Technical efficiency and total factor productivity in Czech agriculture

Lukáš Čechura

Department of Economics, Faculty of Economics and Management, Czech University of Life Sciences Prague, Prague, Czech Republic

Abstract: The paper deals with the analysis of technical efficiency and the total factor productivity (TFP) in Czech agriculture. The aim is to identify the key factors determining the efficiency of input use and the TFP development. The Fixed Management model is used for the estimation of technical efficiency and the construction of TFP for the total agriculture and its individual branches. The results show that technical inefficiency is an important phenomenon in Czech agriculture and its individual branches. The TFP development is determined by all components, i.e., technical efficiency, scale effect, technological change and management. Their contributions differ intrasectorally and intersectorally, and also in time. Finally, the developments in the individual branches are characterized by idiosyncratic factors, as well as the systemic effect, especially in the animal production. The most important factors which determine both technical efficiency and TFP are the factors connected with institutional and economic changes, in particular a dramatic increase in the imports of meat and increasing subsidies.

Key words: technical efficiency, technology, heterogeneity, total factor productivity (TFP), Fixed Management model and agriculture

Czech agriculture experienced a couple of institutional and economic changes in the last two decades. The most important one is the accession to the European Union and the accompanying implementation of the CAP principles. These changes had a significant influence on the performance, structure and size of Czech agriculture. With regard to this, an important question arises: are Czech farmers taking advantage of the opportunities of the CAP and the common market or are they falling behind? This paper shows the development of the performance of Czech agriculture and its branches, and identifies the factors which determine the successes and failures of the growth of Czech agriculture since the EU accession. In particular, the paper focuses on the development of technical efficiency and the total factor productivity (TFP) and their components in the period 2004–2007.

The following questions will be elaborated. The first relates to the technical change and technical efficiency. The aim is to identify whether agriculture is following a path of sustainable development, characterized by the adoption of innovation and the reduced waste of resource due to the inefficient input use. The second concerns productivity development. The aim is to identify the key factors which determine the productivity development in Czech agriculture. The last question concerns the sector-specific development. The aim is to assess whether the branches are determined by the same factors or whether idiosyncratic developments have occurred.

These questions will be elaborated by estimating a joint stochastic frontier production function model for Czech agriculture. Then, the estimates are used to construct the TFP. Furthermore, the TFP and technical efficiency are broken down into their individual components.

Technical efficiency in Czech agriculture has been analyzed by several authors, e.g., Hughes (1999), Mathijs et al. (1999a, b, 2001), Curtiss (2002), Juřica et al. (2004), Jelínek (2006), Medonos (2006) and Čechura (2009, 2010). We complement these studies with an analysis of technical efficiency and the TFP development, as well as their determining factors, since the Czech Republic accession to the EU.

MATERIAL AND METHODS

The estimation of a stochastic frontier production function model for Czech agriculture follows Čechura (2010). Čechura (2010) showed that the presence of

Supported by the Ministry of Education, Youth and Sports of the Czech Republic (Projects No. MSM 6046070906).

a significant firm heterogeneity overestimates the technical inefficiency. Considering both the theoretical criteria of the production function and significant firm heterogeneity, the author suggests using the Fixed Management model for the measurement and analysis of technical efficiency. This paper will use the same data set, and therefore the Fixed Management model, in the analysis of technical efficiency; the total factor productivity development is considered to be a proper choice. That is, we will re-estimate the Fixed Management model and will use it in the construction of TFP (see also Čechura 2009)[1].

The analysis is based on the assumption that the production possibilities can be approximated by a frontier production function which has the translog form (as in Čechura 2010). The details of the fitted Fixed Management model are provided in the following section, followed by the information about the construction of TFP.

Fixed Management model

Álvarez et al. (2003 and 2004) specified the Fixed Management model as a special case of the Random Parameters model in the following form:

$$\ln TE_{it} = \ln f(t, \mathbf{x}_{it}, m_i; \boldsymbol{\beta}) - \ln f(t, \mathbf{x}_{it}, m_i^*; \boldsymbol{\beta}) \leq 0$$

$$\ln TE_{it} = -u_{it} \quad (1)$$

and

$$\ln y_{it} = \ln y_{it}^* + v_{it} - u_{it} = \ln \alpha_0 + \ln f(t, \mathbf{x}_{it}, m_i^*; \boldsymbol{\beta}) + v_{it} - u_{it} =$$

$$= \alpha_0 + \beta_m m_i^* + \frac{1}{2}\beta_{mm} m_i^{*2} + (\beta_t + \beta_{tm} m_i^*) t + \frac{1}{2}\beta_{tt} t^2 +$$

$$+ (\beta_x + \beta_{xt} t + \beta_{xm} m_i^*)' \ln \mathbf{x}_{it} + \frac{1}{2} \ln \mathbf{x}_{it}' \mathbf{B}_{\mathbf{xx}} \ln \mathbf{x}_{it} + v_{it} - u_{it} \quad (2)$$

