Measuring Performance Growth of Agricultural Sector: A Total Factor Productivity Approach

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Abstract — Agriculture is an important sector of the economy whose performance growth is often monitored by bodies at national and international level. However, it is traditionally measured using macroeconomic indicators. Total factor productivity (TFP) indexes represent a tool of performance measurement which takes into multiple inputs and outputs. In this article, we propose a method of agricultural sector performance measurement based on the Fisher index. We use an aggregation of individual firm accounting data from the Czech agricultural sector to determine the productivity growth, partial factor productivities of inputs and compare the development with the TFP growth in the Czech economy. We found that the productivity growth of agricultural companies does not necessarily move in the same direction as the growth of the economy, which supports the idea that agricultural sector performance depends rather on natural and weather conditions, and that the demand for agricultural products can be relatively steady.

Keywords— Agriculture, Performance Measurement, Total Factor Productivity

I. Introduction

Agriculture is an important sector of the economy which is often monitored by the government and international bodies. Agricultural sector plays an important role in the society. We can state three of its main roles (the list is not exhaustive):

- production role,
- social and demographic role,
- ecologic and landscape aesthetics role.

The production role is associated with the provision of sufficient quantities of affordable products, not only for the needs of food-processing industry, but also as inputs for other industries, such as biofuels, pharmacy or textile industry.

The social and demographic role is related to the generation of employment opportunities and maintaining standards of living especially in the countryside and rural areas.

The authors would like to express their gratitude for the financial support of the University of Economics, Prague - the paper is one of the outcomes of the research project MF/04/2013 “Measuring economic efficiency of agricultural complex using productivity indexes”.

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The ecologic and landscape role is associated with the control of pollution and the creation of a cultural landscape.

Farmers’ behavior and their economic results are significantly affected by agricultural policy. Firstly, the EU Common Agricultural Policy (CAP) provides income support. The aim of the income support (direct payments, LFA payments) is to preserve agriculture and adequate living standards in rural areas [1]. Beyond the objectives of the income support, the CAP offers the agri-environmental measures. The aim of agri-environmental payments (including support of organic farming) is to enhance production of environmental public goods.

Given the importance of this sector, it is necessary to measure its performance and productive efficiency. At the aggregate level, performance of agricultural sectors is measured by government institutions (national statistical offices or agricultural departments and ministries) as well as by international bodies such as Eurostat and OECD. Moreover, agriculture and its efficiency and sustainability are subject to considerable academic attention (see e.g. [28], [33] or [31]).

In this article, we propose a measure of performance of the agricultural sector which is based on the total factor productivity (TFP) approach, but which makes use of accounting data on individual companies. This is an important difference from the traditional approaches which use macroeconomic data, such as gross value added or net capital stock, to estimate the productivity of the Czech agricultural sector.

II. Basic Features of the Czech Agriculture

As the paper deals with the productivity of Czech agriculture, the next paragraphs introduce the specific structural features of the Czech agricultural sector.

Since 2004 the Czech Republic has been member of the European Union, so the Common Agricultural Policy significantly affects the development of the Czech agriculture. In 2012, the share of the agrarian sector, i.e. agriculture, forestry and fishery, in the gross domestic product (GDP) comprised 2.07 %; the share of agriculture itself was 1.32 %.

Compared to the neighboring countries, this is a larger share than in Germany and Austria but less than in Poland and Slovakia.

The share of agriculture in the GDP has been decreasing for a long time. The share of 2.60 % in the total labor force work in the agrarian sector, 2.19 % in agriculture itself.

The Czech Republic has its specific farm structure. Family farms (sole holders) are not as important in today's Czech agriculture as they are in western states of the European Union, which has its roots in the history. The sole holders represent more than 86 % of the farms but they use only 30 % of the agricultural area. The average utilized agricultural area of the sole holders is about 50 ha.

Alternatively, the legal persons are usually large agricultural companies – joint stock companies or cooperatives. They utilize 70 % of the agricultural area and cultivate about 800 ha on average. Thus, the Czech Republic has one of the largest average farm in the EU. The share of sole holders, limited liability companies and joint stock companies increased between 2000 and 2010, while the share of cooperatives decreased.

This structure of the Czech agricultural sector has consequences for the agricultural policy. The existence of large agricultural holdings affects the landscape. Often large fields are cultivated in monoculture of either cereals or rapeseed. In the Czech Republic, farmers own only 23.5 % of the agricultural area in 2010. Most of agricultural holdings use predominantly hired land, nevertheless the share of their own land increases. The price of agricultural land is significantly lower than in the former EU-15. The land rent is lower as well. However, the trend of both indicators is increasing.

