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# Factors determining TFP changes in Czech agriculture

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**Abstract**: The paper deals with an analysis of the factors determining changes in the total factor productivity (TFP) in Czech agriculture. The study focuses on three important sectors – cereals, dairy and pork – and assesses the period after the accession of the Czech Republic to the EU (2004–2011). Firstly, the multiple output distance function models were estimated. Secondly, the TFP was calculated and decomposed into scale efficiency (SE), management component (MAN), technological change (TCH) and technical efficiency (TE). The results show that the TFP development was significantly determined by the TCH in each sector.

**Key words**: fixed management model, output distance function, technical efficiency, total factor productivity

Czech agriculture experienced a couple of important institutional and structural changes in the last two decades. These changes were predetermined by the accession of the Czech Republic to the European Union (EU), an event which significantly influenced the performance, structure and size of Czech agriculture (Čechura 2012) and had various impacts on specific sectors. The most dramatic changes can be found in the pork sector, where a negative trend in the pork production has been evident since 2004. The decline was caused by a combination of different factors. Gebeltová (2012) ranks the following among the most important ones: the growth in feed grain prices, a reduction in breeding sows, a decreased number of weaned piglets, smaller investment opportunities for farmers, and increased imports of the pedigree pigs, with the result that the producers had an insufficient ability to deliver large and standardized supplies of meat to meat processors.

This study focuses on three important sectors in Czech agriculture – cereals, dairy and pork – and identifies the factors determining the total factor productivity (TFP) development in these sectors in the last decade. Our research addresses the following research questions: Can we observe any common factors determining the TFP developments or did an idiosyncratic development of the TFP occur in the analysed sectors? What was the impact of the technical change and technical efficiency on this development?

Despite the fact that technical efficiency and productivity in Czech agriculture has been analysed in a number of studies (e.g. Davidová et al. 2003; Blazejczyk-Majka et al. 2011; Malá 2011; Čechura 2012; Curtiss and Jelínek 2012; Machek and Špička 2013; Machek 2014), only a few sector-specific studies can be found, and they usually suffer from a lack of data availability. Moreover, the studies are primarily focused on the dairy sector and its competitiveness (Špička 2013; Špička and Smutka 2014).

The position of the analysed sectors can be described in terms of the basic production and trade characteristics as follows. The area of agricultural land in the Czech Republic is around 4.2 mil. ha, of which 2.48 mil. ha are sown. Cereals are grown on over one half of this land (57.7%). Wheat represents one quarter of the arable land and barley 14.1%. The domestic production of cereals exhibits significant fluctuations, with a considerable growth in the years 2006 and 2012, which were characterized by the lower domestic production and higher import volume, respectively. The export volume had a positive trend during the period under consideration and increased more than 5 times over the years 1999–2012.

Milk production fluctuates around 2700 mil. litres (the average in 1998–2012 was 2694 mil. l). It declined after the entrance of the CR to the EU in 2004 and again in 2010. Measured in constant prices, a decline was recorded in 2001 and 2010. An increase

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in milk imports was accompanied by a decrease in the domestic production, which led to the significant growth in the import volume ratio during the years 1999–2008. The subsequent reduction in import volume led to the decline in the indicator under consideration until the year 2010, with a subsequent slight increase. A considerable growth in the export volume of milk can be seen in the years 2003–2008, after which the indicator exhibits a quite stable trend, with a fall in the year 2009.

Production of pigs for slaughter sharply decreased between 1998–2012. Whereas the level was almost constant between 2000–2003, the decline accelerated after 2004. In the pork sector, there was a continuous growth in the ratio of pork imports to the domestic production, which resulted from a permanent decline in the domestic production and an increase in the import volume. The export volume of pork had a positive trend during the period under consideration, with two instances of decline, in the years 2003 and 2011.

## MATERIALS AND METHODS

We assume that the production possibilities can be well approximated by the output distance function introduced by Shephard (1970). We use a translog functional form since it is flexible and provides a good approximation of the production process. Moreover, it permits the imposition of homogeneity (Coelli and Perelman 1996). The translog output distance function for 3 outputs ($y$) and 5 inputs ($x$), which is the case in our empirical application, is Equation 1 where subscripts $i$, with $I = 1, 2, \ldots, N$, and $t$, with $t = 1,\ldots, T$, refer to a certain producer and time (year), respectively. α, $\beta$ and $\gamma$ are vectors of the parameters to be estimated.

Following Lovell at al. (1994), we impose the homogeneity as Equation 2.

Introducing the statistical noise, $v_{it}$, and associating $-\ln D_{Oit}$ with the inefficiency term, $u_{it} = -\ln D_{Oit}$, we get Equation 3 where we assume $v_{it} \sim N(0, \sigma_v^2)$, $u_{it} \sim N^+(0, \sigma_u^2)$, and that they are distributed independently of each other and of the regressors (Kumbhakar and Lovell 2000).