where $\mathbf{x}_{it}$ is a vector of inputs containing $K = 4$ production factors – Labour (A_{it}), Capital (C_{it}), Land (L_{it}) and Material (M_{it}). Indices i, where $i = 1, 2,..., N$, and t, where $t \in \Im(i)$, refer to a particular agricultural company and time, respectively, and $\Im(i)$ represents a subset of years T_i from the whole set of years T (1, 2,...,T), for which the observations of the i-th agricultural company are in the data set (see unbalanced panel). α is an intercept (productivity parameter). **β** are parameters to be estimated that determine the production function f. Technical efficiency, $TE_{i(t)}$, with $0 \leq TE_{i(t)} \leq 1$, captures the deviations from the maximum achievable output. v_{it} is the random error and $u_{i(t)}$ is the inefficiency term. The random error (statistical noise) v_{it} and the technical inefficiency term $u_{i(t)}$ of the stochastic frontier production function model are assumed to be $v_{it} \sim iid\ N(0, \sigma_v^2)$, $u_{i(t)} \sim iid\ N^+(0, \sigma_u^2)$ and to be distributed independently of each other, and of the regressors (for further references see Kumbhakar and Lovell 2000). $m_i^* \sim \bullet(0,1)$ represents the unobservable fixed management. The symbol $\bullet$ expresses that m_i^* could possess any distribution with zero mean and unit variance (see Hockmann and Pieniadz 2008). The difference between the real (m_i) and optimal (m_i^*) management determines the level of technical efficiency /see relation (1)/. Technical efficiency is defined by:

$$\ln TE_{it} = \gamma_0 + \gamma_t t + \boldsymbol{\gamma}_{\mathbf{x}}' \ln \mathbf{x}_{it} \quad (3)$$

where $\gamma_0 = \beta_m (m_i - m_i^*) + \frac{1}{2}\beta_{mm}(m_i^2 - m_i^{*2})$

$$\gamma_t = \beta_{tm}(m_i - m_i^*)$$

$$\boldsymbol{\gamma}_{\mathbf{x}} = \boldsymbol{\beta}_{xm}(m_i - m_i^*)$$

Thus, the technical efficiency consists of three components:

(i) time-invariant, firm specific effect – management – γ_0,

(ii) interaction of m^* with time – technological change – γ_t,

(iii) interaction of m^* with the inputs quantity and quality – scale effect – $\boldsymbol{\gamma}_{\boldsymbol{x}}$.

Álvarez et al. (2004) showed that u_{it} can be estimated, according to Jondrow et al. (1982), as (4) with simulated m_i^* according to relation (5).

$$E[u_{it} | \varepsilon_{it}, m_i^*] = \frac{\sigma\lambda}{(1+\lambda^2)} \left[\frac{\varphi(-(\varepsilon_{it}|m_i^*)\lambda/\sigma)}{\Phi(-(\varepsilon_{it}|m_i^*)\lambda/\sigma)} - \frac{(\varepsilon_{it}|m_i^*)\lambda}{\sigma} \right] \quad (4)$$

where

$\lambda = \frac{\sigma_u}{\sigma_v}$, $\lambda = \frac{\sigma_u}{\sigma_v}$ and $\varepsilon_{it} = v_{it} - u_{it}$

$$\hat{E}[m_i^* | \mathbf{y}_i, \mathbf{X}_i, \boldsymbol{\delta}] = \frac{\frac{1}{R}\sum_{r=1}^{R} m_{i,r}^* \hat{f}(\mathbf{y}_i | t, m_{i,r}^*, \mathbf{X}_i, \boldsymbol{\delta})}{\frac{1}{R}\sum_{r=1}^{R} \hat{f}(\mathbf{y}_i | t, m_i^*, \mathbf{X}_i, \boldsymbol{\delta})} \quad (5)$$

The Fixed Management model is fitted with a maximum simulated likelihood in the computer program NLOGIT version 4.0 – LIMDEP version 9.0 (Green 2007). In the model, all variables are divided by their

[1]The estimated model and its application is a part of the comprehensive study of productivity and efficiency in Czech agrarian sector introduced in Čechura (2009).

geometric mean. That is, fitted coefficients represent the production elasticities evaluated on the geometric mean of a particular variable.

Total factor productivity

The total factor productivity is calculated in the form of the Törnqvist-Theil index (TTI) (see, e.g., Čechura and Hockmann 2010). The Törnqvist-Theil index exactly determines the changes in production resulting from input adjustments having a production function the translog form (for the proof see Diewert 1976). Furthermore, Caves et al. (1982) show the TTI extension for the multilateral consistent comparisons.

The index is constructed as the deviation from the sample means. The input index for the variable return to scale (VRS), or the constant return to scale (CRS), respectively, is given by:

$$\ln \iota_{it}^{VRS} = \frac{1}{2}\sum_{j=1}^{K}\left[\left(\varepsilon_{it,j_0} + \varepsilon_j\right)\left(\ln x_{it,j} - \overline{\ln x_j}\right) + \right.$$
$$\left. + \varepsilon_j \overline{\ln x_j} - \overline{\varepsilon_{it,j_0} \ln x_{it,j}}\right]$$

$$\text{with} \quad \varepsilon_{it,j_0} = \frac{\partial \ln f\left(t, x_{it,j}; \boldsymbol{\beta}\right)}{\partial \ln \mathbf{x}_{it,j}} \tag{6}$$

resp.

$$\ln \iota_{it}^{CRS} = \frac{1}{2}\sum_{j=1}^{K}\left[\left(\frac{\varepsilon_{it,j_0}}{\sum_{i=1}^{K}\varepsilon_{it,j_0}} + \frac{\varepsilon_j}{\sum_{i=1}^{K}\varepsilon_{j_0}}\right)\left(\ln x_{it,j} - \overline{\ln x_j}\right) + \right.$$
$$\left. + \frac{\varepsilon_j}{\sum_{i=1}^{K}\varepsilon_{j_0}}\overline{\ln x_j} - \overline{\frac{\varepsilon_{it,j_0}}{\sum_{i=1}^{K}\varepsilon_{it,j_0}}\ln x_{it,j}}\right] \tag{7}$$

