TOTAL FACTOR PRODUCTIVITY CHANGE IN THE CZECH POULTRY SECTOR

Marie Pechrová – Tomáš Medonos

Abstract

The poultry sector experienced an important change in technology in 2012 when certain type of battery cages was banned. The increased investments to new technologies might have influenced the performance of the farms. Therefore, the aim of the paper is to assess the changes in total factor productivity (ΔTFP), technology (ΔTECH) and efficiency (ΔTE) of the poultry farms in the Czech Republic during years 2007–2013. Malmquist index was used to construct input oriented frontier and to assess the change in total factor productivity. It was further decomposed to technical and efficiency change. The results show that TFP and TE were negatively affected by the financial crisis in years 2008-2009. However, there is a difference between those two. While the changes in TE were negative until 2009, the ΔTFP was between years 2007-2008 positive. Overall efficiency (under constant returns to scale) of farms was on average at 81.58% level. Pure technical efficiency (under variable returns to scale) amounted on average to 91.46%. The technological progress is desirable, but the ΔTECH in 2009-2010 implies the downward shift of the technology frontier. It might be due to the requirements on breeding technology required since 1st January 2012.

Key words: efficiency change, Malmquist index, technical change, total factor productivity

JEL Code: H21, C33

Introduction

The poultry sector experienced an important change in technology since 1st January 2012 when certain type of battery cages was banned by Directive 1999/74/EC. The main argument was the animal welfare which "is a public good which, once provided for one person, is also provided for everyone (non-rival in consumption) and no one can be prevented from enjoying the benefits of improved animal welfare (non-excludable)" (Harvey and Hubbard, 2013). The farms in EU and hence in the CR had to adjust the cages and also the production halls. While some member states tried to postpone the date of force of the legislation (which was decided already in 1999), Czech producers rather decided to adjust the technologies already in 2008.

Impact of level of battery cages on egg production should not be significant as study of Ioniţă et al. (2015) showed that "the influence of the battery level cage, when using continuous lighting and a batch of differences between productive performance of quail on 5 levels are not significant unless specific environmental consumption and sustainability". However, there might be the influence on the economy of farm. As a result of necessary investments by the firms in 2011, the number of utility laying hens decreased by 3.9%. There were 4.28 million of them at the end of the year 2012, but only 4.12 million CZK at the end of 2013 (CZSO, 2013). The production capacities stayed larger as according to the legislation, the farmers could keep old production halls when they were not housing there any hens. It was expected that after the reconstructions and adjustments the capacities of rearing laying hens would decrease by 1 million from 5.1 to 4.1 million (Kütner, 2012). However, some breeders build new or larger halls. The increased investments to new technologies might have influenced the efficiency and the productivity of the farms. Therefore, the aim of the paper is to assess the changes in total factor productivity (ΔTFP), in technology (ΔTECH) and in efficiency (ΔTE) of the poultry farms in the Czech Republic during years 2007–2013.

The paper is structured as follows. Firstly, the results of previous researches in poultry sector are presented. Next section describes used data and method (Malmquist productivity index). Then the results of the analysis are displayed and discussed. Last section concludes.

There are several methods, how the TFP can be calculated. It can be based on the national account data; hence, it measures the productivity of the economy as a whole or of its sectors; or it can utilize farm-level data (as it is the case in our paper); then the productivity of the agricultural sector as an aggregation of farm-level productivity is assessed.