The agrarian trade balance has been negative for a long period. The share of agrarian goods in total Czech imports were 6.25 % in 2012. On the other side, the share of agrarian goods in total Czech exports were 4.81 % in 2012. The main agricultural exports are milk and milk products (incl. eggs and honey), drinks (incl. alcoholic ones), cereals and oil seeds. The main import goods are a variety of meat, fruits and nuts, milk and milk products (incl. eggs and honey).

The main trading partner is the EU. The Czech Republic exports mainly to Slovakia, Germany, Poland and Austria. The most important import partners are Germany, Poland, Slovakia, the Netherlands and Italy.

The Czech Republic exports mainly agricultural products with lower value added, such as live animals, raw milk, rape seeds and wheat. On the other hand, processed food products with higher value added are imported.

III. The Farm income in the Czech Republic

The farm structure, type of farming, the Common Agricultural Policy support and the agricultural foreign trade are the most important determinants of the farm income. Even if the Czech Republic has been the EU member state since 2004, it is still labelled as the "new member state" (EU-12 excl. Croatia).

The Economic Accounts of Agriculture shows that the farm income level in the new member states, measured through the Factor Income per AWU in PPS, reaches only 40 % of the old member states (EU-15) level. Nevertheless, the gap between the EU-12 and the EU-15 slightly diminishes.

Current subsidies have decisively contributed to an improvement of the farm income situation after the EU accession [1]. Without the current subsidies, many farms would not be profitable and viable. Compared with the pre-accession period, the current agricultural policy stimulates more an extensive cattle breeding (suckler cows) in less favored areas (LFA) on farms utilizing various agro-environmental programmes, including organic farming. It results in a relatively very good income situation of the extensive farms and a dynamic growth of the net value added per worker (NVA/AWU) in mountain areas. On the other hand, farms located out of LFA have more risky position, particularly in the connection with increasingly variable weather conditions.

Concerning the income disparity within the Czech agriculture, there is a relatively deep gap between the worst and best type of farming, measured through the NVA/AWU. As mentioned above, the larger farms with *extensive livestock farming* in the less favored mountain areas have the highest income level. The high NVA/AWU results from the combination of low labor input (as a consequence of an extensive livestock breeding) and high current subsidies per hectare. The farms usually receive direct payments, LFA payments and agri-environmental payments. Moreover, they gain national top-up payments for agricultural land and suckler cows. The NVA/AWU of the farms specialized on extensive livestock farming was 16 408 EUR on average in 2010-2011.

Alternatively, the specialized *pig breeding* farms have the lowest income level for a long time. After the EU accession in 2004 the Czech pig producers got under the competitive pressure, the imports sharply increased and the demand of the Czech meat processors for the Czech port meat dropped. The competitiveness of the Czech pig farms slumped. Although the Czech agricultural holdings have been reducing the number of pigs and sows for a long time, the development has been considerably more dynamic after the EU accession. The low NVA/AWU is the result of the relatively high labour input (due to the intensive pig breeding) and low current subsidies. The financial support of the pig production is relatively low compared to other types of farming since most of pig producers do not have agricultural land. Therefore, only indirect subsidies are applicable for them, not the direct payments. The NVA/AWU of the farms specialized on granivores was 8 913 EUR on average in 2010-2011.

IV. Total Factor Productivity

Traditionally, productivity is defined as the ratio of output over input. In the case of only one output and one input, the situation is straightforward.

However, in a more realistic situation when a firm produces multiple products and uses multiple inputs, it is necessary to aggregate the set of outputs and inputs. The total factor productivity (TFP) approach takes into account *all* possible inputs and outputs of the firm.

A. Traditional approaches to TFP measurement

Authors engaged in measuring the productive efficiency of agriculture use various approaches to measuring the TFP.

Coelli and Rao [9] estimate the levels and trends in agricultural output and productivity in 93 developed and developing countries that account for a major portion of the world population and agricultural output. They use Data envelopment analysis (DEA) to derive Malmquist productivity indices. The paper also attempts to derive the shadow prices and value shares that are implicit in the DEA-based Malmquist productivity indices.

