Estimating Total Factor Productivity of Agricultural Sector Based on Firm-Level Accounting Data

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Abstract: - In this paper, we present a method to estimatethe productivity development of the Czech agricultural sector. While traditional productivity measures are based on macroeconomic data, we use individual accounting data of firms and determine the productivity development using the Fisher total factor productivity index. The results suggest that the development of agricultural sector is not highly sensitive to the overall economic development, which corresponds to the fact that agriculture depends more on the changing natural conditions and foreign demand.

Key-Words: Total Factor Productivity, Agriculture, Productivity, Index Analysis, Accounting

1 Introduction

Agriculture is an important sector of the economy which is often monitored by the government and international bodies. Agricultural sectorplays 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 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. On the one hand, the EU Common Agricultural Policy (CAP) providesincome support. The aim of the income support (direct payments, LFA payments) is to preserve agriculture and adequate living standards in rural areas.Beyond the objectives of the income support, the CAP offers theagri-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 international bodies such as Eurostat and OECD.

In this article, we propose a measure of agricultural sector performance 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.

2 Total Factor Productivity

Traditionally, productivity is defined as the ratio of output over input. In economic practice, TFP is measured by productivity indexes. Indexes are a common tool to measure price or quantity changes between two periods. Since in TFP calculations, we deal with the ratio of output and input quantities, we employ quantity indexes.

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 labour (L) and capital (K) inputs are considered (see for example [14]) we can

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express the change in aggregate product between two periods as

Equation 1

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

where Y_1/Y_0 is the index of 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 (the residual).

At the individual firm-level, the total factor productivity (TFP) approach takes into account all possible inputs and outputs of the company. 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. [5]). Among measures based on distance function, we can cite the Malmquist productivity index [3]. 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 [16]or Fisher productivity index [7]. These measures require data about input and output prices, but can be derived directly from empirical data and based on only two observations. In this paper, we will use the Fisher index to measure productivity growth.

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

Let us first introduce the Fisher index of productivity [7]. It is 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 indexX_L, respectively as

Equation 2

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

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

Equation 3

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

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

Equation 4

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

Fisher (and Törnqvist) indexes have several interesting properties, because of which they are classified as exact and superlative indexes (more on this subject in [6]). 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.

3 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. [9].

Quantity information can be obtained either directly (in physical measures such as number of MHW produced, number of employees etc.), or indirectly. Indirect quantity data are obtained by deflating the revenue or cost of a particular output or input by an average price. There are arguments in favor of both approaches; however, if the direct quantities are not observable, the indirect measurement becomes inevitable.

3.1 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 production process. They should reflect how much is being produced and with what effort.

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.[8]). There is an academic debate over which of these approaches performs the best. However, when prices of outputs are not directly observable, some degree of inaccuracy is practically inevitable.

3.2 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: labour (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.

Labour (L) is most often measured by the number of employees or man-hours, which should be treated with attention, 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, labour is sometimes incorporated into operating expenditures (OPEX) which are taken together as an aggregate measure of labour and materials. However, labour 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.

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, companies and even company departments. The capital can be measured directly in physical units, or indirectly. Both approaches have their advantages and disadvantages; they are well discussed in [8].

4 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.

4.1 Input and Output Variables

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

Only one category of output is considered (this approach is similar to e.g.[4]):

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

Further, fivecategories 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 costsper 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[2];
- x_3: other OPEX (in particular, services and depreciation)(CZK), i.e. the difference between OPEX and labour and energy costs;
- 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[11];
- 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 [13]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 labour costs, energy costs and other costs in OPEX.

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

4.2 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 index to calculate the input quantity index, the output quantity index, TFP growth and partial productivities of individual input factors.

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

5 Results and Discussion

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

5.1 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). Output quantity index is denoted by Y_F, input quantity index byX_F.The results can be also illustrated using Fig 1.

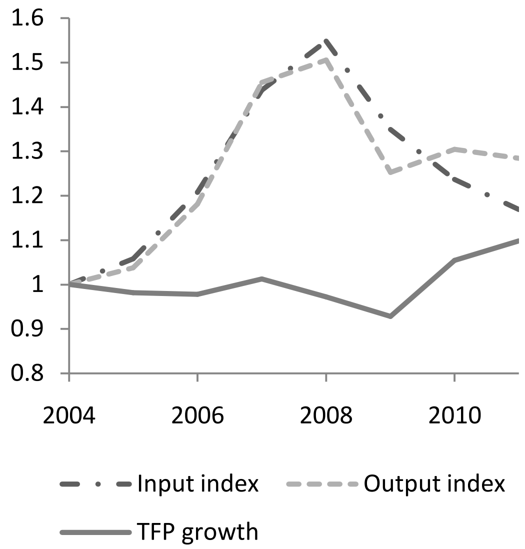
Tab. 2: Output and Input Quantity Indexes and TFP Growth

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

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.

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 decoupledpayments serve as a "financial pillow" increasing the level of the farmers' income and extending the farmers' decision-makingpossibilities [15].

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.

5.2 Partial Factor Productivities

Partial factor productivity is the ratio of the aggregate output over a specific input which

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measures the efficiency of input utilization. Formally, the partial factor productivity may be defined as

Equation 5

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

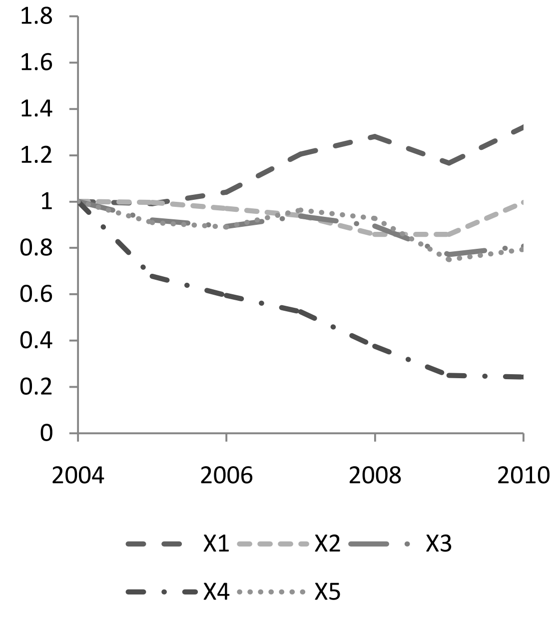
where Y is the output quantity index and X_i is the individual input quantity index.

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

Tab. 3: Partial factor productivities growth

Year	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 favourable, 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.

5.3 Trend Productivity Growth for 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. [10]). 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.

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, [12])**
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. The demand for agricultural production has been relatively steady. Thus, the agricultural TFP growth does not move in the same direction asthe growth of the economy.

6 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.

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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 2004-2011, 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 sectorprovides 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 has been relatively steady. Together with these arguments, the results of our analysis suggest that the agricultural TFP growth does not necessarily move in the same direction asthe growth of the economy.

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