} \ln z_{mit} t$$
$$+ \tau_{Ct} \ln C_{it} t + \frac{1}{2} \left\{ \sum_{k=1}^{J} \sum_{j=1}^{J} \beta_{jk} \ln w_{jit} \ln w_{kit} + \beta_{CC} (\ln C_{it})^2 + \sum_{n=1}^{M} \sum_{m=1}^{M} \mu_{ml} \ln z_{mit} \ln z_{lit} \right\} \tag{18}$$
$$+ \sum_{m=1}^{M} \sum_{j=1}^{J} \gamma_{jm} \ln w_{jit} \ln z_{mit} + \sum_{j=1}^{J} \gamma_{jC} \ln w_{jit} \ln C_{it} + \sum_{m=1}^{M} \theta_{mC} \ln z_{mit} \ln C_{it} + v_{it} - u_{it}$$

$$S_{jit} = -\frac{e_{yjit}}{e_{yCit}} + \xi_{jit}, \ \forall j = 1, \ldots, J-1, \tag{19}$$

where

$$e_{yCit} = \alpha_C + \tau_{Ct} t + \beta_{CC} \ln C_{it} + \sum_{j=1}^{N} \gamma_{jC} \ln w_{jit} + \sum_{f=1}^{M} \theta_{fC} \ln z_{fit} \tag{20}$$

$$e_{yjit} = \alpha_j + \tau_{jt} t + \gamma_{jC} \ln C_{it} + \sum_{k=1}^{N} \beta_{jk} \ln w_{kit} + \sum_{f=1}^{M} \gamma_{jf} \ln z_{fit} \tag{21}$$

Since the input share equations are not independent (their sum being unity), one input share equation has to be dropped to avoid the problem of singularity of the disturbance covariance matrix. This is automatically done when one input price is used as the numeraire. The econometric model consists of (18) and (19) which give a system of J equations. Note that we have added stochastic terms ξ_{jit} in the share equations. These noise terms can be viewed as allocative/optimization errors which can have zero or non-zero means. Non-zero means can be interpreted as systematic over- (under-) utilization of inputs.

4.2 Single-step vs. two-step method of estimation

Our interest is not only to estimate the parameters in the IPF but also inefficiency, which is treated as a random variable. This can be done in a single-step using the stochastic frontier modeling approach (see Kumbhakar and Lovell, 2000) that relies on the maximum likelihood method. To implement the ML method we need to make distributional assumptions on all the stochastic components in the model. If these distributional assumptions are right, the ML estimates are consistent and efficient. However, one can never be sure about the distributional assumptions. To guard against possible misspecification so far as distributional assumptions are concerned, it is often better to use a two-step procedure in which the estimators in the first-step are free from distributional assumptions. However, to estimate inefficiency, we need to make distributional assumptions. These distributional assumptions do not affect the parameter estimates in the first-step. Furthermore, the estimation procedure is much simpler when one uses the two-step procedure which is what we do here.

First-step: In conducting the fist-step procedure we rewrite the composed error term in the IPF as $\varepsilon_{it} \equiv v_{it} - u_{it} = v_{it} - (u_{it} - E(u_{it})) - E(u_{it}) = \varepsilon_{it}^{*} - E(u_{it})$ so that the mean of ε_{it}^{*} is zero. The $E(u_{it})$ term is subsumed in the intercept if its mean is a constant. By doing so we get a seemingly unrelated regression (SUR) equation system that can be easily estimated without making any specific distributional assumptions on ε_{it}^{*} and ξ_{jit}, except that their means are zero. The SUR procedure gives consistent estimate of all the parameters, except for the intercept in the IPF which is biased because it includes the $E(u_{it})$ term. The bias can be corrected using the correction factor that can be obtained from the second-step.