The DEA approach has also been used by Błazejczyk-Majka, Kala and Maciejewski [2] to consider the question whether a higher specialization and a bigger economic size class of farms determine a higher technical efficiency at the same scale for the farms from the new and old countries of the EU. Based on the FADN data (Farm Accountancy Data Network) from 80 European regions they find that specialized field crop farms in average are less efficient than mixed farms, although the difference between efficiencies decreases with an increase of their economic size.

Jin et al. [18] used TFP to better understand the productivity trends in China's agricultural sector during the reform era-with an emphasis on the 1990-2004 period. Using a stochastic production frontier function approach they estimate the rate of change in TFP for each agricultural commodity. They find that that most of the change is accounted for by technical change. So, the new technologies have pushed out the production functions.

Bokusheva, Hockmann and Kumbhakar [3] analysed regional productivity and technical efficiency development in Russian agriculture. They combine the system Generalized Method of Moments approach (system GMM), which gives consistent estimates of the production technology parameters, with the standard stochastic frontier approach to estimate technical efficiency and its determinants.

Čechura [8] identified the key factors determining the efficiency of input use and the TFP development. The total factor productivity is calculated in the form of the Törnqvist-Theil index. He concludes that 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.

At the aggregate level, total factor productivity is measured indirectly. It is the output growth not explicable by changes in the amount of inputs (often referred to as Solow residual).

In the traditional two-factor model, where only labor (L) and capital (K) inputs are considered (see for example [29]), we can express the change in aggregate product between two periods as

$$\frac{Y_1}{Y_0} = \frac{A_1}{A_0}\left(\frac{L_1}{L_0}\right)^{\alpha}\left(\frac{K_1}{K_0}\right)^{1-\alpha} \tag{1}$$

where Y_1/Y_0 is the index of the aggregate output (e.g. GDP), L_1/L_0 is the index of labor, K_1/K_0 is the index of capital, and A_1/A_0 is the productivity index which measures the productivity growth (the residual).

B. Productivity indexes

As we already noted above, at the individual firm-level, the total factor productivity (TFP) approach takes into account all possible inputs and outputs of the company. Total factor productivity can be measured using productivity indexes (in the form of ratio) or productivity indicators (in the form of difference). In this article, we will focus on productivity indexes. In this case, it is necessary to aggregate the set of outputs and inputs to obtain scalar values in the numerator and denominator.

Company-level indexes can be based on distance function or on price aggregation (for detailed discussion, see e.g. [10]). Among measures based on distance function, we can cite the Malmquist productivity index [7] or Hicks-Moorsteen productivity index [13]. These measures require optimization problem solving (data envelopment analysis) or regression methods (known under the acronyms OLS, COLS, or MOLS) which measure the distance of firms from a real, but unknown frontier.

Other TFP measures are based on price aggregation, such as Törnqvist productivity index [32] or Fisher productivity index [16]. These measures require data about input and output prices, but can be derived directly from empirical data and based on only two observations. We will discuss the three most frequently used representatives: the Malmquist, Törnqvist and Fisher indexes.

In the following text, let N be the number of outputs and M the number of inputs. Further let $\mathbf{x} = (x_1,x_2,\ldots,x_n)$ denote the vector of input quantities, let $\mathbf{y} = (y_1,y_2,\ldots,y_m)$ denote the vector of output quantities, $\mathbf{w} = (w_1,w_2,\ldots,w_n)$ is the vector of input prices and $\mathbf{p} = (p_1,p_2,\ldots,p_m)$ is the vector of output prices.

C. Malmquist index of productivity

In order to define Malmquist index, we have first to introduce the notion of efficiency. The *efficiency* of a firm can be defined as a ratio of observed values of inputs and outputs to their optimal values.

The analysis of efficiency can be oriented either on minimizing inputs with given outputs or maximizing outputs with given inputs (these approaches are dual to each other). In this section, we will adopt the output-maximizing approach. Koopmans [19] defines efficiency in the following way: a firm is considered technically efficient if increasing any output requires reducing at least one another output or increasing at least one input.