Productivity finds its expression in the shape of (3), and thus in the parameter vectors (α, β, γ). Technological change is introduced using a trend variable ($t$). Moreover, the heterogeneity in technology is captured using a Fixed Management model. Álvarez et al. (2003 and 2004) specified the Fixed Management model as a special case of the Random Parameters model. Thus, the resulting function to be estimated is Equation 4, where $m_i^* \sim \bullet(0,1)$ represents the unobservable fixed management. The symbol • expresses that $m_i^*$ could possess any distribution with zero mean and unit variance. The difference between the real ($m_i$) and optimal ($m_i^*$) management determines the level of technical efficiency.

We fitted the Fixed Management model by the maximum simulated likelihood in the SW NLOGIT 5.0 and estimated the technical efficiency according to Jondrow at al. (1982).

$$D_{0it} = \alpha_0 + \sum_{m=1}^{3}\alpha_m \ln y_{mit} + \frac{1}{2}\sum_{m=1}^{3}\sum_{n=1}^{3}\alpha_{mn}\ln y_{mit}\ln y_{nit} + \sum_{k=1}^{5}\beta_k \ln x_{kit} + \\ + \frac{1}{2}\sum_{k=1}^{5}\sum_{l=1}^{5}\beta_{kl}\ln x_{kit}\ln x_{lit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{n=1}^{3}\gamma_{km}\ln x_{kit}\ln y_{mit} \qquad (1)$$

$$\ln D_{0it} - \ln y_{1it} = \alpha_0 + \sum_{m=2}^{3}\alpha_m \ln y^*_{mit} + \frac{1}{2}\sum_{m=2}^{3}\sum_{n=2}^{3}\alpha_{mn}\ln y^*_{mit}\ln y^*_{nit} + \sum_{k=1}^{5}\beta_k \ln x_{kit} \\ + \frac{1}{2}\sum_{k=1}^{5}\sum_{l=1}^{5}\beta_{kl}\ln x_{kit}\ln x_{lit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{m=2}^{3}\gamma_{km}\ln x_{kit}\ln y^*_{mit} \qquad (2)$$

$$\text{where } y^*_{mit} = \frac{y_{mit}}{y_{1it}}$$

$$-\ln y_{1it} = \alpha_0 + \sum_{m=2}^{3}\alpha_m \ln y^*_{mit} + \frac{1}{2}\sum_{m=2}^{3}\sum_{n=2}^{3}\alpha_{mn}\ln y^*_{mit}\, ln y^*_{nit} + \sum_{k=1}^{5}\beta_k \ln x_{kit} \\ + \frac{1}{2}\sum_{k=1}^{5}\sum_{l=1}^{5}\beta_{kl}\ln x_{kit}\ln x_{lit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{m=2}^{3}\gamma_{km}\ln x_{kit}\ln y^*_{mit} + u_{it} + v_{it} \qquad (3)$$

$$-\ln y_{1it} = \alpha_0 + \sum_{m=2}^{3}\alpha_m \ln y^*_{mit} + \frac{1}{2}\sum_{m=2}^{3}\sum_{n=2}^{3}\alpha_{mn}\ln y^*_{mit}\ln y^*_{nit} + \sum_{k=1}^{5}\beta_k \ln x_{kit} \\ + \frac{1}{2}\sum_{k=1}^{5}\sum_{l=1}^{5}\beta_{kl}\ln x_{kit}\ln x_{lit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{m=2}^{3}\gamma_{km}\ln x_{kit}\ln y^*_{mit} \\ + \delta_t t + \frac{1}{2}\delta_{tt}t^2 + \sum_{m=2}^{3}\alpha_{mt}t\ln y^*_{mit} + \sum_{k}^{5}\beta_{kt}t\ln x_{kit} \\ + \alpha_{m*}m_i^* + \frac{1}{2}\alpha_{m*m*}m_i^{*2} + \delta_{tm*}m_i^* t + \sum_{k=1}^{5}\beta_{km*}m_i^*\ln x_{kit} + u_{it} + v_{it} \qquad (4)$$

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$$\ln TFP_{it} = \ln \psi_{it} - \ln t_{it}^{CRS} = \underset{SE}{\ln t_{it}} + \underset{TE}{\ln v_{it}} + \underset{TCH}{\ln \tau_{it}} + \underset{MAN}{\ln \mu_{it}} \quad \text{with} \quad \ln t_{it} = \ln t_{it}^{VRS} - \ln t_{it}^{CRS} \tag{5}$$

$$\text{where } \ln \psi_{it} = \ln y_{it} - \overline{\ln y_{it}} \text{ and } \ln v_{it} = \ln TE_{it} - \overline{\ln TE_{it}}$$