A bar over a variable specifies the arithmetic mean over all observations. If no aggregation is needed, i.e., only the development of one variable is depicted, the index simplifies into the deviation from the mean of the variables. That is, the output index and efficiency index are:

$$\ln \psi_{it} = \ln y_{it} - \overline{\ln y_{it}} \quad \text{and} \quad \ln \upsilon_{it} = \ln TE_{it} - \overline{\ln TE_{it}} \tag{8}$$

Since TFP is a combination of scale effect, technical efficiency effect, technological change effect and management effect, the required indices are defined:

$$\ln \tau_{it} = \frac{1}{2}\left[\left(\varepsilon_t + \bar{\varepsilon}_t\right)\left(t - \bar{t}\right) + \bar{\varepsilon}_t \bar{t} - \overline{\varepsilon_t t}\right]$$

$$\text{with} \quad \varepsilon_t = \frac{\partial \ln f\left(x_{it,j}, t, m_i\right)}{\partial t} \tag{9}$$

$$\ln \mu_{it} = \frac{1}{2}\left[\left(\varepsilon_{m_0} + \varepsilon_m\right)\left(m_i - \bar{m}_i\right) + \varepsilon_m \bar{m}_i - \overline{\varepsilon_m m_i}\right]$$

$$\text{with} \quad \varepsilon_m = \frac{\partial \ln f\left(x_{it,j}, t, m_i\right)}{\partial m_i} \tag{10}$$

Using these definitions, TFP and its breakdown is given by:

$$\ln TFP_{it} = \ln \psi_{it} - \ln \iota_{it}^{CRS} = \underset{SE}{\ln \iota_{it}} + \underset{TE}{\ln \upsilon_{it}} + \underset{TCH}{\ln \tau_{it}} + \underset{MAN}{\ln \mu_{it}}$$

$$\text{with} \quad \ln \iota_{it} = \ln \iota_{it}^{VRS} - \ln \iota_{it}^{CRS} \tag{11}$$

Changes in TFP can be expressed either as a ratio (on the mean) of the output and input index (for CRS) or as a multiplication of the TFP components, i.e., scale effect (SE), technical efficiency effect (TE), technological change effect (TCH) and management effect (MAN).

Data set

Since the same panel data set is used in Čechura (2010), the data description provides only basic information.[2] The panel data set is drawn from the database of the Creditinfo Firms' Monitor, collected by the Creditinfo Czech Republic, s.r.o. The database contains all registered companies and organisations in the Czech Republic.

Since the Creditinfo database does not contain information about the quantity of land employed in the production of a particular agricultural company, the database LPIS is used for the input factor Land. Price indices and the regional wages are drawn from the Czech Statistical Office. The source of the official land prices is a study by Němec et al. (2006).

The analysis uses information from the final accounts of the companies whose main activity is agriculture, according to the OKEČ classification (OKEČ 01). Therefore, the analysis concerns agricultural companies, i.e., corporations. Since not all information can be found for all agricultural companies in the database, only those companies having two or more final accounts in the database over the period 2004–2007 are used; non-zero and positive values are used for the variable of interest. In addition, outliers were removed. After the cleaning process,

[2]For a detailed description of the employed data set see Čechura (2010).

the unbalanced panel data set contains 1004 agricultural companies with 3103 observations, covering the period from 2004 to 2007, i.e., 3.09 observations per company in average.

The following variables, as defined above, are used in the analysis: Output, Labour, Land, Capital and Material. Output is represented by the total sales of goods, products and services of the agricultural company. Output was deflated by the index of agricultural prices (2005 = 100). The Labour input is the total personnel costs per company, divided by the average annual regional wage in agriculture (region = NUTS 3). The total quantity of land employed in the production process of a particular agricultural company is adjusted by the land quality. Land quality is expressed as the ratio of the official land price of the j-th region to the maximal official regional land price. That is, the total quantity of land employed in the production process of the i-th company was multiplied by the quality index of the region to which the company belongs. Capital is represented by the book value of tangible assets and it is deflated by the index of processing (industry) prices (2005 = 100). Finally, the Material variable is used in the form of the total costs of material and energy consumption per company, and it is deflated by the index of processing prices (2005 = 100).[3]

The development indicators show (see Čechura 2010) that the average growth rate of the output as well as all inputs is negative in the data set. Despite this, labour productivity, land productivity, land intensity and capital intensity in the sample increased in the period from 2004 to 2007. This suggests that agricultural companies are subject to substantial adjustment processes regarding the structure of production factors.

RESULTS

Parameter estimates

First, the results of parameter estimates are discussed. The estimated production elasticities (Table 1) satisfy the criterion of both monotonicity and quasi-concavity, i.e., the elasticities are positive and the diminishing marginal productivity for each input was estimated ($\beta_{rr} + \beta_r^2 - \beta_r < 0$, for $r = A, L, C$ and M). That is, the estimates are consistent with the economic theory (at least on the sample mean).