The production technology can be represented using a set of couples (input-output vectors)

$$T = \{(\mathbf{x},\mathbf{y})\} \text{ where } \mathbf{x} \text{ is input to produce } \mathbf{y}. \tag{2}$$

Another possible representation of production technology is the output requirement set $P(\mathbf{x})$, e.g.

$$P(\mathbf{x}) = \{\mathbf{y} : (\mathbf{x}, \mathbf{y}) \in T\} \tag{3}$$

As a measure of efficiency, we can use the Debreu-Farrell approach ([11], [15]). Using the above-described notation, we can define the Debreu-Farell measure of technical efficiency as the maximum possible equiproportional increase of given output so that it still belongs to the output requirement set.

$$TE(\mathbf{x}, \mathbf{y}) = \max\{\Phi : \Phi\mathbf{y} \in P(\mathbf{x})\} \tag{4}$$

The inverse value of technical efficiency is called distance function.

$$D(\mathbf{x}, \mathbf{y}) = \min\{\lambda : \mathbf{y} / \lambda \in P(\mathbf{x})\} \tag{5}$$

When applying the output-maximizing approach, the lesser the distance from a production frontier, the better the efficiency score is. In the real world, the production frontier is unknown and has to be estimated using econometric methods (e.g. corrected ordinary least squares, COLS) or mathematical programming (e.g. data envelopment analysis, DEA). Using the above described definitions, we can define the Malmquist index of productivity. Consider a period during which the production has changed from $(\mathbf{x_t},\mathbf{y_t})$ to $(\mathbf{x_{t+1}},\mathbf{y_{t+1}})$. The Malmquist index of productivity for period t , respectively for period $t+1$, would be the ratio

$$\begin{aligned} M_t(\mathbf{x}_t, \mathbf{y}_t, \mathbf{x}_{t+1}, \mathbf{y}_{t+1}) &= \frac{D_t(\mathbf{x}_{t+1}, \mathbf{y}_{t+1})}{D_t(\mathbf{x}_t, \mathbf{y}_t)} \\ M_{t+1}(\mathbf{x}_t, \mathbf{y}_t, \mathbf{x}_{t+1}, \mathbf{y}_{t+1}) &= \frac{D_{t+1}(\mathbf{x}_{t+1}, \mathbf{y}_{t+1})}{D_{t+1}(\mathbf{x}_t, \mathbf{y}_t)} \end{aligned} \tag{6}$$

If the technology has changed during the period, these two indexes would result in different values. Therefore, it is common to employ the geometric mean of the two indexes and specify the Malmquist index of productivity as

$$M(\mathbf{x}_t, \mathbf{y}_t, \mathbf{x}_{t+1}, \mathbf{y}_{t+1}) = \sqrt{\frac{D_t(\mathbf{x}_{t+1}, \mathbf{y}_{t+1})}{D_t(\mathbf{x}_t, \mathbf{y}_t)} \times \frac{D_{t+1}(\mathbf{x}_{t+1}, \mathbf{y}_{t+1})}{D_{t+1}(\mathbf{x}_t, \mathbf{y}_t)}} \tag{7}$$

Malmquist index is of great theoretical importance. However, it is necessary to estimate the real but unknown production frontier using econometric or mathematical programming methods. Often, it is more practical to employ the indexes based on price aggregation, which can be calculated only from two observations. We will deal with these indexes in the following text.

D. Törnqvist index of productivity

Törnqvist index is an example of indexes which can be calculated from observed empirical data without having to estimate the unknown production frontier. These indexes are often called superlative indexes. Under certain conditions, they approximate the Malmquist index [14]. The calculation is based on observed prices (weights) of input and output factors. Törnqvist index of productivity is defined as a ratio of output quantity index Y_T and input quantity index X_T . Usually, the two quantity indexes are specified in their logarithmic form as

$$\begin{aligned} \ln Y_T &= \frac{1}{2}\left(\sum\nolimits_m \left[\frac{p_{m,t}y_{m,t}}{\sum_m p_{m,t}y_{m,t}} + \frac{p_{m,t+1}y_{m,t+1}}{\sum_m p_{m,t++}y_{m,t+1}}\right]\ln\frac{y_{m,t+1}}{y_{m,t}}\right) \\ \ln X_T &= \frac{1}{2}\left(\sum\nolimits_n \left[\frac{w_{n,t}x_{n,t}}{\sum_n w_{n,t}x_{n,t}} + \frac{w_{n,t+1}x_{n,t+1}}{\sum_n w_{n,t++}x_{n,t+1}}\right]\ln\frac{x_{n,t+1}}{x_{n,t}}\right) \end{aligned} \tag{8}$$

And finally, the Törnqvist index of productivity can be specified as

$$\Pi_T = \frac{Y_T}{X_T} = e^{\ln Y_T - \ln X_T} \tag{9}$$

E. Fisher index of productivity

Now, let us introduce the Fisher index of productivity [16]. It is defined as a geometric average of Laspeyres and Paasche indexes.