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

$$\text{with} \quad \varepsilon_{it,j_0} = \frac{\partial \ln f(\mathbf{y}_{mit}^{*}, \mathbf{x}_{it}, t, \mathrm{m}_i^{*}; \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\gamma}, \boldsymbol{\delta})}{\partial \ln \mathbf{x}_{it,j}}$$

$$\text{and } \ln t_{it}^{CRS} = \frac{1}{2}\sum_{j=1}^{K}\left[\left(\frac{\varepsilon_{it,j_0}}{\sum_{i=1}^{K}\varepsilon_{it,j_0}} + \frac{\bar{\varepsilon}_j}{\sum_{i=1}^{K}\varepsilon_{j_0}}\right)\left(\ln x_{it,j} - \overline{\ln x_j}\right) + \frac{\bar{\varepsilon}_j}{\sum_{i=1}^{K}\varepsilon_{j_0}}\overline{\ln x_j} - \overline{\frac{\varepsilon_{it,j_0}}{\sum_{i=1}^{K}\varepsilon_{it,j_0}}\ln x_{it,j}}\right]$$

The total factor productivity can be 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 the input adjustments if a function has the translog form (for the proof see Diewert 1976). Moreover, TFP is a combination of the scale effect (SE), the technical efficiency effect (TE), the technological change effect (TCH) and the management effect (MAN) (Equation 5).

VRS represents the variable returns to scale, CRS is the constant returns to scale, and the arithmetic mean is used.

The analysis uses an unbalanced panel data set drawn from the FADN database provided by the European Commission. The data covers the period from 2004 to 2011. Information on three types of production are used: cereals (3658 cases), milk (3701 cases) and pork (746 cases). The multiple output distance function is estimated for each type of production. In each production, we use three outputs and five inputs:

**Cereal production**: $y_1$ cereal production, $y_2$ other plant production, $y_3$ animal production, $x_1$ labour, $x_2$ land, $x_3$ capital, $x_4$ specific material and $x_5$ other material.

**Dairy production**: $y_1$ milk production, $y_2$ other animal production, $y_3$ plant production, $x_1$ labour, $x_2$ land, $x_3$ capital, $x_4$ specific material and $x_5$ other material.

**Pork production**: $y_1$ pork production, $y_2$ other animal production, $y_3$ plant production, $x_1$ labour, $x_2$ land, $x_3$ capital, $x_4$ specific material and $x_5$ other material.

Labour is represented by the total labour measured in AWU. Land is the total utilised land. Capital is the sum of the contract work and depreciation. Specific material in the cereal production is represented by the costs of seeds, plants, fertilisers and crop protection. Specific material in the dairy production is the cost of feed for grazing livestock, and in pork production, the cost of feed for pigs and poultry.

Outputs as well as inputs (except for labour and land) are deflated by the country price indices (individual output and input indices (2005 = 100) – source the EUROSTAT database).

The multiple output distance function is estimated only for specialized producers. Specialization exists when there is at least a 50% share of the cereal production in the total plant production, of the dairy production in the total animal production, or of the pork production in the total animal production, as the case may be.

## RESULTS AND DISCUSSION

The results of the multiple output distance function (4), estimated for the cereal sector, are presented in Table 1.

As expected, almost all parameters are significant, even at the 1% significance level. The estimated function also satisfied the properties of an output distance function. The function is non-decreasing, positively linearly homogenous and convex in outputs, as well as decreasing and quasi-convex in inputs. Since all variables are normalised in logarithm by their sample mean, the first-order parameters of outputs represent the shares of outputs $y_2$ and $y_3$ in the total output. Since other plant production plays an important role in Czech farms specialized in cereal production, we can conclude that Czech farms diversify their production. The parameters of inputs can be interpreted as the elasticities of production on the sample mean. In terms of the multiple output distance function, a negative sign on the inputs implies that all inputs have a positive effect on cereal prodution. The material

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inputs have the strongest positive effects. A negative sign on the technical change coefficient also suggests a positive effect on cereal prodution. Adding up the coefficients of inputs, one can see whether the production can be improved in terms of the economies of scale. We can conclude that there is no indication of the economies of scale for the average cereal farm.

The coefficients on unobservable management are highly significant as well. We can conclude that heterogeneity among companies is an important characteristic of farmers with the cereal specialization. The unobservable management contributes positively to production; and the positive impact of the unobservable management is accelerating. The management has a positive impact on the production elasticities of both types of materials. However, it negatively affects the production elasticities of the remaining inputs. Finally, technological change makes a significant positive contribution to the production possibilities, and its positive impact accelerates over time. Based on the biased technical change, we can conclude that the cereal production is characterized by the material-using and labour- and capital-saving technical change.