TFP growth is generally estimated by parametric or non-parametric approaches. First mentioned require use the stochastic frontier to estimate the cost or production functions. Non-parametric methods utilize accounting techniques and index numbers. Rodriguez et al. (2010) used Tornqvist index to assess the TFP change in the poultry sector of the Philippines. They found out that TFP growth had a significant impact in explaining the increase in revenues and reduction in production costs for the sector. Čechura et al. (2015) searched for the determinants of the TFP changes in cereals, dairy, and pork branches of Czech agricultural sector. Karimi et al. (2014) assessed the technical efficiency change in agriculture in Iran during 5 year development plan between years using stochastic Malmquist index. They found that in the poultry sector, the index was higher than 1 since the second year of the realization of the plan implying that it brought the desirable results. Vasiliev et al. (2011) analysed the productivity change of Estonian dairy farms before (2001–2003) and after (2004–2006) the

accession to the EU. However, they found negative productivity growth in both periods. Nin et al. (2004) calculated partial factor productivity under the constant returns to scale (CRS) assumption and assessed the average annual productivity growth rate for pig and poultry sectors in China and other countries. They found out that "annual average rate of technical change in poultry sector for the period 1961–1997 was 3.0% and for the period 1961–1997 2.4%" (Nin et al., 2004).

2 Methods and Data

TFP change is an important performance indicator which measures technological progress and improvement in production efficiency. Productivity improvement is a cornerstone for farmers to make profits and keep their businesses competitive. In a narrower sense the competitiveness is the level of productivity of resources compared to competitors in other countries (MoA, 2014). Productivity measures how much output is produced with a given set of inputs (output orientation) or how much input is used for a given set of outputs (input orientation). Based on the orientation type, Malmquist TFP index (MPI) gives different results. Its changes are a sum of technical and efficiency changes. Technical change (ΔTECH) measures the production frontier–shift due to innovations and efficiency change (ΔTE) the "catch-up" effect, i. e. how companies improve their efficiency to get closer to the frontier technology. "The Malmquist TFP index measures the TFP change between two data points by calculating the ratio of the distances of each data point relative to a common technology." (Coelli et al., 2005) When panel data are available, data envelopment analysis (DEA) can be used to observe the changes in productivity between period *s* (base year) and *t*. Detailed approach of MPI calculation using DEA frontier can be found e.g. in Coelli et al. (2005). Supposing that the company produces **q** outputs with **x** inputs, MPI is written as the ratio of input distance functions d_i (1):

$$m_i^s(\mathbf{x}_s, \mathbf{q}_s, \mathbf{x}_t, \mathbf{q}_t) = \frac{d_i^s(\mathbf{x}_t, \mathbf{q}_t)}{d_i^s(\mathbf{x}_s, \mathbf{q}_s)}, \tag{1}$$

where the reference technology is taken from period *s* and as (2):

$$m_i^t(\mathbf{x}_s, \mathbf{q}_s, \mathbf{x}_t, \mathbf{q}_t) = \frac{d_i^t(\mathbf{x}_t, \mathbf{q}_t)}{d_i^t(\mathbf{x}_s, \mathbf{q}_s)}, \tag{2}$$

where the reference technology is taken from period *t*. The calculations are equivalent only if technology is Hicks output neutral. Therefore, a geometric mean of both is used (3):

$$m_i(\mathbf{x}_s, \mathbf{q}_s, \mathbf{x}_t, \mathbf{q}_t) = \sqrt{\frac{d_i^s(\mathbf{x}_t, \mathbf{q}_t)}{d_i^s(\mathbf{x}_s, \mathbf{q}_s)} x \frac{d_i^t(\mathbf{x}_t, \mathbf{q}_t)}{d_i^t(\mathbf{x}_s, \mathbf{q}_s)}}, \tag{3}$$

Value of m_i greater than one indicates positive TFP growth. The equation (3) can be rearranged to show that it is equivalent to the product of technical efficiency change index and an index of technical change (4).