The Laspeyres index weights the quantities with the prices of the basic period. We can specify the Laspeyres output quantity index Y_L or input quantity index X_L, respectively as

$$Y_L = \frac{\sum_{n=1}^{N} p_{n,t}y_{n,t+1}}{\sum_{n=1}^{N} p_{n,t}y_{n,t}}, \quad X_L = \frac{\sum_{m=1}^{M} w_{m,t}x_{m,t+1}}{\sum_{m=1}^{M} w_{m,t}x_{m,t}} \tag{10}$$

The Paasche index weights the quantities with the prices of the current period. The Paasche output quantity index Y_P, resp. input quantity index X_P, can be specified as

$$Y_P = \frac{\sum_{n=1}^{N} p_{n,t+1}y_{n,t+1}}{\sum_{n=1}^{N} p_{n,t+1}y_{n,t}}, \quad X_P = \frac{\sum_{m=1}^{M} w_{m,t+1}x_{m,t+1}}{\sum_{m=1}^{M} w_{m,t+1}x_{m,t}} \tag{11}$$

Since productivity is defined as a ratio of output over input, it is possible to define the Fisher index of productivity as the ratio of geometric averages of Laspeyres and Paasche output and input indexes, so the total factor productivity growth can be specified as

$$\Pi_F = \frac{Y_F}{X_F} = \frac{\sqrt{Y_L Y_P}}{\sqrt{X_L X_P}} \tag{12}$$

Fisher (and Törnqvist) indexes have several interesting properties, because of which they are classified as exact and superlative indexes (more on this subject in [12]). If the production is represented by translog function, the Törnqvist index approximates the ideal Malmquist index and similarly, if the production is represented by quadratic function, the Fisher index approximates the ideal Malmquist index.

V. Data Issues in TFP Measurement

Productivity indexes require price and quantity data on each output and input. The measurement of the data is subject to certain issues; for detailed discussion, see e.g. [22]. Basically, the issues with TFP analyses can be divided into four groups.

The first category of issues is related to defining the set of comparable firms. Many factors, such as the degree of competition in the market, the extent of government regulation, economies of scale, firm size, geographical conditions and historic development have to be taken into consideration.

The second category is associated with specifying the time period. TFP estimates should be based on long time series and the period should include the whole business cycle and be representative and exclude extraordinary events.

The third group of issues is related to defining and measuring the inputs and outputs. Since a number of difficulties are associated with labor input measurement, it is often included into operating expenditures along with materials and services. The measurement of capital is even more contentious. The outputs should reflect performance, complexity and quality of service rendition.

Finally, the fourth category of problems concerns determining the costs of inputs and outputs (cost-based indexes) or defining and measuring the reference technology (distance-based indexes), where some degree of arbitrary judgment and inaccuracy is inevitable.

In the following text, we will discuss the issues associated with the measurement of outputs and inputs.

A. *Measurement of outputs*

The definition and measurement of outputs and their prices is one of the challenging tasks. Outputs should represent the complete basket of services and products provided by the transformation process. They should reflect how much is being produced, with what effort, and they should not omit the quality of service. The definition of the quality aspect is particularly challenging.

Moreover, one of the main concerns is that if the set of outputs is too large, one may encounter the problem of degrees of freedom and the analysis becomes complicated. In this case, it may be suitable to aggregate the outputs into smaller categories, in which case the so-called Hicks–Leontief conditions for aggregation should be respected ([17], [21]).

The prices of outputs should as well be treated carefully and price level changes should not be omitted. If the prices are not directly observable, it is necessary to approximate their weights in the total revenue and derive the prices numerically. These weights are calculated from the share of each output in the total revenue of the process. This approach involves either arbitrary judgments about the relative importance or econometric estimation of cost function (see e.g. [20]). There is an academic debate over which of these approaches performs the best.

However, when the prices of outputs are not directly observable, some degree of inaccuracy is practically inevitable.

B. *Measurement of inputs*

Another challenging task is to define and measure accurately the inputs and their prices. Traditionally, the economic theory takes into account at least the following categories of input factors: labor (L), capital (K) and materials (M). Sometimes, within materials, energy (E) and services (S) are also considered, and all these factors together are referred to as KLEMS.

Labor (L) is most often measured by the number of employees or man-hours, which should be corrected, since outsourcing of activities can distort the results. Moreover, it is preferable to distinguish among the people according to their skills, education and experience, since more skilled employees contribute to the productivity growth to a greater extent.