The parameter σ provides information about the joint variation of $u_{it}$ and $v_{it}$. λ is the relation between the variance of $u_{it}$ and $v_{it}$. Since λ is significant and smaller than one, the estimates indicate that differences in the efficiency of input use are rather small among Czech cereal producers. This can also be seen from the statistical characteristics of technical efficiency in the cereal sector: the mean value 0.923, the standard deviation 0.012, the minimum 0.806, the maximum 0.970. This suggests that the Czech

Table 1. Cereals – parameters estimate

| Means for random parameters | | | | Coefficients on unobservable fixed management | | | |
|---|---|---|---|---|---|---|---|
| Variable | Coeff. | SE | P [\|z\|>Z*] | Variable | Coeff. | SE | P [\|z\|>Z*] |
| Const. | –0.44188 | 0.03175 | 0.0000 | Alpha_m | 0.03094 | 0.00361 | 0.0000 |
| Time | –0.00658 | 0.00259 | 0.0111 | Time | 0.00800 | 0.00144 | 0.0000 |
| X1 | –0.09235 | 0.01306 | 0.0000 | X1 | 0.07318 | 0.00704 | 0.0000 |
| X2 | –0.13690 | 0.01477 | 0.0000 | X2 | 0.20586 | 0.00805 | 0.0000 |
| X3 | –0.03019 | 0.00819 | 0.0002 | X3 | 0.07618 | 0.00387 | 0.0000 |
| X4 | –0.38914 | 0.01241 | 0.0000 | X4 | –0.06748 | 0.00522 | 0.0000 |
| X5 | –0.36730 | 0.01478 | 0.0000 | X5 | –0.24167 | 0.00708 | 0.0000 |
| | | | | Alpha_mm | 0.19137 | 0.00491 | 0.0000 |
| Variable | Coeff. | SE | P [\|z\|>Z*] | Variable | Coeff. | SE | P [\|z\|>Z*] |
| TT | –0.00390 | 0.00157 | 0.0128 | X13 | –0.04791 | 0.01091 | 0.0000 |
| Y2 | 0.32777 | 0.01032 | 0.0000 | X14 | –0.02160 | 0.01432 | 0.1314 |
| Y3 | 0.17689 | 0.00395 | 0.0000 | X15 | –0.02857 | 0.02088 | 0.1713 |
| Y2T | 0.00389 | 0.00257 | 0.1305 | X23 | 0.04154 | 0.01008 | 0.0000 |
| Y3T | –0.00031 | 0.00070 | 0.6619 | X24 | 0.03977 | 0.01453 | 0.0062 |
| Y22 | 0.07836 | 0.00594 | 0.0000 | X25 | –0.04173 | 0.01886 | 0.0269 |
| Y33 | 0.04525 | 0.00163 | 0.0000 | X34 | 0.02534 | 0.00851 | 0.0029 |
| Y23 | –0.01084 | 0.00271 | 0.0001 | X35 | 0.03164 | 0.01096 | 0.0039 |
| X1T | 0.00695 | 0.00342 | 0.0422 | X45 | 0.05399 | 0.01629 | 0.0009 |
| X2T | –0.00263 | 0.00400 | 0.5119 | Y2X1 | 0.03164 | 0.01067 | 0.1151 |
| X3T | 0.00436 | 0.00201 | 0.0301 | Y2X2 | 0.01663 | 0.01266 | 0.1892 |
| X4T | 0.00022 | 0.00280 | 0.9374 | Y2X3 | –0.00435 | 0.00546 | 0.4250 |
| X5T | –0.00831 | 0.00389 | 0.0328 | Y2X4 | –0.04554 | 0.01203 | 0.0002 |
| X11 | 0.00742 | 0.02087 | 0.7220 | Y2X5 | 0.02229 | 0.01038 | 0.0318 |
| X22 | –0.04764 | 0.02583 | 0.0651 | Y3X1 | 0.00172 | 0.00351 | 0.6248 |
| X33 | –0.04634 | 0.00719 | 0.0000 | Y3X2 | 0.00033 | 0.00400 | 0.9343 |
| X44 | –0.11447 | 0.01146 | 0.0000 | Y3X3 | 0.00832 | 0.00233 | 0.0004 |
| X55 | –0.07555 | 0.02753 | 0.0057 | Y3X4 | –0.00335 | 0.00345 | 0.3315 |
| X12 | 0.08983 | 0.01889 | 0.0000 | Y3X5 | 0.00785 | 0.00449 | 0.0804 |
| Sigma | 0.19603 | 0.01136 | 0.0000 | | | | |
| Lambda | 0.53816 | 0.23543 | 0.0223 | | | | |