$$\begin{aligned} \Delta TFP = m_i(\mathbf{x}_s, \mathbf{q}_s, \mathbf{x}_t, \mathbf{q}_t) = \frac{d_i^t(\mathbf{x}_t, \mathbf{q}_t)}{d_i^s(\mathbf{x}_s, \mathbf{q}_s)} \sqrt{\frac{d_i^s(\mathbf{x}_t, \mathbf{q}_t)}{d_i^t(\mathbf{x}_t, \mathbf{q}_t)} x \frac{d_i^s(\mathbf{x}_s, \mathbf{q}_s)}{d_i^t(\mathbf{x}_s, \mathbf{q}_s)}} = \\ = \Delta TE_i(\mathbf{x}_s, \mathbf{q}_s, \mathbf{x}_t, \mathbf{q}_t).\Delta TECH_i(\mathbf{x}_s, \mathbf{q}_s, \mathbf{x}_t, \mathbf{q}_t), \end{aligned} \tag{4}$$

Accountancy data were obtained from Albertina database of Bisnode, s.r.o. There were 168 observations for 24 poultry firms (NACE5A 01470). As calculation of MI requires balanced panel data, there were 7 observations per each farm for years from 2007 to 2013 (see descriptive characteristics in Tab. 1).

Tab. 1: Statistical description of the sample (variables in thous. CZK per year)

	Production *y*	**Personal costs x_1**	**Intermediate consumption x_2**	**Capital x_3**
2007	174 009	25 039	136 710	9 892
2008	172 664	26 551	159 250	10 083
2009	196 954	22 535	117 506	8 960
2010	189 647	23 071	121 393	8 514
2011	168 893	23 271	142 952	8 985
2012	199 552	25 778	171 020	9 727
2013	185 396	23 754	161 740	8 878
Mean	183 874	24 285	144 367	9 291
Stand. dev.	259 124	37 987	208 440	15 981
2013/2007	1,07	0,95	1,18	0,90

Source: own elaboration

Production (*y*) is expressed in CZK per year and is deflated by price index of agricultural producers. It would be more appropriate to use deflator for slaughter poultry or for eggs, because the price development was different during years. It can be seen from Tab. 2 that in 2009 the prices of eggs increased while the prices of slaughter poultry and of agricultural producers as a whole decreased. The opposite situation occurred in 2011 and 2013. While the agricultural producers' prices decreased in 2012, the prices for slaughter poultry and eggs increased. Therefore, the development of productivity might vary among different producers. We tried to divide the companies on those more targeted to slaughter

poultry and eggs production, but many of them produce both or have also other production. It was not possible from available data to precisely distinguish the production structure of farms. Personal costs (x_1) deflated by index of annual growth of wages in agriculture are used as a proxi for the number of employees. Intermediate consumption (x_2) and capital (x_3) represents the production resources. Capital consists of depreciations of tangible and non-tangible assets and paid interests for credits used for acquisition of these assets (x_2 was deflated by index of input prices for agriculture and x_3 by price index for goods and services contributing to agricultural investment). The calculations were done in Stata 11.2.

Tab. 2: Price index of agricultural producers and of slaughter poultry and eggs

Price index	2007	2008	2009	2010	2011	2012	2013
Agricultural producers	1.000	1.088	0.818	0.862	1.027	0.895	1.073
Slaughter poultry	1.000	1.080	0.983	0.965	1.050	1.097	1.125
Eggs	1.000	1.049	1.035	0.978	0.856	1.332	0.685

