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Content:

Comparison of Agricultural Costs Prediction Approaches

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Abstract

The paper submitted offers an assessment and comparison of three approaches to agricultural cost inputs short-term forecasting, that have been proposed as possible alternatives to tackle the problem. The data applied have been taken from the Czech Statistical Office and the Farm Accountancy Data Network data sources. The forecasts were prepared using time series analyses based on methods of exponential smoothing and Box-Jenkins methodology of autoregressive integrated process moving averages. The proposed change index numbers for the 2012, 2013 and 2014 years from three approaches were confronted with the real development of costs time series as it was found in the statistical FADN survey results. The main conclusion drawn pointed out that, for the purpose of economic income estimation based on the FADN database, the cost prediction approach based on the same database, i.e., on time series analysis of the FADN panel data, is the most applicable one. However, it is recommended, too, to use other approaches for crops protection products cost and labour cost development.

Keywords

Time series analysis, exponential smoothing, ARIMA models, cost inputs in agriculture, Farm Accountancy Data Network (FADN).

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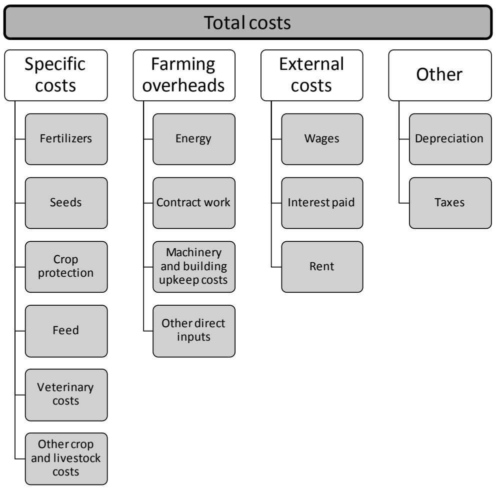
Introduction

The business development in agriculture considers the economic, environmental and social sustainability, based on the fundamental functions of agriculture for life in the landscape and society. For assessment of the economic sustainability of agriculture usually the production outcomes are considered, incomes in the shape of subsidies and the cost inputs. Applying this set of information, the economy results can then be expressed using various indicators.

Among those most important belongs the multi-factor productivity rate (the ratio of agricultural outputs to agricultural inputs), which is employed using various approaches for performance appraisal of agricultural holdings (Kostlivý et al., 2017) on the one side, and for agricultural policies assessment on the other side (Quiroga et al., 2017; Rizov et al., 2013). Another important measure of the final economy outcome is income, that can be expressed, e.g., using indicators of the type of Farm Net Value Added or Farm Net Income (European Commission – FADN EU, 2016) having been applied in many differently aimed analytical works (Špička, 2014; Deppermann et al., 2016). To support the management of agricultural holdings and the assessment of planned agricultural policies, a model has been formed based on the micro-economic data from the FADN network in the Czech Republic, for estimation of the economic outcomes of agriculture, using the indicators mentioned above (Hloušková et al., 2014). The paper presented here is dealing with the partial problem of year-on-year change of selected cost items, with the intention to submit a recommendation for agricultural incomes estimation modeling in its complex.

Costs can be sorted according to various viewpoints. The present text is considering the approach to costs sorting that is applied in the FADN and displayed in the Figure 1. The total costs are subdivided into Specific costs, Farming overheads, External costs and Other costs. The external costs are applied in the Family Farm Income indicator evaluation, what corresponds to profit after wages, interest and renting costs subtraction, and investment subsidies addition, less the investment tax. The biggest portion of the total costs is represented by intermediate consumption, set up of specific costs and farming overheads (European Commission – EU FADN, 2016). European Commission (2016) states that seeds, feed, energy and fertilizers belong among the intermediate consumption main costs; the long-term depreciation prediction (European Commission, 2016) is based on the production and inflation development function, and for costs projection the macro-economic data from the Economic Accounts for Agriculture are employed.