Source: own calculations

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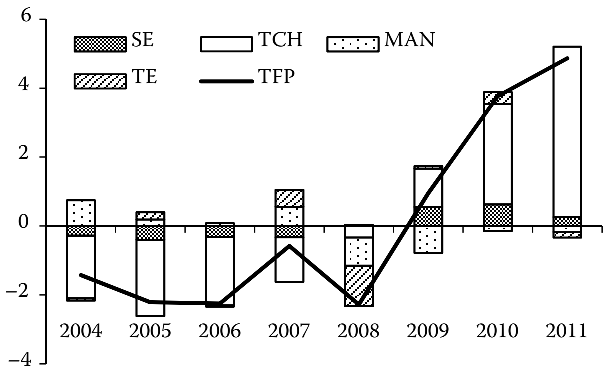


Figure 1. Development of TFP and its components in the cereals sector

Source: Own calculations

cereal producers highly exploit their production possibilities.

The Total Factor Productivity (TFP) (Figure 1) stagnated in the years 2004–2008, then it experienced a significant improvement after 2008.

The increase was predominantly influenced by the technical change (TCH) component. That is, the technological progress seems to be a significant source of growth in the cereals sector. We can presume that the technical change was speeded up by the increase in subsidies. Moreover, we can presume that the technological improvements resulting in lower average costs were the reaction on the unstable market environment and significant price fluctuations in the past period. That is, the technological progress lead to a higher competitiveness of the Czech producers. Furthermore, we can observe that the management (heterogeneity effect) had a positive effect in the years 2004, 2005, 2007 and technical efficiency had a positive effect in the years 2005, 2007 and 2010. It was predominantly in the years with a record harvests or in the following years, respectively. On the other hand, the effect of the management and technical efficiency was negative in the year 2008. This was the result of bad weather conditions and the subsequent poor harvest in the year 2007, and in spite of the fact that cereal producers saw a record-breaking harvest in the year 2008; however, this harvest did have a positive effect on the output in the following year (with respect to the market realisation). Finally, the scale effect contributed negatively in the period 2004–2008. This suggests that firms did not produce at the optimal scale. However, the negative effect was not large. The production was improved in terms of the economies of scale since 2009. This can be connected with the technological change which shifted up the production frontier. Moreover, it can be the result of the commodity structure changes. The analysed period can be characterized by a slightly increase of the winter wheat in the structure of cereals. We can conclude that the competitiveness of cereal producers has increased since 2009 and has been significantly determined by the technical change, supported by subsidies. In this point of view, we can recommend targeting the agriculture support to the modernization and innovation in the cereals sector.

The results of parameter estimates of the multiple output distance function for the dairy production are presented in Table 2.

From the statistical point of view, almost all estimated parameters are significant at the 1% significance level. The estimated parameters also fulfilled the theoretical properties of the output distance functions – the monotonicity of outputs and inputs and convexity in inputs.

The farms specialized in dairy production are also characterized by a high share of the plant production. This could be related to the diversification of their production in an effort to minimize the production risk or with the production of their own feed in an effort to minimize costs. All the analysed inputs positively affect dairy prodution. Material has the strongest impact (similarly to the cereal production). Moreover, we estimated that land has a strong effect and capital has a very low impact. This could be the result of the capital market imperfections and/or the farmer specialization (extensive vs. intensive breeding). Moreover, we can conclude that farms specialized in the dairy production are characterized by decreasing returns to scale.

Similarly to the cereal production, the unobservable management contributes positively to production, and the positive impact of the unobservable management is accelerating over the time. The technological change has a significant positive impact on the production possibilities, and the parameter $\beta_{TT}$ is not significant. Moreover, the dairy production is characterized by the labour-saving and land-using technical change. Finally, the parameter $\lambda$ is significantly higher than one. That is, the estimates indicate that the efficiency differences among dairy producers are important reasons for variations in the production. These differences are apparent from the basic statistical characteristics of technical efficiency in the dairy sector: the mean value 0.921, the standard deviation 0.035, the minimum 0.665, the maximum 0.978. In other words, the majority of dairy produc-

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Table 2. Dairy – parameters estimate