Second-step: In the second-step our primary objective is to obtain estimates of inefficiency. Since inefficiency appears only in the IPF, we use the residuals from the IPF to recover parameters associated with *u* and also obtain-observation-specific estimates of *u*. To do so we make some distributional assumptions which are standard in the stochastic frontier literature (see Kumbhakar and Lovell, 2000). These are: (i) *u* is iid $N(0,\sigma_u^2)$ truncated at zero from below; (ii) *v* is iid $N(0,\sigma_v^2)$; and (iii) *u* and *v* are distributed independent of each other. Based on these assumptions the probability density function of (*v*-*u*) can be easily obtained using the convolution formula. The model in the second stage is:

$$\tau_{it} = \alpha_0 + v_{it} - u_{it} \quad (22)$$

where τ is the residual from the IPF (calculated without using the estimated intercept). The ML method can be used on the above model in (18) to obtain estimates of $\alpha_0, \sigma_u^2, \sigma_v^2$. These are used to estimate *u* for each observation (see Kumbhakar and Lovell, 2000, for details).

The technical inefficiency model can be extended in several directions. One is to allow inefficiency to be explained in terms of some covariates. This can be done by allowing the mean and/or variance of technical inefficiency to be a function of some covariates, which are labelled as determinants of technical inefficiency. The other extension is allow heterogeneity/heteroskedasticity by making the variance of the noise term a function of covariates. Finally, it is also possible to allow systematic over-(under-) use of inputs due to allocative inefficiency (optimization error) by making the mean of the share equations functions of covariates.

5 Data

To test the IPF formulation of stochastic frontier model we employ the data obtained in the framework of a farm survey of 90 agricultural enterprises in Orel, Samara and Stavropol regions. The data contains farm accounting data for the period from 1999 to 2003 as well as results of structured interviews with farm managers. Having calibrated the data and excluded farms with high level of specialisation on a particular production line, we formed an unbalanced panel data set containing 347 observations from totally 73 farms. In addition, the study utilizes data on the price indices for agricultural output and inputs as provided by the Russian State Statistical Agency - Rosstat (Rosstat 2005).

For the IPF empirical specification we define farms' production output as annual farm revenue from agricultural production (*Y*). Land (*L*) and fixed capital (*K*) are regarded as quasi-fixed inputs, while farm permanent and hired labor (*A*), fertilizer (*Fert*), fuel and other materials (*Fuel*) are defined as variable inputs. The quantity of land is measured by the area of sown land adjusted by the farm's average soil fertility index. The value of farm's fixed assets in agricultural production is used as proxy for capital[2].

Variable inputs are defined by means of farms' input prices and shares of respective inputs in the farm total variable cost in agricultural production. We use farm average annual labor wages (w^A) measured in 1000 Rub per one farm's average agricultural worker, aggregated fertilizer prices[3] (w^{Fert}) measured in 1000 Rub per one tonne of fertilizer active substance, and fuel prices (w^{Fuel}) measured in 1000 Rub per one tonne of fuel, as variable input prices. Additionally, to take account of all remaining variable inputs (plant protection, seed, electricity etc.), which we don't have any prices for, we assume that their prices can be approximated by the farms' fuel prices. Respectively, we aggregate their cost share with the fuel cost share. Moreover, we use fuel prices to normalize the prices of 2 other variable inputs considered in the study, i.e. of labour and fertilizer.

Since no data were available for the farm predetermined expenditure, we follow Lee and Chambers (1986) and define the expenditure variable as the farm observed expenditure on variable inputs in individual years[4].

The set of exogenous variables used to explain the heteroskedasticity in technical efficiency contains following individual characteristics of the study farms: farm age (q^{age}), ownership structure (q^{own}), size (q^{size}), initial technology level (q^{tech99}), managerial competence (q^{manag}), diversification level (q^{div}), and severity of production risk (q^{risk})[5]. These variables were constructed by means of factor analysis and were found to explain a substantial part the variance in the original data set containing 31 farm characteristics related to basic characteristics of the farms, enterprise organization, managerial characteristics, production-related characteristics and farm business environment.