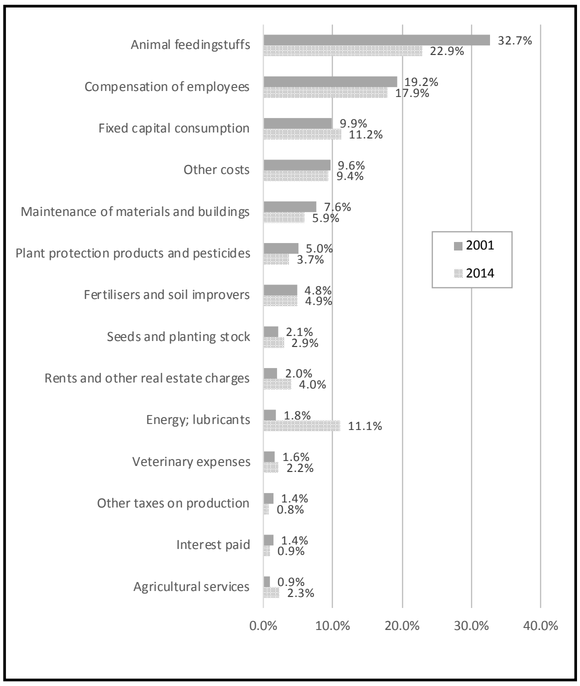


Source: own processing based on FADN methodology

Figure 1: Costs sorting scheme.

As a target of the paper presented, a comparison of the three approaches to the short-term prediction of cost inputs into agriculture can be assumed, and selection of the most suitable method for the cost component given. Solutions of the year-on-year prediction considered start from various data sources and different methods use. As data sources, the macro-economic data from the Czech Statistical Office (CZSO) and the micro-economic data from the Farm Accountancy Data Network in the Czech Republic (FADN CZ) have been applied. Among the cost items tested there are seed costs, fertilizers, crop protection, electricity costs, wages, and rent paid.

The shares of separate cost types on the total costs and the development of these between 2001 and 2014 years is presented in Figure 2. During that period, a significant reduction could have been observed of the cost shares on feed, pesticides, wages and maintenance of machinery and buildings. On the other hand, the shares of cost items on depreciation, renting, energy, seeds and agricultural services have risen. The fertilizer costs share remains the same. These changes observed are related to the development of agriculture´s structure and of the market environment.



Source: own processing based on Economic Accounts for Agriculture (CZSO)

Figure 2: Shares of cost items on the total costs (%).

Processing predictions in agriculture is complex in general, since the results are often affected by unforeseeable circumstances. In particular, it is the development of weather, infection situations in animal breeds, political instability (Allen, 1994) and unexpected changes in global development. These phenomena have an impact not only upon the agricultural production quality and quantity but upon the agricultural commodities market prices, too, the market situation, the consumer behaviour, and last but not least, upon the cost-input prices. In recent years there have been large fluctuations in commodity prices, which pose a problem in developing strategies both for farmers and agribusiness entrepreneurs and for policy makers (Khalid et al., 2014). For example, seed costs and feed costs belong among the basic costs of production consumption that are closely related to the results of agricultural production.

The specifics of agriculture should be reflected not only in modeling but for all the kinds of analyses (Allen, 1994). Usually, data on crop yields, numbers of animals or agricultural prices have been predicted using the time series in agriculture (Allen, 1994; Labys, 2003; Ishaque and Ziblim, 2013; Hamjah, 2014). For forecasting purposes, the exponential smoothing methods and the autoregressive integrated moving average (ARIMA) have been used in modeling most frequently. In case of cost prediction, it is advisable to consult research outside the field of agriculture, too. Many works have been dedicated to the crude oil prices projection, where E et al. (2017) have arrived with a combination of the variational mode decomposition methods, independent component analysis and ARIMA methods, whereby more precise forecasts have been reached.