| Means for random parameters | | | | Coefficients on unobservable fixed management | | | |
|---|---|---|---|---|---|---|---|
| Variable | Coeff. | SE | P [\|z\|>Z*] | Variable | Coeff. | SE | P [\|z\|>Z*] |
| Const. | –0.13204 | 0.00865 | 0.0000 | Alpha_m | 0.21931 | 0.00361 | 0.0000 |
| Time | –0.02414 | 0.00126 | 0.0000 | Time | 0.00998 | 0.00167 | 0.0000 |
| X1 | –0.16483 | 0.00800 | 0.0000 | X1 | –0.02215 | 0.01008 | 0.0281 |
| X2 | –0.27093 | 0.01182 | 0.0000 | X2 | 0.09434 | 0.01314 | 0.0000 |
| X3 | –0.01704 | 0.00605 | 0.0049 | X3 | –0.02506 | 0.00631 | 0.0001 |
| X4 | –0.26162 | 0.00773 | 0.0000 | X4 | –0.05525 | 0.00802 | 0.0000 |
| X5 | –0.29573 | 0.01085 | 0.0000 | X5 | –0.01683 | 0.01252 | 0.1788 |
| | | | | Alpha_mm | 0.03322 | 0.00627 | 0.0000 |
| Variable | Coeff. | SE | P [\|z\|>Z*] | Variable | Coeff. | SE | P [\|z\|>Z*] |
| TT | –0.00083 | 0.00121 | 0.4945 | X13 | –0.03860 | 0.01232 | 0.0017 |
| Y2 | 0.08856 | 0.00371 | 0.0000 | X14 | 0.05652 | 0.01768 | 0.0014 |
| Y3 | 0.43992 | 0.00522 | 0.0000 | X15 | –0.02647 | 0.02558 | 0.3009 |
| Y2T | –0.00418 | 0.00163 | 0.0102 | X23 | 0.06000 | 0.01648 | 0.0003 |
| Y3T | 0.00991 | 0.00204 | 0.0000 | X24 | 0.12034 | 0.02535 | 0.0000 |
| Y22 | 0.01490 | 0.00183 | 0.0000 | X25 | 0.02168 | 0.03304 | 0.5117 |
| Y33 | 0.13355 | 0.01121 | 0.0000 | X34 | –0.03012 | 0.01430 | 0.0353 |
| Y23 | 0.00120 | 0.00573 | 0.8348 | X35 | –0.00159 | 0.01790 | 0.9291 |
| X1T | 0.01142 | 0.00302 | 0.0002 | X45 | 0.08841 | 0.02459 | 0.0003 |
| X2T | –0.01559 | 0.00470 | 0.0009 | Y2X1 | –0.00964 | 0.01013 | 0.3412 |
| X3T | 0.00239 | 0.00240 | 0.3194 | Y2X2 | –0.01175 | 0.01114 | 0.2915 |
| X4T | 0.00077 | 0.00305 | 0.8018 | Y2X3 | 0.01626 | 0.00676 | 0.0162 |
| X5T | 0.00266 | 0.00442 | 0.5473 | Y2X4 | 0.02128 | 0.00975 | 0.0291 |
| X11 | 0.04038 | 0.02730 | 0.1390 | Y2X5 | –0.01775 | 0.01076 | 0.0992 |
| X22 | –0.09408 | 0.03237 | 0.0037 | Y3X1 | 0.03944 | 0.01181 | 0.0008 |
| X33 | 0.00734 | 0.01192 | 0.5384 | Y3X2 | 0.01174 | 0.01464 | 0.4224 |
| X44 | –0.23469 | 0.02695 | 0.0000 | Y3X3 | –0.05834 | 0.00791 | 0.0000 |
| X55 | –0.13311 | 0.04524 | 0.0033 | Y3X4 | –0.01830 | 0.01427 | 0.1997 |
| X12 | –0.04914 | 0.02471 | 0.0468 | Y3X5 | –0.00802 | 0.01385 | 0.5626 |
| Sigma | 0.13270 | 0.00434 | 0.0000 | | | | |
| Lambda | 1.29912 | 0.14567 | 0.0000 | | | | |

Source: own calculations

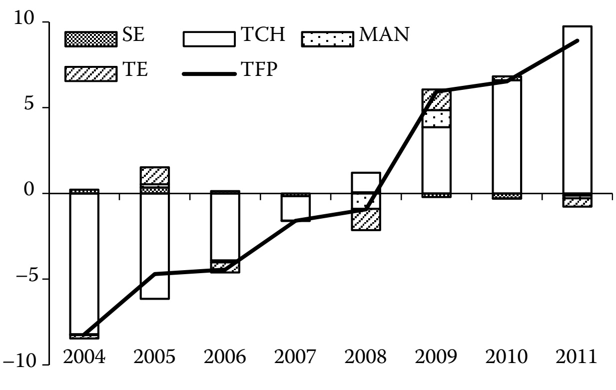


Figure 2. Development of TFP and its components in the dairy sector

Source: Own calculations

ers are highly technically efficient. However, there are also producers with a low technical efficiency.

Figure 2 provides the development of the TFP in the dairy sector. Similarly to the cereals sector, the TFP experienced a positive trend, with the difference that the TFP constantly increased in the period under consideration. The trend of the TFP development was mainly influenced by the TCH component. However, the technical change significantly contributed to the TFP increase over the analysed period. Technological improvements seem to be a result of the agricultural policy changes (the Common Market Organization, milk quotas, the Rural Development Programme). That is, the dairy sector was strongly affected by the Common Agricultural Policy. Moreover, the technical change in the dairy sector is also connected with

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the changes in the production structure towards the free stabling or pasture breeding which are labour-saving and land-using.