Source: Czech statistical office, own elaboration

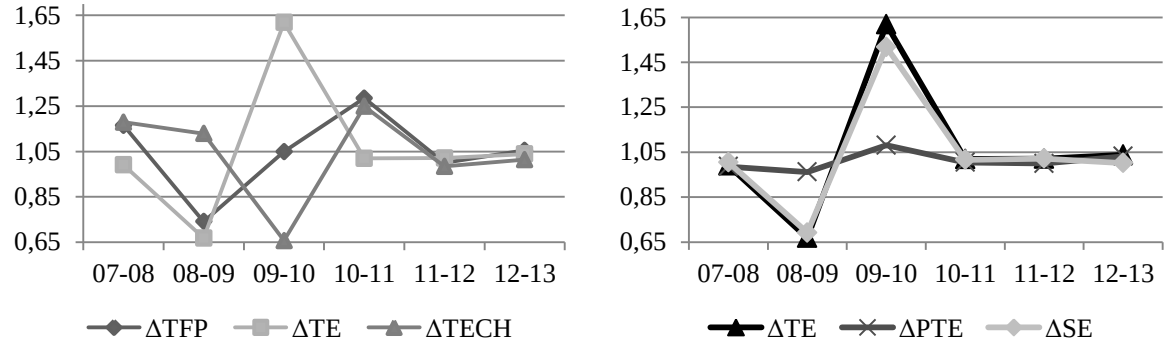
Results

MPI shows that there was an increase in TPF in poultry sector by 4.89 percentage points (p.p.) during the examined period 2007–2013. The development of TFP in previous period (2004–2007) was analysed by Čechura (2012). He found out that TFP for the total agriculture increased between the years 2004 and 2005, but entered a decreasing trend since that. Particular, "the sector of animal production experienced a significant decrease in TFP in the last year of the analysed period." (Čechura, 2012). On average for the period 2007–2013 the technical change (increase by 3.52 p.p.) contributed to the ΔTFP less than change in TE (increase by 5.92 p.p.), but it was more variable (std. dev. 0.33). It means that the poultry companies experienced rise of productivity more due to individual improvement in efficiency than due to shift of the frontier and technology improvement.

The development of observed variables in time is displayed at Fig. 1. As expected, the highest deflection of TFP change was between years 2008–2009 during economic crisis. Only ΔTECH was not affected that significantly in that year. According to Čechura et al. (2012) the most important factors which influencing TFP of agriculture in the CR in years 2004–2007 were those connected with economic and institutional changes (particularly a dramatic increase of meat imports and increasing subsidies). In our research, the companies had already accommodated the changes related to the entrance to the EU, but the changes related to the

requirements of new battery cages might have had negative influence on ΔTECH between years 2009–2010. According to the speaker of Czech-Moravian poultry union, Czech producers started to adjust the technologies since 2008. They were able to comply with legislation in 2012. However, 13 member states and especially Polish producers (as Czech main competitors) were not able to fulfil the requirements which created unequal conditions (Mach, 2012). Despite that, the impact on ΔTFP was not significant as it achieve value close to 1 in years 2011–2012 and 2012–2013.

Fig. 1: Development of ΔTFP, ΔTECH and ΔTE, ΔPTE, ΔSE



Source: own elaboration

While the ΔTFP continued in positive growing trend and ΔTECH was remarkably lower than 1 (on average 0.66; half of companies had ΔTECH even less than 0.62) in years 2009–2010, ΔTE was highly positive (on average 1.62; three companies had ΔTE even higher than 2). However, its role might have played the price index as the prices of eggs and slaughter poultry producers decreased significantly between those years, but agricultural producers' prices in general increase. Nevertheless, between those years, the total production continued to decrease (see Tab. 1), but the personal costs and interim production increased. On the other hand, the use of capital was the lowest in year 2010 from the observed period. The catch-up effect (i.e. inefficient firms trying to cope with the leaders) was on average more pronounced than the technology change during the examined period. While the changes in technical efficiency under constant returns to scale were dramatic as same as the changes in scale efficiency (there was the same drop between years 2008–2009), the changes of efficiency under variable returns to scale (changes in pure technical efficiency) were mild.

Average company was efficient from 81.58% if the technology exhibits constant returns to scale. There were 27 companies 100% efficient. If there were variable returns to scale (increase in input by 1 unit mean increase of output by more or less than one unit), than

an average firm would be efficient from 91.46%. Scale efficiency was on average 88.99% as in 27 cases the farms were 100% efficient and operated at optimal scale. Efficiency was the highest in 2012. On the other hand, the most pronounced drop was in 2008 due to economic crisis. The results are displayed in Tab. 3.