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[2] All monetary variables are measured in 1,000 Rub. Farm agricultural revenue and the capital stock value were adjusted to the price level in 2003 by employing annual price indices for agricultural output and machines in agriculture, respectively.
[3] We construct an aggregated fertilizer price by dividing the farm total fertilizer cost by the fertilizer physical amount calculated as a sum of active substances in different types of fertilizers applied in the production.
[4] Descriptive statistics for the variables employed to specify the IPF can be found in Table A1.
[5] Description of these variables can be found in Table A2.

6. Estimation results

Table 1 reports the estimates of IPF for the farms considered in this analysis. To take account for possible regional differences we introduced into the model dummy variables for 3 selected regions.[6] Though only one dummy variable has a significant estimate (in case of Stavropol farms), LR test indicate that the IPF specification with regional dummies appears to be more appropriate than the specification which does not account for regional differences at the 5% level significance. One third of the parameters have significant estimates. The insignificant parameters are primarily associated with the square-term and cross-product variables. However, a simple model such as the Cobb-Douglas is rejected against the translog model at the 1% level of significance using the standard LR test.

Table 1 IPF parameter estimates

variable	coefficient estimate	t-value	variable	coefficient estimate	t-value
constant	1.92	0.79	wFert*wFert	0.00	-0.26
dummy Samara	-0.07	-1.15	wLabor*wLabour	-0.05	-3.17
dummy Stavropol	0.20	3.54	wFert*wLabour	0.00	0.04
wFert	-0.21	-4.29	C*C	0.08	0.85
wLabour	-0.47	-4.18	Land*Land	0.16	1.35
C (expenditure)	1.61	3.98	Capital*Capital	0.04	0.82
Land	-0.90	-1.57	Land*Capital	0.05	0.41
Capital	0.08	0.28	wFert*Land	0.01	0.86
t	0.06	0.34	wFert*Capital	0.03	4.15
t*t	0.03	4.30	wLabour*Land	0.03	1.26
wFert*t	-0.06	-2.69	wLabour*Capital	0.05	0.41
wLabour*t	0.05	2.03	wFert*C	-0.02	-2.77
C*t	0.00	-0.30	wLabour*C	0.01	0.25
Land*t	0.04	1.62	Land*C	-0.07	-0.90
Capital*t	-0.05	-2.64	Capital*C	-0.07	-1.28

Source: Authors' own estimation.

The partial elasticities for the quasi-fixed inputs, i.e., land and capital, are positive (0.16 and 0.05 at the mean values of the data, respectively). The output supply elasticity with respect to the farms budget for variable inputs is equal 0.92 on average, indicating that output is expected to rise by 0.92 per cent by a one per cent rise in budget. The output supply elasticities with respect to fertilizers and labor are 0.19 and 0.13 on average, respectively. Consequently, the output supply elasticity of further

[6] The IPF constant term coefficient is the intercept estimate for farms in Oroel region. The coefficient estimates for the dummy variables present differences of the intercept estimates' for the farms from Samara and Stavropol, respectively, compared to the farms from Oroel.

variable inputs including fuel equals to 0.61.[7] These results show that Russian farms output is much more sensitive to changes in the availability of variable than quasi-fixed inputs and, thus, underline the importance of farm budget constraints. Additionally, the sensitivity of the farms to the availability of additional funds for purchase of variable inputs seems not to decrease during the considered period – the coefficient at the time-expenditure product term *C*t* is not significantly different from zero. Besides, our results suggest the land-using and capital-saving impact of technological change.

In Table 2 we present the results of our assessment regarding the expenditure constraints and related output losses in the study farms. We calculate the level of expenditure constraint for the individual farms as a difference between the desired budget and the farm's observed expenditures.[8] The results show that 331 from totally 347 farms face expenditure constraints: the level of farm actual expenditures has been on average by 13 per cent lower than the desired level; with the half of the farms being expenditure constrained at the level more than 0.12. In addition, according to our calculations, the expenditure constraints have caused an output loss of 11 per cent, on average.