Because of these difficulties, labor is sometimes incorporated into operating expenditures (OPEX) which are taken together as an aggregate measure of labor and materials. However, labor costs often represents the major portion of total input costs and therefore, this input should be treated carefully in order to obtain reliable TFP estimates. Wage deflators can be taken into consideration to capture the effects of wages inflation.

However, the most contentious is the measurement of capital (K). The capital input should reflect the total service flow from capital assets used in the process. The assets can be of tangible or intangible nature; such as computers, software in IT, chemical reactors in chemistry production processes, transport equipment, heavy machinery etc. Of course, the set of assets will vary a lot across industries and even company departments.

The capital can be measured directly, in physical units, or indirectly in money value. Both approaches have their advantages and disadvantages; they are well discussed in [20].

The productive capital stock can be measured by the perpetual inventory method proposed by OECD [26]. If we denote the productive capital stock by K_t^P, then

$$K_t^P = \sum_{\tau=0}^{T} h_\tau F_\tau \frac{IN_{t-\tau}}{q_{t-\tau,0}} \tag{13}$$

where:

- h_τ is an age-efficiency profile, tracing the loss in productive efficiency as an asset ages, taking values between 1 (when the assets is new) and 0 (when it has lost its entire productive capacity).
- F_τ is a retirement function that quantifies the share of assets of age τ that are still in service. This function is declining and takes values between 1 (when all assets are in existence) and 0 (when all assets have been retired).
- IN_τ is the nominal investment expenditure on the asset at time τ, which is deflated by an investment price

index $q_{t-\tau,0}$ where subscripts indicate a price index for the asset of age zero (a new asset) in year τ.

Following the same manual, the cost of capital (rental price) can be determined using the following formula:

$$\mu_t = q_t(r_t + d_t) - (q_t - q_{t-1}) \tag{14}$$

where q_t is the market price of a new asset, d_t is the depreciation rate and r_t is some measure of the cost of financial capital such as the market rate of interest.

However, it is also possible to approximate the cost of capital inputs using regression methods following [20].

VI. PROPOSED MODEL

Our aim here is to propose a model to determine aggregate productivity growth based on individual firm-level accounting data. Given the nature of financial statements, we are able to extract only some of the outputs and inputs, which we describe below.

A. Input and output variables

In our model, we measured all input and output variables indirectly using their monetary value.

Because of the internal heterogeneity of the agricultural sector and diversities among agricultural firms, only one category of output is considered (this approach is similar to e.g. [8]):

- y: total sales of goods, products and services.

Further, five categories of input are considered:

- x_1: number of employees (-), which is proxied by total personnel costs divided by the average wages in the industry in the corresponding year [1];
- x_2: energy consumption (toe - tonnes of oil equivalent), which is obtained by the total energy costs divided by the energy consumption in the agricultural sector in the corresponding year [6];
- x_3: other OPEX (in particular, services and depreciation) (CZK), i.e. the difference between OPEX and labor and energy costs; this input reflects services, material consumption and other operational expenses;
- x_4: quantity of land used (ha), approximated by the book value of land divided by the average cost of one hectare in the appropriate year [24];
- x_5: other tangible assets (CZK).

For the TFP calculation, the variables were weighted by revenue shares. The weight of the single output is of 1.

As to the inputs, we adopt a similar approach to [27] and determine the weight of operating expenses (OPEX) as OPEX/revenue. The OPEX part is then divided among x_1, x_2 and x_3 according to the proportion of labor costs, energy costs and other costs in OPEX.

The remaining portion (1 – OPEX/revenue) is attributed to the remaining variables (x_4, x_5) according to their proportion in total tangible assets.

B. Data and methodology

To gather the data on the Czech agricultural sector we used the Albertina database which contains about more than 2,700,000 subjects with registered ID in Czech Republic.

We focused on the agricultural companies in the period 2004-2011. Companies containing incomplete data were excluded from the analysis. This way we obtained 10,045 observations in total. Table 1 summarizes the number of companies operating in the industry in the corresponding year.

For the above-mentioned output and input variables, we aggregated the yearly data and determined their weights and prices. Then we used the Fisher and Törnqvist indexes to calculate the input quantity index, the output quantity index, TFP growth and partial productivities of individual input factors. However, the values of these two types of indexes differ only minimally, so in the following text, we mention only the values of Fisher index.

Tab. 1: Number of evaluated companies

Year	**No. of subjects**
2004	923
2005	1085
2006	1248
2007	1385
2008	1429
2009	1441
2010	1415
2011	1119

VII. RESULTS AND DISCUSSION

In this chapter, we present the results from the above-described analysis.