The scale component had a negative impact, since milk producers did not operate on the optimal scale. This can be the result of structural changes faced by the Czech dairy sector. The background to the mentioned changes can be seen in the overproduction and the strong market power of milk business chains (Gebeltová 2012). This resulted in a decrease in the number of cows, a higher concentration of dairy cows and an increase in milk yields.

On the other hand, the best-practise farms used the opportunity to finance their modernization through subsidies. Dairy producers received preferences in the modernisation programmes (Bošková and Ratinger 2013), and the innovation became a key tool for improving competitiveness (Krause 2012) in the dairy sector as well.

Table 3 presents the results of the multiple output distance function estimate for the pork production. As in the case of the cereal and dairy production, the majority of parameters is statistically significant even at the 1% level. The parameters on other animal production ($y_2$) and plant production ($y_3$) indicate that pork producers also diversified into other types of production, especially the plant production. However, there is also a high proportion of other animal production. Similarly to previous specializations, the inputs satisfy the monotonicity assumption, and material inputs have the strongest effect on production. As in the case of cereal production, there is no indication of the economies of scale for the average pork farm in the Czech Republic.

Table 3. Pork – parameters estimate

| Means for random parameters | | | | Coefficients on unobservable fixed management | | | |
|---|---|---|---|---|---|---|---|
| Variable | Coeff. | SE | P [\|z\|>Z*] | Variable | Coeff. | SE | P [\|z\|>Z*] |
| Const. | –0.27497 | 0.01526 | 0.0000 | Alpha_m | –0.06208 | 0.00270 | 0.0000 |
| Time | –0.00564 | 0.00134 | 0.0000 | Time | –0.02746 | 0.00122 | 0.0000 |
| X1 | –0.12826 | 0.00666 | 0.0000 | X1 | 0.03127 | 0.00634 | 0.0000 |
| X2 | –0.06892 | 0.00854 | 0.0000 | X2 | –0.12350 | 0.00632 | 0.0000 |
| X3 | –0.03267 | 0.00597 | 0.0000 | X3 | 0.02210 | 0.00424 | 0.0000 |
| X4 | –0.25086 | 0.00433 | 0.0000 | X4 | –0.03227 | 0.00194 | 0.0000 |
| X5 | –0.53401 | 0.01006 | 0.0000 | X5 | 0.07752 | 0.00860 | 0.0000 |
| | | | | Alpha_mm | 0.26397 | 0.00483 | 0.0000 |
| Variable | Coeff. | SE | P [\|z\|>Z*] | Variable | Coeff. | SE | P [\|z\|>Z*] |
| TT | –0.01195 | 0.00122 | 0.0000 | X13 | –0.05437 | 0.00994 | 0.0000 |
| Y2 | 0.23696 | 0.00265 | 0.0000 | X14 | –0.03058 | 0.00957 | 0.0014 |
| Y3 | 0.48171 | 0.00406 | 0.0000 | X15 | –0.08369 | 0.02106 | 0.0001 |
| Y2T | –0.01034 | 0.00094 | 0.0000 | X23 | 0.06947 | 0.01280 | 0.0000 |
| Y3T | 0.00217 | 0.00153 | 0.1562 | X24 | 0.03476 | 0.00945 | 0.0002 |
| Y22 | 0.05027 | 0.00111 | 0.0000 | X25 | –0.09837 | 0.02451 | 0.0001 |
| Y33 | 0.09978 | 0.00348 | 0.0000 | X34 | –0.04981 | 0.00709 | 0.0000 |
| Y23 | –0.03966 | 0.00154 | 0.0000 | X35 | 0.08858 | 0.01424 | 0.0000 |
| X1T | 0.00339 | 0.00287 | 0.2377 | X45 | 0.14419 | 0.01188 | 0.0000 |
| X2T | –0.01502 | 0.00328 | 0.0000 | Y2X1 | 0.01178 | 0.00332 | 0.0004 |
| X3T | –0.00676 | 0.00240 | 0.0048 | Y2X2 | 0.02216 | 0.00398 | 0.0000 |
| X4T | –0.01088 | 0.00190 | 0.0000 | Y2X3 | –0.01275 | 0.00261 | 0.0000 |
| X5T | 0.03173 | 0.00440 | 0.0000 | Y2X4 | –0.01535 | 0.00224 | 0.0000 |
| X11 | 0.14594 | 0.01723 | 0.0000 | Y2X5 | 0.01835 | 0.00521 | 0.0004 |
| X22 | 0.00641 | 0.01515 | 0.6725 | Y3X1 | –0.03820 | 0.00731 | 0.0000 |
| X33 | –0.06147 | 0.00873 | 0.0000 | Y3X2 | 0.01047 | 0.00701 | 0.1352 |
| X44 | –0.05325 | 0.00341 | 0.0000 | Y3X3 | –0.05168 | 0.00543 | 0.0000 |
| X55 | –0.11302 | 0.04050 | 0.0053 | Y3X4 | 0.01727 | 0.00278 | 0.0000 |
| X12 | 0.01132 | 0.01533 | 0.4602 | Y3X5 | 0.07291 | 0.00940 | 0.0000 |
| Sigma | 0.13912 | 0.00676 | 0.0000 | | | | |
| Lambda | 0.70694 | 0.18458 | 0.0001 | | | | |