In agriculture, medium-term and short-term forecasts have been applied (European Commission, 2017) or, forward-looking forecasts (European Commission, 2016; OECD, 2017). The present paper offers forecasts of change index numbers for one year ahead, i.e., it is a short-term forecast. Exponential smoothing methods and the Box-Jenkins autoregressive integrated processes methodology have been applied in the processing proper. The index numbers predicted have been compared with the actual time series development of the separate costs using the method of differences and totals, as it had been disclosed from the FADN statistical survey outcomes. This way, the most appropriate approach to the costs estimate has been found subsequently, and the resulting recommendation for the separate cost items forecast presented.

The main finding of the contribution is then the recommendation for use of the data source as well as the procedure for prediction processing of the cost component, which is a part of the comprehensive estimate of the income results of agricultural enterprises based on FADN CZ data.

Materials and methods

Three ways are accessible for prediction of the cost variables employed by the FADN method in the Czech Republic, in the business outcomes estimation.

Firstly, (***i***), it is possible to apply index numbers from the Czech Statistical Office output "Input agricultural price indices (corresponding period of previous year = 100)". A disadvantage of this approach, anyway, is in the late availability of the data – these are published quarterly with one-and-half month lag. It means, the information on index development during the estimated year could be available in the middle of February next year. The farm income prediction methodology has applied in the cost items estimation the "Input agricultural price indices" for the 3rd quarter of the year, which then was available at mid-November of the year estimated, from the Czech Statistical Office public database (Hloušková et al., 2014). Nevertheless, this index does not contain the cost prices development over the last three months of the year.

As a second approach (***ii***), the cost items time series panel data forecast from FADN database in the CR was identified. Results of this processing have been presented by Hloušková et al. (2015) in their final report. The process designed utilizes the population of panel data in time series since 2001. The basic advantage of panel data application is the reduction of impact of farm variation within the sample, upon results of the forecast. Among other advantages mentioned by Hsiao (2014) are, e.g., "more accurate predictions for individual outcomes", or, "providing micro-foundations for aggregate data analysis". Both the advantages of panel data mentioned have been utilized by the methodology described above in obtaining an accurate estimate of the representative FADN sample, generalized by weights and subsequently aggregated upon the level of the entire CR agriculture.

By the third way (***iii***), the prediction is utilized based on the time series of cost items in current prices from the Economic Accounts for Agriculture (EAA) published by CZSO. Prediction modeling based on the EAA data (CZSO, 2016b) has been performed within this paper. The time series available publicly contains data since 2001. STATISTICA CZ 12 programme has been employed in the processing.

In the second (***ii***) and third (***iii***) approaches, five models for data prediction in short time horizon have been applied, i.e., one-year prediction has been performed based on annual time series:

1. ARIMA (1,1,0), time series stationarisation by means of the first difference, autoregression parameter 1, with Melard method of exact estimate;
2. ARIMA (1,1,0), without estimate of the constant, stationarisation by means of the first difference, autoregression parameter 1, with Melard method of exact estimate;
3. Linear Holt exponential smoothing, without seasonal component, level smoothing parameter $\alpha = 0.1$, trend smoothing parameter $\beta = 0.1$;
4. Smoothing of the time series by means of Fourier transformation, ARIMA (1,1,0), time series stationarisation by means of the first difference, autoregression parameter 1, with Melard method of exact estimate;

5. Smoothing of the time series by means of Fourier transformation, linear Holt exponential smoothing, without seasonal component, level smoothing parameter $\alpha = 0.1$, trend smoothing parameter $\beta = 0.1$.

Six cost items obtained from the resources given above have been processed in comparison of the indices change. These are: purchased seed and seedlings, purchased fertilizers, plant protection costs, electrical energy, personal costs and renting costs. In order to obtain the change index numbers, time series since 2001 have been applied in the ***ii*** and ***iii*** approaches. The results have been verified on actual data from the given periods by means of differences and totals. To obtain reliable conclusions, testing has been performed for three years predicted, 2012, 2013 and 2014.