Production elasticities were also found to be robust under different model specifications (see Čechura 2010). Material has the highest impact on production, with production elasticities (β_M) 0.63419, which is also consistent with the empirical observations. Labour elasticity (β_A) is 0.227, which corresponds to the ratio of personnel costs to the total output. The production elasticity of Land is at the same level as the elasticity of Capital. However, Capital determines production with a lower intensity than we would expect. This might be caused by two factors that work together. Since we are working with accounting data, the variable Capital does not contain the information about leasing. However, leasing is an important source of capital in Czech agriculture. Its role is reinforced by the imperfections in the Czech capital market.

Technical change has a positive impact on production; however, it decelerates over time. The hypothesis that the parameters are time-invariant (H_0: $\beta_T = \beta_{TT} = \beta_{AT} = \beta_{LT} = \beta_{CT} = \beta_{MT} = 0$)[4] was rejected at a 5% level of significance. Moreover, the null hypothesis about the Hicks neutral technological change (H_0: $\beta_{AT} = \beta_{LT} = \beta_{CT} = \beta_{MT} = 0$)[5] was rejected as well. The technological progress was Material using and Labour, Land and Capital saving.

Furthermore, the z-test and LR test reject the null hypothesis about the statistical insignificance of the parameter lambda (LR = 1941.66; critical value $'\text{mixed}'\chi^2_{1-0,025}(1) = 2.71$). Thus, the value of the parameter suggests that the variation in the u_{it} is more pronounced than the variation in the random component v_{it}. 2.48 implies that efficiency differences among firms are an important reason for variations in production.

The monotonicity requirements on management imply that the first derivatives of the production function with respect to management are positive for all companies, i.e., $\frac{\partial y_{it}}{\partial m_i} > 0$. The level of the actual management, m_i, is unknown and must be calculated. Relation (3) was used for the calculation of the actual management for each company. The results show that an increase in management implies an increase in production for all companies. Thus, the estimates are consistent with the economic theory.

Coefficients of the unobservable fixed management (β_m, β_{mm}, β_{Am}, β_{Cm}, β_{Mm}) are statistically different from zero, even at a 1% significance level. This can be regarded as an evidence of correctly choosing the Random Parameter model as opposed to the

[3]For the basic descriptive statistics of the employed variables see Čechura (2010).

[4]LR test: FM model (LR = 1399.69); $\chi^2_{1-0.05}(6) = 12.592$.

[5]LR test: FM model (LR = 16.828); $\chi^2_{1-0.05}(4) = 9.488$.

Table 1. Parameter estimates

Variable	Fixed Management model						
	coefficient	std. error	$P[\|Z\| > z]]$	variable	coefficient	std. error	$P[\|Z\| > z]$
Means for random parameters				TT	−0.03485	0.00322	0.00000
Constant	0.07224	0.00306	0.00000	AT	−0.00442	0.00187	0.01790
A	0.22737	0.00421	0.00000	LT	−0.00960	0.00250	0.00010
L	0.05479	0.00315	0.00000	CT	−0.00344	0.00160	0.03140
C	0.05410	0.00321	0.00000	MT	0.01578	0.00300	0.00000
M	0.63419	0.00442	0.00000	AA	0.05010	0.00174	0.00000
T	0.00657	0.00163	0.00010	LL	0.01481	0.00490	0.00250
Coefficient on unobservable fixed management				CC	0.02900	0.00205	0.00000
Beta_m	0.13525	0.00149	0.00000	MM	0.07671	0.00702	0.00000
A	−0.02641	0.00263	0.00000	AL	−0.04235	0.00416	0.00000
L	−0.00236	0.00196	0.22860	AC	−0.02497	0.00267	0.00000
C	0.01910	0.00204	0.00000	AM	0.03161	0.00489	0.00000
M	−0.07300	0.00292	0.00000	LC	0.04565	0.00291	0.00000
T	0.00051	0.00152	0.73600	LM	−0.03866	0.00410	0.00000
Beta_mm	−0.04207	0.00195	0.00000	CM	−0.03597	0.00369	0.00000
Log likelihood function		2 103.539		Lambda	2.47794	0.13604	0
No. of parameters		30		Sigma	0.1397	0.00167	0
Sigma v		0.05228		Sigma v		0.12955	

Source: own calculations

conventional stochastic frontier approach. Since the coefficients of the unobservable fixed management for Land and Technological Change are not statistically different from zero, this implies that Land and Technological Change did not contribute to the change in the management productivity in the analyzed period (see $\beta_{Lm} = 0$, $\beta_{Tm} = 0$). Then, the positive sign on management $\beta_m > 0$ and the negative on squared management $\beta_{mm} < 0$ implies that the management determines production positively (see monotonicity)

Table 2. Production elasticities with optimal (m_i^*) and actual management (m_i)

	Production elasticities with	
	m_i^*	m_i
A	0.22872	0.24482
L	0.05557	0.05701
C	0.05282	0.04117
M	0.63853	0.68304
RTS	0.97563	1.02604

RTS = Returns to Scale

Source: own calculations

but with a decreasing effect. The increase in management causes the increase in the production elasticity and the marginal productivity of inputs – Labour, Land and Material (see $\beta_{Am} < 0$, $\beta_{Lm} < 0$, $\beta_{Mm} < 0$), and the decrease in the production elasticity and marginal productivity of Capital ($\beta_{Cm} > 0$).