Source: own calculations

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The unobservable management contributed negatively to production; however, the negative impact of the unobservable management has been decelerating. Technological change made a significant positive contribution to the production possibilities, and this positive impact was accelerating over time. The biased technological change was land- and capital using. For the material inputs, we estimated that the specific material using and other material saving biased technological change.

Finally, the parameter λ is significantly less than one. That is, the estimates indicate that the differences in the efficiency of the input use are rather small among Czech pork producers. The basic statistics of technical efficiency in the pork sector are as follows: the mean value 0.925, the standard deviation 0.029, the minimum 0.718, the maximum 0.977.

The TFP in the pork sector changed over the period 2004–2011. The primary decrease was replaced by an increase in the year 2008. This development reflected the trend of the TCH component, which can be characterized by a significant increase beginning in 2007. On the other hand, the management component (MAN) has negatively affected the TFP since 2008. The scale component (SE) had a marginal effect on the TFP changes. This shows that pork producers have the optimal size of production, at least from the static point of view.

The situation in the pork sector was the most problematic from the analysed sectors. The producers had to face high investment requirements in an effort to fulfil the veterinary, sanitary and other regulations after the Czech Republic accession to the EU. However, these investments were not supported by the agricultural policy measures. Moreover, the producers faced the increase in the feed prices, the low and highly volatile realization price, the decrease of the domestic pork demand and the increase of the imported pork volume. This led to an unsustainable economic situation of pork producers and abolishing of their business. The mentioned situation seems to be significantly influenced by the Rural Development Programme which started in 2007 and pork producers received preferences in modernisation programmes. This contributed to a catching up effect in 2009 and 2010 and a strong technological progress in 2010 and 2011.

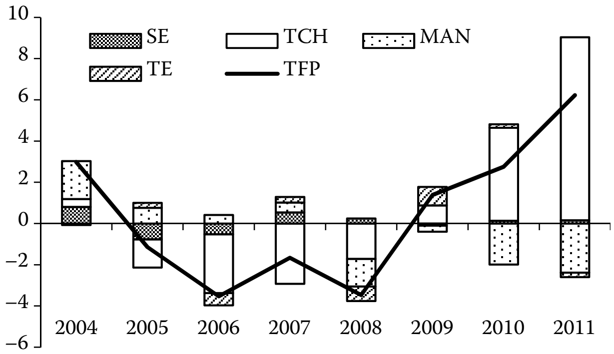


Figure 3. Development of TFP and its components in the pork sector

Source: Own calculations

As far as the productivity development is concerned, we can conclude that in the terms of productivity, pork producers improved their competitiveness over the last four years, and this was especially driven by technological improvements.

## CONCLUSION

The results show that we can observe a positive trend in the TFP for all sectors, determined mainly by the technical change. Specifically, in the cereal sector, the technological progress, which seems to be a significant source of growth, was supported by an increasing level of direct payments. On the other hand, bad weather conditions resulted in a negative impact on the technical efficiency, especially in the year 2007. The dairy sector faced many market problems in the initial analysed years, and dairy producers did not operate at the optimal scale. The productivity in the dairy sector has significantly increased since 2008. Pork producers also improved their competitiveness over the last four years, and this was especially driven by technological improvements. We can presume that in both sectors, the technological improvements were positively influenced by the national subsidies.

The development of the TFP shows that there was a gap in the TFP growth between 2004 and 2008, which could have been due to the fact that the amount of direct payments was lower than in the older member states until 2008. Since 2008, when the gap between direct payments in the old and new member states began to significantly decrease, the TFP has increased in all analysed sectors, and the TCH as well as the TE follow almost the same pattern in all sectors. So we can conclude that the subsidies (direct payments) have a positive effect on the TFP development.

From the character of the Common Agricultural Policy, we can assume that subsidies under the first

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pillar give incentives to farmers to invest in the technology. On the other hand, subsidies from the second pillar (first axis) are less efficient, as there might be an adverse selection and higher moral hazard problems.

To conclude, we argue that it is more efficient to subsidize farmers from the first pillar (e.g., suggest transferring money from the second to the first pillar of the CAP). It is better to leave the decision about where to invest up to the farmers.

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