Advanced time series analysis adaptive techniques have been employed in the processing. Adaptive time series smoothing procedures using different parameters in separate short sections can be applied in such a case, when the time series cannot be explained by one function, i.e., the trend function is changing in time and it does not have constant parameters. When using the adaptive models, it is supposed that, the most up-to-date data have the strongest impact upon future development. Therefore, the most up-to-date data are preferred here, and older information in the time series given is assigned lower weights. For example, the method of moving averages or the exponential smoothing method can be included here. When shorter time series, typical for all the three varieties compared in this work become the object of study, among the various methods, e.g., the exponential smoothing method can be applied (Artlová and Artl, 1995). Using weighted averages, weights are assigned to separate observations and the weights become exponentially reduced, i.e., the lowest weights become linked to the oldest observations. We can then distinguish between simple exponential smoothing, double (Brown) exponential smoothing or Holt linear exponential smoothing.

Using the expanded simple exponential smoothing Holt succeeded already in 1957 at predicting time series with a trend. The Holt linear exponential smoothing model is composed of the balancing equation for estimation of the linear trend level in time t and of the balancing equation for estimation of the linear trend angle in time t, for h = 1, 2, ... and it can be expressed as

$$\hat{y}_t = l_t + hb_t \qquad (1)$$

where the estimate of the level is equal to

$$l_t = \alpha y_t + (1-\alpha) * (l_{t-1} + b_{t-1}) \qquad (2)$$

and the trend estimate can be derived from

$$b_t = \beta^*(l_t + l_{t-1}) + (1-\beta^*)b_{t-1} \qquad (3)$$

where α is the level equalizing constant ($0 \leq \alpha \leq 1$) and $\beta*$ is the trend equalizing constant ($0 \leq \beta* \leq 1$) (Hyndman and Athanasopoulos, 2013).

Another approach applied in time series forecasting in this work is the Box-Jenkins methodology of moving averages autoregressive integrated processes, called ARIMA modeling.

The aim of the models is to describe autocorrelation in the data. Autocorrelation informs about the power of linear relationship between random variables, where each observation is composed of the random error component (random shock) and a linear combination of previous observations. Partial autocorrelation cleans the random quantities from the impact of quantities situated among them. Applying graphical expression of autocorrelation, it can be simply discovered, whether the time series is a stationary one (Artl et al. 2002).

The Box-Jenkins methodology is assuming time series stationarity. As far as the time series properties are not dependent upon time of the series studied, the series can be considered a stationary one. Time series with trends or with seasonality are not stationary, since trend and seasonality should influence the time series values at different times. Conversely, a time series with white noise processes is stationary. Stationary processes are not frequent, therefore various methods can be applied in time series stabilization. One of these is the differentiation, where differences between subsequent observations are evaluated (Linden et al., 2003). In time series smoothing the Fourier transformation has been applied, too, so far used in commodity prices modeling in agricultural issues, e.g., by Enders and Holt (2012).

ARIMA models are based on the moving average processes (MA) and on autocorrelation processes (AR) and contain three parameters: p, d and q. The writing of such a model is done as ARIMA (p, d, q), where p is the autoregression parameter, d means the number of differentiations and by q is the moving average (Mošová, 2013).

The verification that, a function is not autocorrelated, has been done by means of graphical expression of the residual autocorrelation function (ACF), which is the expression of linear dependence of lagged values (horizontal axis) on autocorrelation coefficients of the residues rk (vertical axis).

The non-systematic component is not autocorrelated in case, that none of the autocorrelation coefficients exceeds the limits of 95% confidence interval $(\frac{-2}{\sqrt{T}}, \frac{2}{\sqrt{T}})$. In case, that annual time series are being analysed, it is recommended to use time series length of 30 years or more (Hanke and Wichern, 2008; StatSoft, 2013), which may be misleading in some cases. As Hyndman and Kostenko (2007) state, the time series length depends especially on data variation and number of applied parameters. The problem of EAA and FADN data use are short time series, available since 2001 only. They are annual time series unable to expand and not containing the seasonal component. Considering absence of other data sources at such a high discrimination level of cost items and taking into account the relevant outcomes, the methods applied at selected cost items have not been refused despite the risk of a less exact model construction.