The interpretation of the coefficients of the unobservable fixed management (β_m, β_{mm}, β_{rm}, where $r = A, L, C, M, T$) can be reformulated for the relation management and technical efficiency. Since the technical efficiency of the i-th company at time t depends on the level of input factors entering production, the technical efficiency change resulting from the unit change in management depends on the utilization of the individual inputs (see Álvarez et al. 2004). The change in technical efficiency resulting from the change in management and in inputs is given by:

$$\frac{\partial \ln TE_{it}}{\partial m_i} = \beta_m + \beta_{mm} m_i + \beta_{tm}\mathbf{t} + \boldsymbol{\beta}_{xm}\mathbf{lnx}_{it}$$

$$\frac{\partial \ln TE_{it}}{\partial \mathbf{lnx}_{it}} = \boldsymbol{\beta}_{xm}\left(m_i - m_i^*\right) \text{ and } \frac{\partial \ln TE_{it}}{\partial t} = \beta_{tm}\left(m_i - m_i^*\right) \quad (12)$$

It follows from (12) together with $\beta_m > 0$ and $\beta_{mm} < 0$, that the increase in m_i has a positive but decreasing

Table 3. Production elasticities (with m_i^*) and Returns to Scale* (RTS)

	OKEČ				
	1000 – Agriculture	1100 – PlP	1200 – AnP	1300 – CoP	1400 – OtP
A	0.22872	0.22154	0.26606	0.22879	0.21558
L	0.05557	0.05636	0.04432	0.05547	0.06566
C	0.05282	0.04500	0.00781	0.05464	0.03762
M	0.63853	0.60450	0.68209	0.64094	0.60444
RTS	0.97563	0.92739	1.00027	0.97984	0.92330

*The calculations are carried out on the sample mean of the given branch, i.e., for the average company in the branch

Source: own calculations

effect on technical efficiency. Moreover, the higher is the level of the inputs Labour, Land and Material, the higher is the technical efficiency for the given level of management, m_i. Capital inputs have a converse effect, i.e., an increase in Capital causes a decrease in technical efficiency, ceteris paribus. This may imply unused capacities of large agricultural companies.

The impact of management on production elasticities can be considered with both the optimal management (m_i^*), i.e. on the production frontier, and the actual management (m_i) according to relation (13).

$$\frac{\partial \ln y_{it}^{(*)}}{\partial \ln x_{rit}} = \beta_r + \beta_{rm} m_i^{(*)} + \beta_{rt}\mathbf{t} + \sum_l \beta_{rl} \ln x_{lit}$$

for r and $l = A, L, C, M$ (13)

Table 2 presents production elasticities with the optimal and actual management calculated on the mean of the sample according to relation (13). The production elasticities with the optimal management (m_i^*), i.e., on the production frontier, are very close to the means of random parameters (see Table 1). This is especially due to the fact that the coefficients of the unobservable fixed management (β_{rm}, for $r = A, L, C, M$) are very low compared to the means of random parameters. In addition, the mean of the optimal management is close to zero, –0.07434. Since the mean of the actual management is –0.68413, production elasticities calculated with the actual management differ compared to the means of random parameters. In particular, the production elasticity of Material increased significantly. On the other hand, the production elasticity of Land is nearly identical for both with and without management. Labour and Capital elasticities changed only slightly.

The sum of production elasticities with optimal management is equal to 0.97563, and with the actual management to 1.02604. That is, for an average company in the full sample, there is no indication of the economies of scale for both optimal and actual management, since the sum of the elasticities is about one. However, the situation is different for the individual branches. Table 3 provides information about the production elasticities in animal production (AnP), plant production (PlP), combined production (CoP) and other production (OtP). The average company in the plant production has decreasing returns to scale (0.92739), and so does the average company in other production (0.92330). This suggests that the impact of the scale effect on a productivity change could be relatively high when compared to animal and combined production. There is no indication of the economies of scale for the average company in animal and combined production. However, Table 4 shows that the differences among companies are large in all branches.

Finally, if management is considered to be a production factor, there is a dramatic change in the

Table 4. Descriptive statistics of Returns to Scale

OKEČ	Mean	Std. Dev.	Minimum	Maximum	Cases
1000	0.97563	0.07443	0.60797	1.20354	2 999
1100	0.92739	0.07619	0.79055	1.14261	202
1200	1.00027	0.08236	0.77515	1.20065	58
1300	0.97984	0.07210	0.60797	1.20354	2 676
1400	0.92330	0.08056	0.71804	1.05659	57

Source: own calculations

economies of scale. The direct effect of management is given by:

$$\frac{\partial \ln y_{it}^{(*)}}{\partial m_i^*} = \beta_m + \beta_{mm} m_i^{(*)} + \beta_{tm}\mathbf{t} + \boldsymbol{\beta}_{xm}\mathbf{lnx}_{it} \qquad (14)$$

For the average company in the full sample, the direct effect of management is 0.14022 for the optimal management and 0.16587 for the actual management. This suggests that if management enters the production function as a production factor, the agricultural company has increasing returns to scale. However, the interpretation of marginal values of management is difficult, since management does not have explicitly defined units. On the other hand, the results suggest that management might be considered to be an important determinant of agricultural production.

Technical efficiency development

The development of technical efficiency and its components for agriculture and its sectors is shown in Figure 1. We may observe that the development of efficiency in Czech agriculture was considerably volatile for the years 2004–2007. Technical efficiency increased in 2005 and decreased in the following year. In 2007, the level of technical efficiency returned to roughly the level it had in 2004. To be precise, technical efficiency experienced only a small increase in the analysed period, compared to the years 2004 and 2007.