Tab. 3: Descriptive characteristics of TE, PTE, and SE

	Mean	Std. dev.	2007	2008	2009	2010	2011	2012	2013
TE	0.8158	0.1591	0.8348	0.8247	0.5488	0.8598	0.8644	0.8762	0.6851
PTE	0.9146	0.0965	0.9142	0.9001	0.8731	0.9290	0.9167	0.9303	0.7111
SE	0.8899	0.1372	0.9144	0.9103	0.6499	0.9273	0.9417	0.9487	0.7230

Source: own elaboration

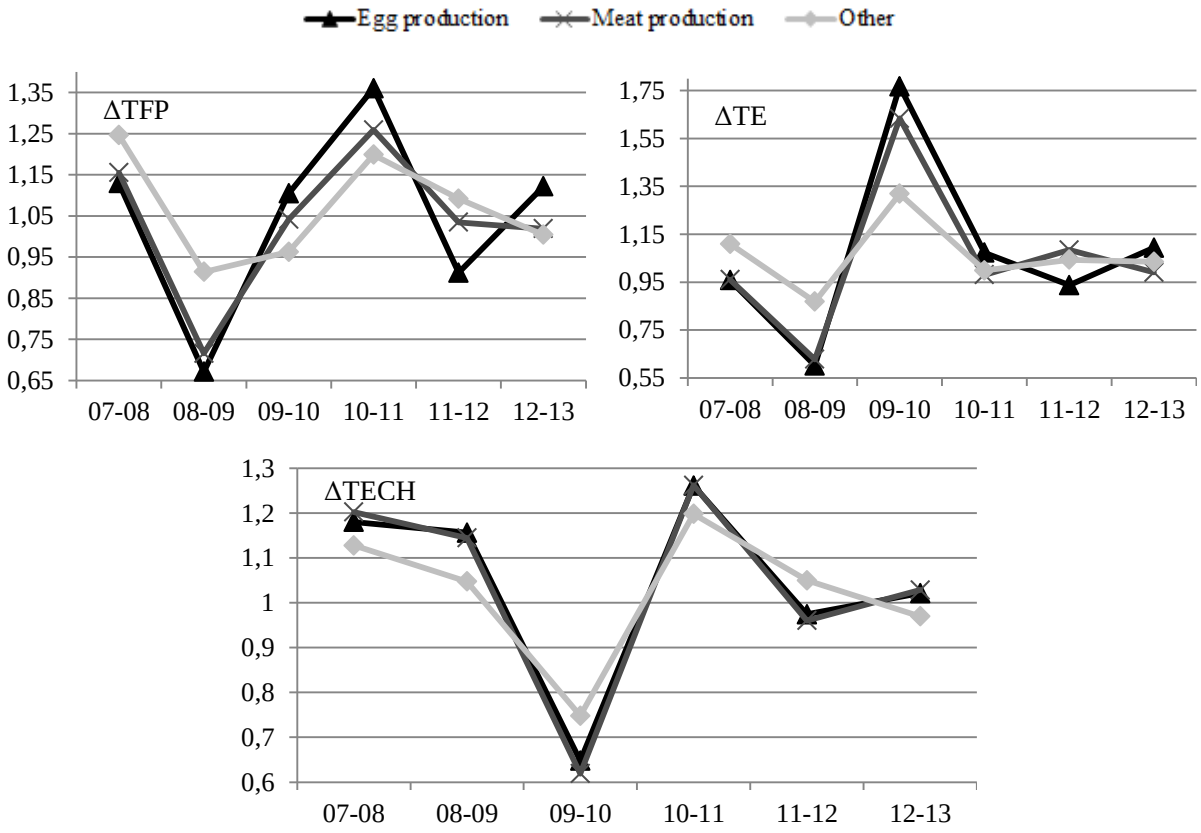
Regarding the production type there were 9 companies producing eggs and 10 broilers (meat production). The rest (5) had either both types of production or was concerned with water poultry. In this category, the ΔTFP was the highest (1.06) thanks to higher ΔTE (1.06). On the other hand, the lowest ΔTFP was in meat poultry production (1.04) due to low ΔTE (1.04). Eggs producers had the highest ΔTE (1.07) and ΔTECH (1.04). It is possible to see that the highest ΔTFP occurred in case of other production (1.07), than eggs production (1.05). However, the TE and TECH changes were the most pronounced in cases of producers of eggs. They were able to achieve high overall technical efficiency change due to high scale efficiency change (1.05). Nevertheless, in absolute terms, their input overall efficiency (74.25%), pure technical efficiency (85.67%) and scale efficiency (86.04%) were the lowest from all. The best situation was in meat production.