Results and discussion

The solution is presenting a comparison of outcomes of the three approaches described above, in processing of development forecasts of selected cost items, where the predicted change index numbers have been confronted with the actual FADN results over the 2012-2014 period.

The change index numbers for the first approach (***i***) have been taken over from the published estimates of the year-on-year change in the inputs into agriculture quarterly index numbers (CZSO, 2016a). Change index numbers for the second approach (***ii***) have been taken over from the outputs of internal research project titled "Estimation of economic results in agriculture with low or null information on development in predicted year based on FADN" (Hloušková et al., 2015). The index numbers for the third designed approach (***iii***), which have been derived from the Economic Accounts for Agriculture (CZSO, 2016b), have been processed as part of this study based on the time series analysis methodology as given above.

The comparison of results of the selected cost items change index numbers considered for use in the micro-economic model of the agricultural income estimate based on FADN CZ is presented in Table 1. This table contains the actual year-on-year change index numbers, too, based on the results of finished FADN surveys. Results for the 2012, 2013 and 2014 years estimates have been compared here. Within the (***ii***) and (***iii***) approaches the analysis based on 10-year, 11-year and 12-year time series of year-on-year index numbers, begun within the 2002/2001 period, has been presented.

Most frequently, in fifteen cases, the ARIMA (1,1,0) method has been applied for forecasting. In eight cases the ARIMA (1,1,0) method with smoothing has been used. In six cases the ARIMA (1,1,0) constant-free method and the Holt linear exponential smoothing have been used. In one case, the Holt linear exponential smoothing method with time series smoothing using transformation has been used.

In the next step, deviations of each index number predicted from the actual year-on-year change of the cost items results registered by FADN survey were evaluated. The deviations are compared in Table 2, where the best fitting predictions for every cost item and period are highlighted in bold figures. Most occurrences with the lowest deviation from reality observed have been identified within the second approach which is based on time series analysis methods applied on the FADN CZ panel data. This approach suits best in the seed costs and renting forecasts. The first approach

Indicator predicted	Period	Approach	Index number predicted	Method (source)	Actual index number (2)
Seed and seedlings	2012/2011	*i*	1.0350	(1)	1.0735
		ii	1.0491	3 (3)	
		iii	1.0367	1 (4)	
	2013/2012	*i*	1.0780	(1)	1.0341
		ii	1.0132	3 (3)	
		iii	1.1290	3 (4)	
	2014/2013	*i*	0.9770	(1)	1.0152
		ii	1.0186	3 (3)	
		iii	1.0276	1 (4)	

Note: (1) Change index number taken from CZSO (2016a), (2) Change index number of weighted FADN results, (3) Change index number taken from Hloušková et al. (2015), (4) Own processing, data source CZSO (2016b), NA: not available
Source: own processing based on FADN methodology

Table 1: Results of change index numbers (to be continued).