The rather random development in technical efficiency might be a result of adjustment processes connected with the accession to the EU since it can be expected that important changes in the institutional and economic environments demanding adjustments in the organisational structure and structure of inputs of agricultural companies have had a negative impact on technical efficiency. This and the other factors determining the development of technical efficiency are identified based on the breakdown of technical efficiency into its components.

The breakdown shows that the development of technical efficiency and its variability was especially determined by the management and scale effects. Technological change did not contribute significantly to the efficiency development in the analyzed period. However, its constant trend, together with the symmetry of technical change distribution, suggests that the gap between the best and worst agricultural companies did not change within the analyzed period. The negative impact of management could be connected with the entrance of the Czech Republic into the EU in 2004. The positive scale effect might be a result of the positive impact of weather. The yield in almost all branches of plant production was close to record values. The other years were also significantly predetermined by the impact of weather, on the qualitative side of production as well as the quantitative side. In particular, production in 2006 was negatively influenced by the extreme weather.

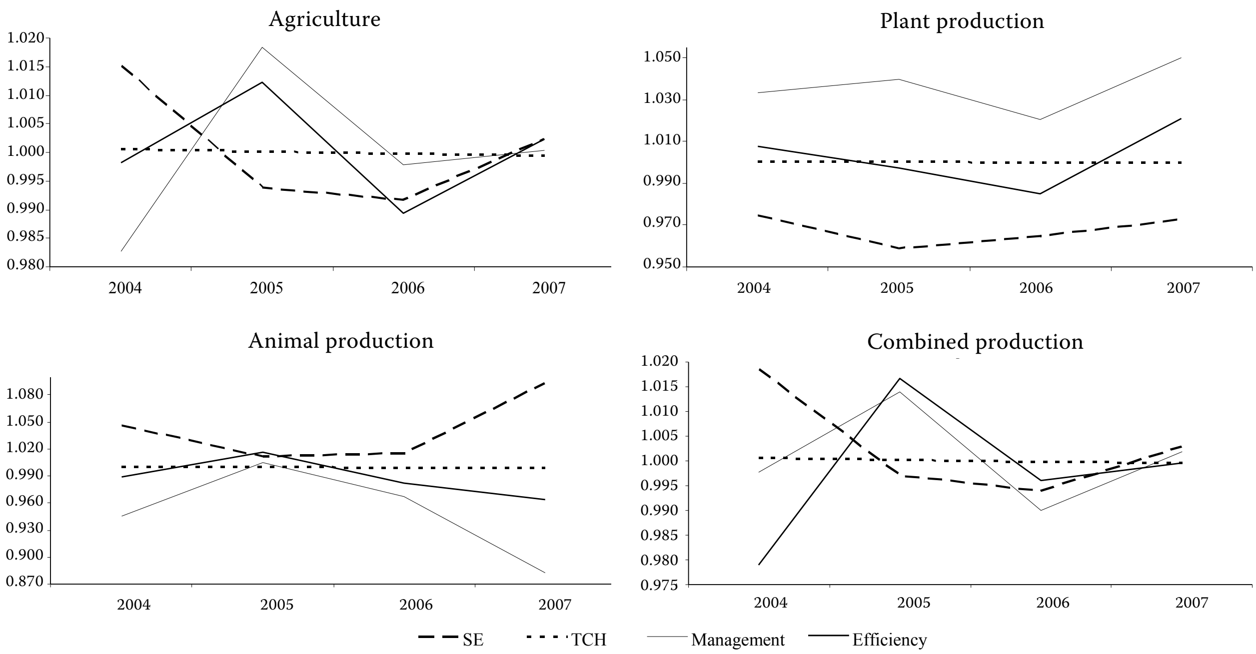

Figure 1. Technical efficiency development in agriculture and by its sectors

Source: own calculations

Moreover, Figure 1 shows the development of technical efficiency by sectors. Technical efficiency in plant production stagnated between 2004 and 2007. The development was given by the management and scale effects. The positive effect of management suggests that the companies specialized in plant production adjusted better to the institutional and economic changes, and hence could be more competitive in the market compared to producers in animal or combined production. Moreover, the impact of weather, especially the negative impact in 2006, was not so strong in this sector compared to combined production. On the other hand, the negative scale effect, which is the result of the estimated decreasing returns to scale, suggests that the companies are producing at a higher than the optimal scale.

Technical efficiency in animal production entered a decreasing trend in 2005. This trend was significantly determined by management. Both the management and scale effects reflect the situation in the market. The growing imports of meat, which were not compensated by exports, resulted in the increasing competition in the domestic market. This can be observed beginning from the year 2005. However, the surplus of supply over demand was remarkably large in 2007. The decrease in production that resulted from a decline in competitiveness of Czech agricultural companies and potentially Czech food producers brought about a decrease in technical efficiency, since agricultural companies were left with unused capacities. The decrease in production can be observed from the increase of the scale effect and the decrease of the management effect.

The development of technical efficiency in combined production is almost identical to the development in the agricultural sector as a whole. That is, the same factors which determine the level of technical efficiency could be mentioned (see above). Combining the results, we may state that the technical efficiency of companies with combined production is determined by the same factors as in specialized companies. The diversification of production can decrease the negative effects of those factors which determine animal or plant production. On the other hand, the adjustment processes have a negative impact on technical efficiency and may cause its development to be volatile.