The decline of TFP change was caused mainly due to reduction of efficiency during crisis years 2008–2009. The technical change was the lowest in next period 2009–2010 for whole types of production. However, the less affected seems other production which is also the less variable from all types of production. Despite that the change of TFP in other production was the less affected by the economic crisis in 2008–2009, it stayed lower than 1 in the next period. Eggs producers managed to recover from crisis the quickest. Meat producers were less affected in terms of TFP change by the crisis in 2008–2009 and change of legislation in 2011–2012. Regarding ΔTECH, meat and eggs producers did not differ much.

In 2009 the production of poultry meat decreased by 4.3 %, but the consumption of it was almost constant. The difference was solved by imports which were on the highest level since year 1998. (MoA, 2010) It is due to the price decrease between years 2008 and 2009. The production of consumption eggs decreased further between years 2009 and 2010 by 7.4%

and the sale of slaughter poultry decreased by 18.6%. (CZSO, 2010). Despite that, TFP change was positive between those years in eggs production (1.11) and meat production (1.04). Only in case of other production it was negative (0.96). The highest TFP change (1.36) experienced poultry sector between years 2010 and 2011. ΔTE change contributed to this increase less (1.07) than ΔTECH change (1.26). It seems that needed change in technology (battery cages) played its role. Development through examined period is displayed at Fig. 2.

Fig. 2: Development of ΔTFP, ΔTE and ΔTECH according to the type of production



Source: own elaboration

Conclusion

The aim of the paper was to assess the changes in total factor productivity (ΔTECH), technology and efficiency in poultry sector between years 2007–2013. Non-parametric method was used. Particularly Malmquist productivity index was calculated based on input oriented DEA and decomposed on technical change (ΔTECH) and efficiency change (ΔTE).

Results indicate that during the examined period occurred total factor productivity growth (1.05) as same as positive efficiency change and technological progress. The catch-up effect (i.e. inefficient firms trying to cope with the leaders) was on average more pronounced (1.06) than the technology change (1.04) during the whole examined period. TFP and TE

were negatively affected by the financial crisis in years 2008–2009. The changes in TE stayed negative until 2009, but ΔTFP was between years 2007–2008 positive. The value of ΔTECH in 2009–2010 implies the downward shift of the technology frontier. It might be due to the requirements on breeding technology required since 1st January 2012. Between years 2010 and 2011 a technical change occurred in eggs production sector (ΔTECH amounted to 1.26), but in 2011–2012 it was negative again as same as between years 2009–2010. We might conclude that the farms might have been affected by the necessary investments. However, further investigation of investment activities (also in relation to subsidies) and of labour productivity is needed. Also more precise division of companies according to the type of production is desirable. Those are challenges for future research.

Acknowledgment

The paper was supported from the This paper was created within the Internal Research Project (IVP) no. 1273/2016 of Institute of Agricultural Economics and Information.

References

Coelli, T.J., Rao, D.S.P., O'Donell, C.J. & Battese, G.E. (2005). *An Introduction to Efficiency and Productivity Analysis* Retrieved March 30, 2016, from http://facweb.knowlton.ohio-state.edu/pviton/courses/crp394/coelli_Intro_effic.pdf.