Table 2 Expenditure constraints, output loss and technical efficiency estimates

	Lambda	Expenditure constraints (C*-C)/C	Output loss $(Y^*-Y^{IPF})/Y^{IPF\ a)}$	Technical efficiency TE
Mean	1.13	0.13	0.11	0.82
S.D.	0.08	0.08	0.08	0.06
Quantiles				
99%	1.33	0.33	0.31	0.92
95%	1.28	0.28	0.24	0.91
90%	1.24	0.24	0.21	0.90
75%	1.17	0.17	0.14	0.88
50%	1.12	0.12	0.09	0.84
25%	1.08	0.08	0.06	0.81
10%	1.04	0.04	0.03	0.77
5%	1.00	0.00	0.00	0.71

Notes: [a)] Y^{IPF} is constrained output level (deterministic part of the IPF); Y* is unconstrained output level (calculated by replacing the observed farm's expenditure *C* by the desired budget level *C**).

Source: Authors' own estimations.

Technical inefficiency presents another source of farms' output loss. We estimated the basic model without heteroskedasticity in the noise terms and determinants of inefficiency. This model

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[7] Output supply elasticity for the variable input used for the input price normalization (in our case – fuel and further variable inputs) can be calculated as the difference between the output supply elasticity with respect to the farms budget and the output supply elasticities of all remaining variable inputs employed in the IPF. This

[8] We determine the desired budget level as described in section 2.1.

specification is rejected against the more general models with heteroskedasticity and determinants of inefficiency. First we report results from the model in which determinants of inefficiency is introduced via the variance of u. That is, the model is heteroskedastic in terms of both v and u. The heteroskedasticity in v is explained by such individual farm' characteristics like farm age, ownership and management competence. The parameter estimates are reported in Table 3.

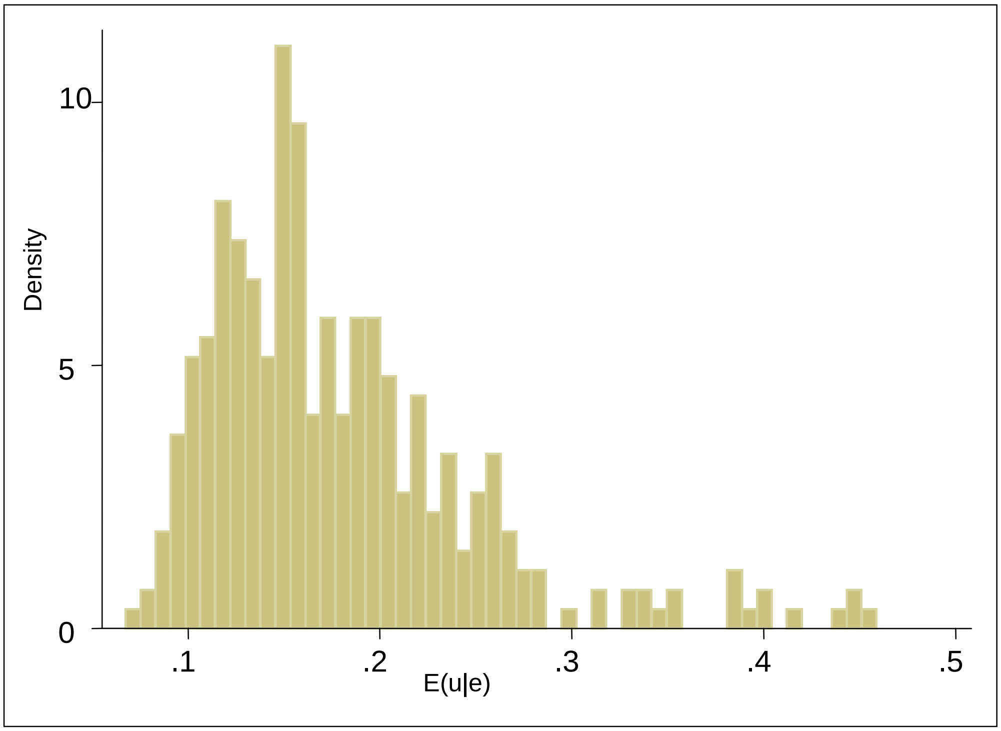
The management variable has negative coefficient which means that better management reduces mean inefficiency. Note that $E(u) = \sqrt{2/\pi}\,\sigma_u(z)$. Thus if z affects σ_u negatively, the mean inefficiency is reduced when z is increased. In the present case, management reduced mean inefficiency by 3.6%. Similarly, age of the farmers and the ownership are found to reduce variability in output, ceteris paribus. On the other hand, management increases variability in output. The average technical inefficiency of farms in the sample is 0.18. That means, output is reduced, on average, by 18% due to technical inefficiency. In Figure 2 we report the frequency distribution of the estimates of technical inefficiency. It can be seen from the figure that technical inefficiency estimates for most of the farms are within the 10%- 25% range. Output loss due to inefficiency can be obtained from the last column of Table 2, viz., from 1-TE.