TFP development

Figure 2 shows the development of TFP in agriculture and by its sectors. TFP for the total agriculture increased between the years 2004 and 2005; however, it entered a decreasing trend in 2005. Combined production experienced the same development. TFP in plant production grew during the whole period, as opposed to animal production. The sector of animal production experienced a significant decrease in TFP in the last year of the analyzed period.

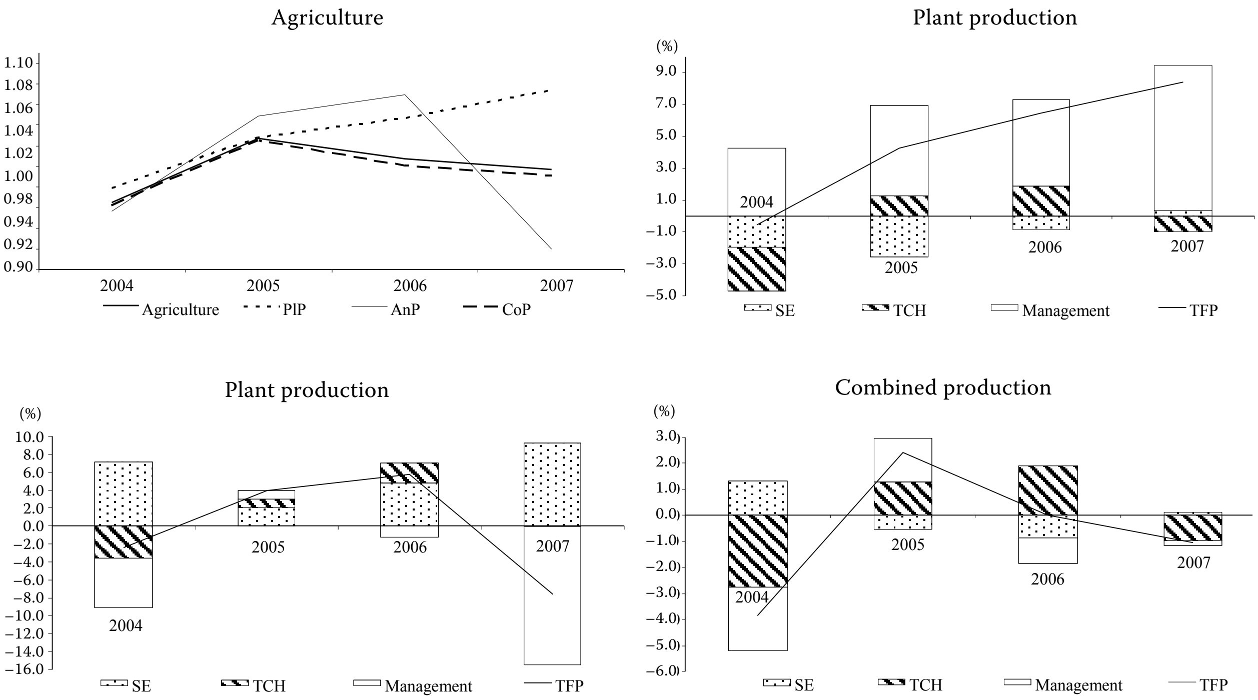

Figure 2. TFP development in agriculture and by its sectors

Source: own calculations

The figures for the individual sectors show the breakdown of TFP into its individual components. The technical efficiency component is not explicitly shown. Since technical efficiency was analyzed in the previous section, we broke it down, and its components added up to the remaining components of TFP, i.e., the scale effect, technological change and management.

We may observe that all components in plant production contributed to the increasing trend in the last year, except for technological change. The development of TFP shows the increasing competitiveness of specialized agricultural companies, which is consistent with the results in the previous section. The negative impact of the scale effect is again a result of the estimated decreasing returns to scale. However, we may observe that agricultural companies are getting closer to the optimal level of scale. In addition, the increase in TFP might be a sign of the positive effects of subsidies in this sector, since subsidies contribute to the competitiveness of producers.

TFP in animal production showed an increasing trend until 2006. This was primarily a result of the positive impact of the technological change and the scale effect. The most important year in the development is the last year. The dramatic drop in the TFP level was a result of all components: technical efficiency, scale effect, technological change and management effect. The drop in production that resulted from decreasing competitiveness in the domestic market was translated into the decline of not only technical efficiency, but also TFP. The calculations show that TFP would decrease even without the technical efficiency component as a result of the reduced production.

The decreasing trend of TFP in combined production since 2005 is again a result of all components. The reason for the decrease in TFP could by caused by the increasing competition in the sector of animal production, which resulted from the increasing imports. Since the producers having combined production are, in average, of different technology and technical efficiency, and they are less competitive compared to specialized producers, they might have experienced problems with competitiveness earlier compared to the specialized companies. On the other hand, since these companies can diversify their production, the drop in TFP was not as dramatic as in the case of the specialized producers.

CONCLUSIONS

In this section, we will concentrate on the questions raised in the introduction, namely those regarding the adoption of innovation and the reduced waste of resources due to the inefficient input use, identification of the key factors which determine the productivity development in Czech agriculture, and the assessment of whether the systemic or idiosyncratic developments in agriculture have occurred.