A. Aggregate TFP growth

The aggregate TFP growth was estimated using input and output quantity indexes. The Fisher index formula produces chain indexes (changes relative to the previous period), which can be converted to fixed-base indexes which are more convenient for TFP growth analysis since they illustrate the TFP development relative to a fixed year (in our analysis, the base year is 2004). However, from the analytical point of view, the use of both expressions is suitable.

In Tab. 2, we summarize the results. Output quantity index is denoted by Y_F, input quantity index by X_F.

We observed that in the period 2004-2011, TFP grew by 10%.

We can also see the negative change of TFP between 2008 and 2009. The productivity decreased by 9%. However, the productivity has been increasing since that time.

The results can be also illustrated using Fig 1.

Tab. 2: Output and Input Quantity Indexes and TFP Growth

Year	Chain indexes			Fixed-base indexes		
	Y_F	X_F	ΔTFP	Y_F	X_F	ΔTFP
2004	-	-	-	1	1	1
2005	1.06	1.04	0.98	1.06	1.04	0.98
2006	1.14	1.14	1.00	1.21	1.18	0.98
2007	1.19	1.23	1.04	1.44	1.46	1.01
2008	1.08	1.03	0.96	1.55	1.51	0.97
2009	0.87	0.83	0.95	1.35	1.25	0.93
2010	0.92	1.04	1.14	1.24	1.30	1.05
2011	0.95	0.98	1.04	1.17	1.28	1.10

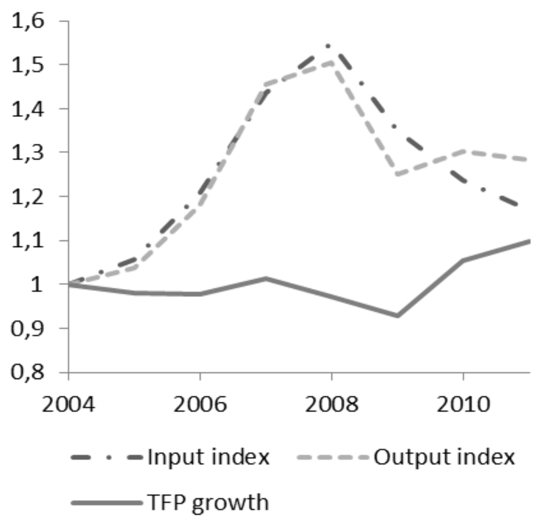

Fig. 1: TFP development in the Czech agricultural sector

In 2004, 2007 and 2011, agricultural enterprises in the Czech Republic attained the best economic results since the EU accession. The main source of income volatility in agriculture is price fluctuation, followed by year-by-year changes in yields (as the result of various weather conditions). However, partially or fully decoupled payments serve as a "financial pillow" increasing the level of the farmers' income and extending the farmers' decision-making possibilities [30].

Besides other things, the sharp drop of agricultural income in 2008 and 2009 had also delayed negative impact on investments. The gross fixed capital formation in 2009 and 2010 was lower than fixed capital consumption (depreciation and amortization). Fortunately, the income level and investment activity of agricultural enterprises in 2011 increased, so agricultural enterprises were able to generate further capital to increase their competitiveness.

The TFP growth is positively affected by the growth of overall output and negatively affected by the growth of inputs. To see more in detail which inputs affect the TFP decline the most, we can analyse the partial factor productivities of individual inputs.

B. Partial factor productivities

Partial factor productivity is the ratio of the aggregate output over a specific input which measures the efficiency of input utilization. Formally, the partial factor productivity may be defined as

$$PFP_i = \frac{Y}{X_i} \tag{13}$$

where Y is the output quantity index and X_i is the individual input quantity index.

We present the fixed-based partial factor productivities of five inputs in Tab. 3 and Fig. 2.