Table 3 Parameter estimates of the frontier model (second stage)

variable	coefficient estimate	t-value
Frontier		
const	0.18	3.14
σ_u *function*		
const	-3.04	-4.79
q^{manag}	-0.40	-1.90
σ_v *function*		
const	-2.38	-15.22
q^{age}	-0.18	-1.82
q^{own}	-0.26	-2.56
q^{manag}	0.37	3.25

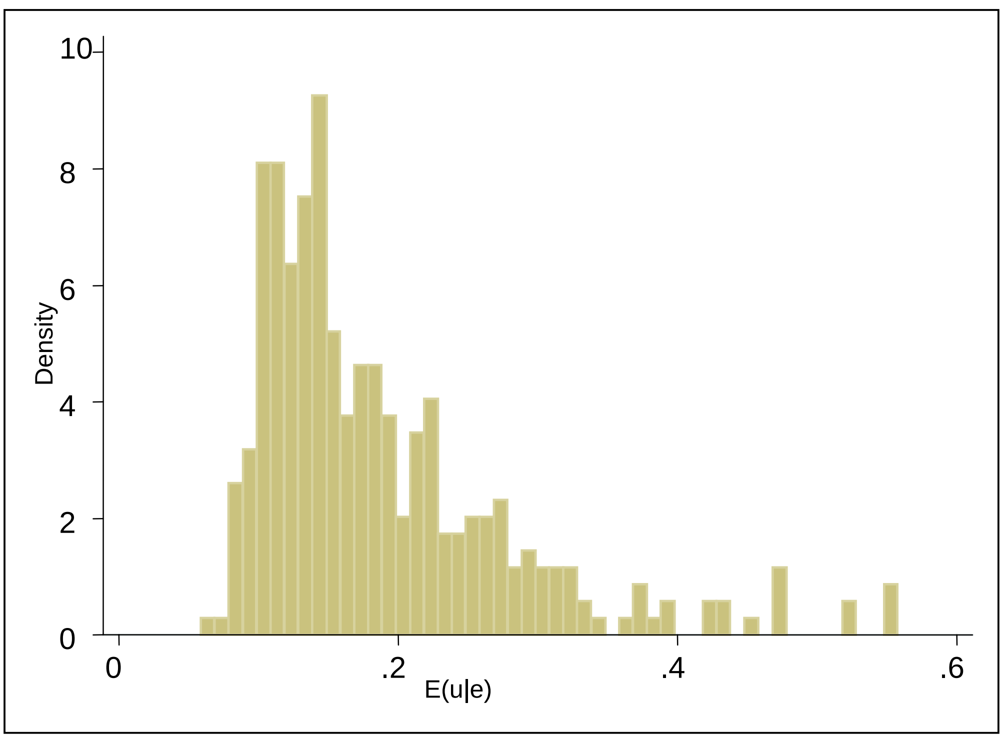
Source: Authors' own estimations.