We estimated that technical change has a positive but declining impact on production. Technical progress was Material using, and Labour, Land and Capital saving. Furthermore, technical inefficiency was identified as an important phenomenon in Czech agriculture, i.e., the efficiency differences among companies are an important reason for the variations in production; this holds true for both intersectoral and intrasectoral comparisons. Moreover, we identified that management is an important factor determining production. In particular, it significantly determines the production elasticity of Material, Labour and Capital. As far as the economies of scale are concerned, we found that for the average company in the sample, there is no indication of the economies of scale. However, the situation is different for the individual branches. Whereas an average company in plant production, as well as other production, has decreasing returns to scale, the sum of production elasticities is about one for the average company in animal and combined production. In addition, the analysis shows that the differences among companies are large in all branches.

The development of technical efficiency is rather random in the total agriculture and combined production. It stagnated in plant production and experienced a decreasing trend in animal production. TFP development for the total agriculture and combined production began to decrease in 2005. Plant production showed an increasing trend for the whole analyzed period. Animal production experienced a significant drop in TFP in 2007. TFP development was influenced by all components, namely technical efficiency, scale effect, technical change and management. Their contributions differ intersectorally as well as intrasectorally. The most important factors which determine both technical efficiency and TFP were factors connected with institutional and economic changes, in particularly a dramatic increase in the imports of meat and increasing subsidies, as well as the impact of weather. Finally, we may conclude that some effects are systemic, i.e., they influence all sectors, but we also identified idiosyncratic factors, especially in animal production.

REFERENCES

Álvarez A., Arias C., Greene W. (2004): Accounting for unobservables in production models: management and inefficiency. Economic Working Papers at Centro de Estudios Andaluces E2004/72, Centro de Estudios Andaluces.

Álvarez A., Arias C., Greene W. (2003): Fixed Management and time invariant technical efficiency in a random coefficient model. Working Paper, Department of Economics, Stern School of Business, New York University.

Caves D.W., Christensen L.R., Diewert W.E. (1982): Multilateral comparisons of output, input and productivity using superlative index numbers. Economic Journal, *92*: 73–86.

Čechura L. (2009): Zdroje a limity růstu agrárního sektoru – Analýza efektivnosti a produktivity českého agrárního sektoru: Aplikace SFA (Stochastic Frontier Analysis). (Sources and Limits of Growth of Agrarian Sector – Analysis of Efficiency and Productivity of Czech Agricultural Sector: Application of SFA –Stochastic Frontier Analysis.) Wolters Kluwer ČR, Praha; ISBN 978-80-7357-493-2.

Čechura L. (2010): Estimation of technical efficiency in Czech agriculture with respect to firm heterogeneity. Agricultural Economics – Czech, 56: 36–44.

Čechura L., Hockmann H. (2010): Sources of Economical Growth in Czech Food Processing. Prague Economic Papers, (2): 169–182.

Curtiss J. (2002): Efficiency and Structural Changes in Transition: A Stochastic Frontier Analysis of Czech Crop Production. [Dissertation.] Institutional Change in Agriculture & Natural Resources. Shaker Verlag GmbH, Germany; ISBN 3832203656.

Diewert W.E. (1976): Exact and superlative index numbers. Journal of Econometrics, *4*: 115–145.

Green W. (2007): LIMDEP version 9.0 User's Manual. Econometric Software, Inc.

Hockmann H., Pieniadz A. (2008): Farm Heterogeneity and Efficiency in Polish Agriculture: A Stochastic Frontier Analysis. In: 12th Congress of the European Association of Agricultural Economists – EAAE 2008, Ghent, Belgium.

Hughes G. (1999): Total factor productivity of farms structures in Central and Eastern Europe. Bulgarian Journal of Agricultural Science, *5*: 298–311.

Jelínek L. (2006): Vztah technické efektivnosti a technologické změny v sektoru výroby mléka. (Relation between technical efficiency and technological change in milk production.) [Dissertation.] PEF ČZU. Prague.

Jondrow J. et al. (1982): On the estimation of technical inefficiency in the stochastic frontier production function model. Journal of Econometrics, *19*: 233–238.

Juřica A., Medonos T., Jelínek L. (2004): Structural changes and efficiency in Czech agriculture in the pre-accession period. Agricultural Economics – Czech, *50*: 130–138.

Kumbhakar S.C., Lovell C.A.K. (2000): Stochastic Frontier Analysis. University Press, Cambridge; ISBN 0521666635.

Mathijs E., Blaas G., Doucha T. (1999a): Organisational form and technical efficiency of Czech and Slovak Farms. MOCT-MOST, *9*: 331–344.

Mathijs E., Dries L, Doucha T., Swinnen J.F.M. (1999b): Production efficiency and organization of Czech Agriculture. Bulgarian Journal of Agricultural Science, *5*: 312–324.

Mathijs E., Tollens E., Vranken L. (2001): Contracting and Production Efficiency in Czech Agriculture. Working Paper, Catholic University of Leuven.

Medonos T. (2006): Investiční aktivita a finanční omezení českých zemědělských podniků právnických osob. (Investment activity and financial constraints of Czech agricultural companies.) [Dissertation.] PEF ČZU. Prague.

Němec J., Štolbová M., Vrbová E. (2006): Cena zemědělské půdy v České republice v letech 1993–2004. (Price of Agricultural Land in the Czech Republic in year 1993–2004.) VÚZE, Prague; ISBN 80-86671-25-9.

Arrived on 25th March 2011

Contact address:

Lukáš Čechura, Czech University of Life Sciences Prague, Kamýcká 129, 165 21 Prague 6, Czech Republic
e-mail: cechura@pef.czu.cz