Indicator predicted	Period	Approach	Index number predicted	Method (source)	Actual index number (2)
Fertilizers and soil improvers	2012/2011	*i*	1.1240	(1)	1.0972
		ii	1.0151	4 (3)	
		iii	1.0282	1 (4)	
	2013/2012	*i*	1.0310	(1)	1.1289
		ii	1.0482	4 (3)	
		iii	1.0167	1 (4)	
	2014/2013	*i*	0.9360	(1)	1.0146
		ii	1.0350	4 (3)	
		iii	1.0189	1 (4)	
Plant protection products	2012/2011	*i*	1.0780	(1)	1.0603
		ii	1.0123	4 (3)	
		iii	1.0006	1 (4)	
	2013/2012	*i*	1.0340	(1)	1.0823
		ii	1.0249	4 (3)	
		iii	0.9708	5 (4)	
	2014/2013	*i*	1.0200	(1)	1.0671
		ii	1.0204	4 (3)	
		iii	0.9912	1 (4)	
Electrical energy	2012/2011	*i*	1.0830	(1)	0.9733
		ii	0.9833	4 (3)	
		iii	1.0198	2 (4)	
	2013/2012	*i*	1.0310	(1)	1.0386
		ii	1.0017	1 (3)	
		iii	1.1137	2 (4)	
	2014/2013	*i*	0.8860	(1)	0.9118
		ii	1.0020	1 (3)	
		iii	1.0037	2 (4)	
Wages paid	2012/2011	*i*	*NA*		1.0358
		ii	1.0109	1 (3)	
		iii	1.0305	3 (4)	
	2013/2012	*i*	*NA*		1.0335
		ii	1.0123	1 (3)	
		iii	1.0249	3 (4)	
	2014/2013	*i*	*NA*		1.0557
		ii	1.0124	1 (3)	
		iii	1.0092	1 (4)	
Rent paid	2012/2011	*i*	*NA*		1.0772
		ii	1.0543	1 (3)	
		iii	1.0433	2 (4)	
	2013/2012	*i*	*NA*		1.1324
		ii	1.0515	1 (3)	
		iii	1.0319	2 (4)	
	2014/2013	*i*	*NA*		1.1078
		ii	1.0477	4 (3)	
		iii	1.0618	2 (4)	

Note: (1) Change index number taken from CZSO (2016a), (2) Change index number of weighted FADN results, (3) Change index number taken from Hloušková et al. (2015), (4) Own processing, data source CZSO (2016b), NA: not available
Source: own processing based on FADN methodology

Table 1: Results of change index numbers (continuation).

(***i***) has estimated the index numbers best in five cases and in case of the third approach, the lowest deviations then have been found in four cases only. For the wages cost change forecast over 2014/2013 almost identical deviations have been found both in the second and third approach cases. Seed forecast for the 2012/2011 period has been obtained very similar in the first and third approach cases. The plant protection products forecast for 2014/2013 is similar for the first and second approach cases.

The lowest mean deviation over all the three approaches compared has been obtained in case of the wages costs. On the contrary, the highest mean differences between predicted and actual year-on-year index numbers have been obtained in fertilizer and electrical energy cost variables. For wages and renting costs the information on agricultural inputs prices index numbers from CZSO is not available, since this data source does not contain the items mentioned.

The amounts of average absolute deviation over all the periods tested for separate cost items (Table 3) define the approach (***ii***) as the best suited one (the analysis of FADN panel data), since four cost items from the total of six items studied have been predicted most accurately. The wages costs development, on the contrary, is best predicted by means of the (***iii***) approach based on the CZSO macro-economic data time series analysis. As an interesting outcome, the most accurate prediction of plant protection products by means of the (***i***) approach has been discovered, where the "Input agricultural price indices" from the first two quarters of the year estimated have been applied (CZSO).

Indicator predicted	Period	Approach		
		i	ii	iii
Seed and seedlings	2012/2011	-0.0385	**-0.0244**	-0.0368
	2013/2012	0.0439	**-0.0209**	0.0949
	2014/2013	-0.0382	**0.0034**	0.0124
Fertilizers and soil improvers	2012/2011	**0.0268**	-0.0821	-0.0690
	2013/2012	-0.0979	**-0.0807**	-0.1122
	2014/2013	-0.0786	0.0204	**0.0043**
Plant protection products	2012/2011	**0.0177**	-0.0480	-0.0597
	2013/2012	**-0.0483**	-0.0574	-0.1115
	2014/2013	-0.0471	**-0.0467**	-0.0759
Electrical energy	2012/2011	0.1097	**0.0100**	0.0465
	2013/2012	**-0.0076**	-0.0369	0.0751
	2014/2013	**-0.0258**	0.0902	0.0919
Wages paid	2012/2011	NA	-0.0249	**-0.0053**
	2013/2012	NA	-0.0212	**-0.0086**
	2014/2013	NA	**-0.0433**	-0.0465
Rent paid	2012/2011	NA	**-0.0229**	-0.0339
	2013/2012	NA	**-0.0809**	-0.1005
	2014/2013	NA	-0.0601	**-0.0460**
The number of occurrences with the lowest deviation		5	9	4

Source: own processing based on FADN methodology

Table 2: Resulting comparison of approaches.