Tab. 3: Partial factor productivities growth

Year	Fixed-base indexes				
	X1	X2	X3	X4	X6
2004	1	1	1	1	1
2005	0.99	1.00	0.92	0.68	0.91
2006	1.04	0.97	0.89	0.59	0.89
2007	1.20	0.94	0.94	0.52	0.96
2008	1.28	0.86	0.89	0.38	0.93
2009	1.17	0.86	0.77	0.25	0.75
2010	1.32	1.00	0.81	0.24	0.79
2011	1.53	0.97	0.89	0.25	0.91

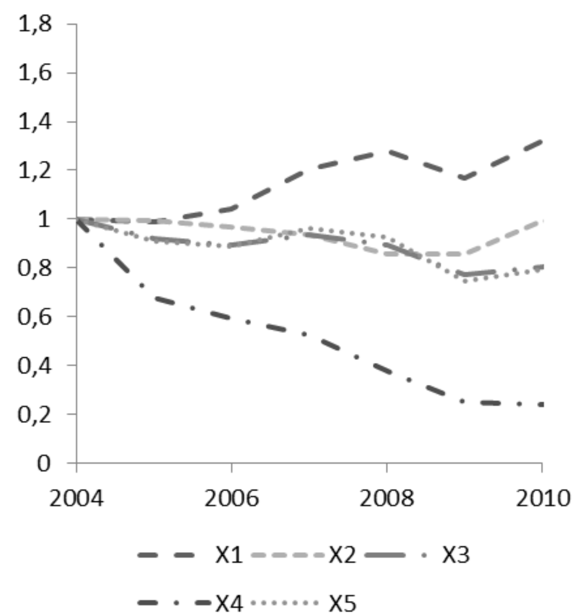

Fig. 2: Partial factor productivities growth

The results suggest that the utilization of the land input is decreasing which has a negative impact on overall TFP growth. However, due to its weight, this input is not much important.

Conversely, the utilization of the labor input is favorable, but this input is a significant one with weights about 20-30% of total inputs.

The most important input, which is the energy input X2, varies around 1. Other inputs are rather declining, but contribute to a minor extent to the total productivity growth.

C. Comparison with the Czech Economy

Agricultural sector is characterized by a relatively high degree of competition, which implies a possibly higher level of productivity than in the regulated or oligopolistic sectors (see e.g. [23]). However, a higher productivity level does not necessarily imply higher productivity growth. On the contrary, firms which are already efficient are likely to have lower productivity improvements, because they are located closer to the efficiency frontier.

We can also compare our results to the total factor productivity of the Czech economy estimated by the Czech Ministry of Finance (tab. 4).

Tab. 4: Agricultural TFP growth compared to the growth of the economy

Year	Chain indexes	
	Estimated TFP growth (agriculture, authors)	TFP growth (economy, [25])
2005	-1.88%	4.0%
2006	-0.34%	3.6%
2007	3.52%	2.7%
2008	-3.94%	1.7%
2009	-4.57%	0.9%
2010	13.65%	0.4%
2011	4.17%	0.3%

Since agriculture provides basic raw material for the peoples' livelihood and it is also highly dependent on changing natural conditions, there is a relatively low sensitivity to the overall economy growth. The price level in agriculture is determined by the price level abroad as well as by the level of supply (and yields) in the previous year. Moreover, the demand for agricultural production has been relatively steady. Thus, the agricultural TFP growth is not likely to move in the same direction as the growth of the economy.

VIII. Conclusion

Agriculture is a specific sector which, due to its high importance, is often monitored by governments and international agencies. In particular, it is desirable to measure the productive efficiency of this sector.

In this article, we presented a measure of agricultural sector performance based on the total factor productivity (TFP) approach which makes use of accounting data on individual companies rather than macroeconomic indicators.

In the first part of the article, we presented the traditional approaches to measuring total factor productivity, both at the aggregate and individual level. Then we discussed the major issues associated with measuring TFP and defining outputs and inputs. Then, we proposed a model to estimate productivity based on financial statements of individual agricultural companies.

The results suggest that between 2004 and 2011, the productivity grew by 10%. The major drop of productivity has been observed between 2008 and 2009, when TFP decreased by 9%. This negative development had a negative impact on the overall level of investment. Conversely, in 2004, 2007 and 2011, agricultural enterprises in the Czech Republic attained the best economic results since the EU accession.

The agricultural sector provides basic inputs for the peoples' livelihood and is highly dependent on changing natural conditions, which would suggest that there is a relatively low sensitivity on the overall economic growth. The price level in agriculture is determined by the foreign price level as well as by the development in the previous year, in particular the weather conditions. On the other hand, the demand for agricultural production is supposed to be relatively steady, unlike the demand for other classes of groups.

Together with these arguments, the results of our analysis suggest that the agricultural TFP growth does not necessarily move in the same direction as the growth of the economy.

The analysis could be improved by using a more accurate set of inputs and outputs. However, the definition of such a set is complex and difficult due to the internal heterogeneity of the agricultural sector and differences among agricultural companies.

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