Czech Statistical Office (CZSO) (2010). *Výsledky chovu drůbeže*. Retrieved March 29, 2016, from https://www.czso.cz/csu/czso/vysledky-chovu-drubeze-2010-znrqd9et0z.

Czech Statistical Office (CZSO) (2013). *Výsledky chovu drůbeže*. Retrieved March 29, 2016, from https://www.czso.cz/csu/czso/vysledky-chovu-drubeze-2013-xmdhv7vq6e.

Čechura, L. et al. (2014). *Total Factor Productivity in European Agricultural Production*. Retrieved April 15, 2016, from http://projects.iamo.de/fileadmin/compete /files/working_paper/COMPETE_Working_Paper_9_TPF_in_Agriculture.pdf.

Čechura, L., Kroupová, Z., Rudinskaya, T. (2015). Factors determining TFP changes in Czech agriculture. *Zemědělská ekonomika,* 12(61), 543–551.

Harvey, D. & Hubbard, C. (2013). Reconsidering the political economy of farm animal welfare: An anatomy of market failure. *Food Policy, 38*(February 2013), 105-114. doi:10.1016/j.foodpol.2012.11.006.

Ioniğă, L. et al. (2015). Study on the Influence of Average Daily Light Duration and Different Levels of Battery Cages on Production Performance of the Baloteti Hens Quail Population. *Agriculture and Agricultural Science Procedia,* 6(2015), 211–215.

Karimi, F., Keyvan, M. Z. & Keyvan, M. Z. (2014). Measuring and Forecasting TFP in Agriculture Subsectors of Iran during 5-year Socio-economic Development Plans. *Indian Journal of Fundamental and Applied Life Sciences*, 4(S4), 1439-1447.

Kütner, D. (2012, July 26). *Pokles chovu nosnic bude nižší*. Retrieved April 1, 2016, from http://zpravy.e15.cz/byznys/zemedelstvi/pokles-chovu-nosnic-bude-nizsi-858445.

Mach, M. (2012). *Vítězství ochránců zvířat: Od letoška se nesmí používat bateriové klece pro chov nosnic*. Retrieved April 5, 2016, from http://ekolist.cz/cz/zpravodajstvi/zpravy/vitezstvi-ochrancu-zvirat-od-letoska-se-nesmi-pouzivat-bateriove-klece-pro-chov-nosnic.

Ministry of Agriculture (MoA) (2010). *Situační a výhledová zpráva; Drůbež a vejce (červen 2010)* Retrieved March 28, 2016, from http://eagri.cz/public/web/file/78258/DRUBEZ_06_2010.pdf.

Ministry of Agriculture (MoA) (2014). *Program rozvoje venkova České Republiky na období 2014–2020*. Retrieved March 29, 2016, from http://eagri.cz/public/web/mze/dotace/program-rozvoje-venkova-na-obdobi-2014.

Nin, A., Hertel, T.W., Foster, K. & Rae, A. (2004). Productivity growth, catching-up and uncertainty in China's meat trade. *Agricultural Economics*, 31, 1–16.

Vasiliev, N. et al. (2011). Productivity of Estonian dairy farms decline after the accession to the European Union. *Zemědělská ekonomika*, 9(57), 457–463.

Rodriguez, U. E., Cabanilla, L. S. & Quilloy, A. J. (2010). Estimating Total Factor Productivity Growth from the Input-Output Table: An Illustration in the Poultry Sector of the Philippines. *Philippine Journal of Development*, 69(2), XXXVII, 99-110.

Contact

Ing. Marie Pechrová, Ph.D.
Institute of Agricultural Economics and Information
Mánesova 1453/75, 120 00 Prague, Czech Republic
Pechrová.Marie@uzei.cz

Ing. Tomáš Medonos, Ph.D.
Institute of Agricultural Economics and Information
Mánesova 1453/75, 120 00 Prague, Czech Republic
Medonos.Tomas@uzei.cz