Indicator predicted	i	ii	iii
Seed and seedlings	0.0402	0.0162	0.0480
Fertilizers and soil improvers	0.0678	0.0611	0.0618
Plant protection products	0.0377	0.0507	0.0824
Electrical energy	0.0477	0.0457	0.0712
Wages paid		0.0298	0.0201
Rent paid		0.0546	0.0601

Source: own processing based on FADN methodology

Table 3: Comparison of deviation averages.

Estimates of economic results of agriculture processed based on the FADN database micro-economic modeling have been presented e.g. by the Natural Resources Institute Finland (2016), where the average agricultural production purchase price index numbers have been employed in the cost development forecasts. As far as plant protection products are concerned, the methodology designed here suits better for the Czech Republic environment needs than the Great Britain approach. This type of estimates is prepared there within the Farm Business Survey (Rural Business Research, 2016) based on the FADN statistical survey. However, plant protection costs are considered at the same amounts as in the last year, because the amounts spent on plant protection are not connected with input costs (oil, natural gas) whose market prices are available. This approach applies the so-called naive forecasting, presuming that, the costs in future years will be at the same height as it is known from the most up-to-date information.

In the USA the income forecasts in agriculture are processed within the Farm Sector Income Forecast (USDA, 2016), where, as data source, the Agricultural Resource Management Survey at farm level is employed.

Other input information is consulted with agricultural project design macro-economic outputs (Agricultural Baseline Projection). Here, e.g., a projection of energy costs until 2025 has been prepared, expecting that, lower prices of oil and gas will bring about a decrease of costs in agriculture, which in particular concerns fertilizers and fuel.

In Canada, the Canadian Agricultural Dynamic Microsimulation Model (CADMS) has been applied, supplying forecasts concerning sales, costs and business assets at enterprise level. The model outcomes, inter alia, offer an overview of revenues in a more detailed shape, what is the value added of this model (Galbraith et al., 2011).

Conclusion

In the Czech Republic, there are limited information sources on prices of the separate cost items entering the production process of agricultural enterprises. For trend determination in the development of costs two relevant sources of representative data are available. These are the CZSO macro-economic data and the FADN CZ micro-economic data.

Outcomes of the studied issues bring new knowledge on the chances of costs forecasting in agriculture. Through comparison of the three approaches designed, differing in processing methodology and input information, it was discovered that, for agriculture income estimation based on the FADN database, the second approach (***ii***), based on the FADN panel data time series analysis, is the best applicable one. The advantage of this approach for the given purpose is data availability. In particular, current data available at the moment of application. Moreover, data can be subdivided in various categories according to needs, and the development of costs can be distinguished by the various enterprise size groups or production farm type. It has been confirmed that, good outcomes can be obtained applying time series of several cost item types, available in FADN CZ database since 2001.

However, other conclusions include the finding that not only one of the tested methodologies can be selected to predict various cost types, even though one approach is identified as the most accurate in many cases tested. When processing a short-term estimate, the cost type has to be taken in account. Based on the results, the "Input agricultural price indices" from the CZSO can be recommended for plant protection products development estimates, that have been found most accurate. The plant protection products time series is not suitable for future development forecasting, using the time series analysis described above, from none of the data sources applied. The development of fertilizer costs, which in each test period approached the real development of another tested technique, appears unclear. On the contrary, the third procedure approach, (***iii***), based on the Economic Accounts for Agriculture time series analysis, has been recommended for the wages costs future development.

The conclusions coming out from the presented paper set up an important background for updating the current methodical approach of the agriculture results estimation based on the FADN data.