We also estimated a model in which systematic allocative optimization errors are allowed. Ownership, management and risk variables are used to explain such systematic errors (means of the error terms in the share equations). The mean output loss due to expenditure constraints is found to be quite similar. For brevity, here we report only efficiency results which are also quite similar (the mean value) from the previous model. The entire distribution is plotted in Figure 3.



Source: Authors' own estimations.

Figure 2: Distribution of technical inefficiency



Source: Authors' own estimations.

Figure 3: Distribution of technical inefficiency with systematic optimization errors.

7. Conclusions

The study applied the indirect production function approach to describe producers' output maximization problem under expenditure constraints. The indirect production function describes the maximum attainable output as a function of the availability of funds, given the price of variable inputs and the quantity of fixed inputs. By deriving conditions for the optimal input use, we determine the effect of expenditure constraints on the producer output. This allows us identifying the potential output loss due to the presence of budget constraint.

An additional source of potential output loss regarded in our analysis is technical inefficiency. To estimate technical efficiency of producers under expenditure constraints, we define IPF as the production frontier. Accordingly, the production frontier is defined as a maximum feasible output subject to a given technology, a set of quasi-fixed inputs and a given budget for the purchase of variable inputs. Thus, IPF allows explaining differences in the producers' input use by both factors - budget constraints as well as technical inefficiencies.

The empirical analysis is based on the survey data for 90 farms from three different regions in Central, South and Volga Russia for the period from 1999 to 2003. Our results show that most of the study farms were expenditure constrained during the considered period – farm actual expenditures have been on average by 13 per cent lower than their desired level. The expenditure constraints have caused on average a potential output loss of 11 per cent.

Additionally, we have found the average technical inefficiency of farms to be 18%. This indicates that even in the presence of imperfections in financial markets, Russian farms have potential for increasing their output, ceteris paribus. Finally, from a set of various farm characteristics only managerial competence has been found to determine significantly the farms' technical efficiency. This is in line with the traditional hypothesis done in the stochastic frontier analyses and shows that management is decisive for reducing technical inefficiencies.

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APPENDIX

Table A1 Descriptive statistics of the IPF variables (1999-2003)

	Output 1000 RUB	Land (hectures of sown area adjusted for soil fertility)	Capital 1000 RUB of 2003	Observed expenditure 1000 RUB	Labor wages 1000 RUB per annum	Aggregated fertilizer price 1000 RUB per tonne	Fuel price 1000 RUB per tonne	Labor cost share	Fertilizer cost share
Mean	37489	3503	52107	27378	18.48	5.43	5.81	0.25	0.07
S.D.	48535	2755	54411	29217	8.65	3.09	2.00	0.09	0.06
Min.	1440	488	295	1868	7.10	1.34	1.67	0.03	0.00
Max.	317239	13047	325205	161283	40.10	16.65	11.20	0.54	0.58

Source: Authors' own calculations.

Table A2 Description of farms' individual characteristics

Variable	Description
Farm age (q^{age})	assessed by considering the period since farm establishment, farm-head's years with the farm, average farm managers' years with the farm;
Farm size (q^{size})	assessed by considering farm agricultural area, number of employees, fixed assets and livestock;
Farm ownership structure (q^{own})	assessed by considering ownership status of the farm-head and share of the farm co-owners in the total number of farm managers.
Farm managerial competence (q^{manag})	assessed by considering share of managers with high education and personnel loyalty;
Level of initial technology (q^{tech99})	evaluated by the farm head with the scores 1 - 'technology is dated' to 5 - 'one of the most modern technologies' for 1999;
Production risk magnitude (q^{risk})	evaluated by the farm head with the scores 1 - 'low' to 5 - 'high';
Farm diversification (q^{div})	assessed by considering diversification within agriculture, use of on-farm processing and membership in a vertically-integrated holding.

Note: Most of farm characteristics are based on the farmers' evaluation of several related characteristics/indicators by using a Likert-scale;

Source: Authors' own assessment.