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Price Transmission Analysis: the Case of Milk Products in Russia

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Abstract

This paper investigates vertical price transmission along the milk supply chain in the Russian market using a vector autoregression model. Monthly farm-gate and retail prices were used in the analysis. Using cointegration technique, we find no empirical evidence for cointegration between farm-gate and retail prices. We show that there is bidirectional Granger causality from farm to retail prices and vice versa. However, response of the farm-gate price to a change in retail price is greater and slightly longer than price response of the retail price to a change at the farm level. The results support the assumption that price changes are not transmitted efficiently from one level to another.

Keywords

Vertical price transmission, market power, cointegration, vector autoregression model, dairy prices, Russia.

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Introduction

In Russia, dairy producers express concerns about the fact, that price changes are not transmitted efficiently from farmers to retailers. This state of play caused reallocation of incomes from rural sector to other sectors. There was a great deal of studies to analyze vertical price transmission that applied time series econometric procedures. However, much analysis on vertical price transmission in the food markets focuses only on selected countries rather than Russia. In this context, we are motivated to study vertical price transmission along the dairy supply chain in Russia to get good insight into the price interaction at the various levels of marketing chain (farm-retail). There is some gap in our knowledge concerning price transmission on Russian food markets that the paper sought to fill. Kharin (2015) used farm-gate and retail prices for estimating the vertical price linkages along the whole milk supply chain in one of the Russian region. The findings provide evidence of unidirectional Granger causality from retail to farm prices and not vice versa. Pokrivcak and Rajcaniova (2013) examine price transmission mechanism between farm and retail levels in vertical chain of potatoes in Slovakia. They found an evidence of structural break and existence of asymmetry in price transmission along the potato supply chain. Dai Jiawu et el. (2017) estimated the VAR systems for pork retail price and price transmissions in different links of China. Empirical results indicated the asymmetry of price transmission in the Chinese pork market, and demand and supply shocks from three food scare incidents were found to impact retail price and price transmissions differentially. Byeong-il Ahn and Hyunok Lee (2015) investigate the asymmetry of price transmission in the marketing chain of shipping points and terminal markets for fresh fruits in the western United States. Their results indicate that the price adjustments and asymmetry patterns are closely related to product characteristics, especially the intensity of product perishability. In the study of Zhuo Ning and Changyou Sun (2014), the degree of vertical integration and the presence of asymmetric price transmission are investigated for saw timber and lumber products in the southern and western United States. Asymmetric price transmission is found along the timber supply chain. In the long term, prices are more responsive when the price margin is increased than decreased. The paper by Byeong-il Ahn and Hyunok Lee (2013) extends the estimation of price relationships in wood processing and empirical assessment of asymmetric price transmission by incorporating time lags in both explanatory and dependent variables. The empirical findings in this study suggest the potential for lower wholesale prices of fiberboard with more competition in wholesale marketing. Fousekis et el. (2016)

investigate vertical price transmission in the US beef supply chain. The empirical results indicate the presence of asymmetry in magnitude for the pair of markets farm-wholesale and the presence of both asymmetry in speed and asymmetry in magnitude for the pair of markets wholesale-retail.

In general, it is clear, that, mostly, prices are imperfectly transmitted along the supply chain. That is, a shock to prices at one level (say, the farm level) is not instantaneously passed through to wholesale and retail prices, as assuming perfect competition and zero profits would predict. There are good reasons for less than full pass-through apart from the existence of market power (for example, menu costs to changing prices, fixed-price contracts).

The main aim of this paper is to investigate vertical price transmission on the diary market in Russia. The paper addresses following research questions. Firstly, the long-term relationship between the milk prices at farm-gate and retail level is analysed. Subsequently, the price transmission elasticity is estimated. The contribution of the paper is twofold. Firstly, it provides a review dealing with the issue of price transmission in Russian dairy market. Secondly, it gives empirical evidence of vertical price linkages in the Russian dairy sector by taking into account the structural breaks.

Materials and methods

The price transmission analysis has been carried out using monthly dairy prices from 2002 to 2014 at the farm-gate and retail levels in Russian Federation. The source of the data is the Federal State Statistics Service of Russia. We use the logarithmic transformation of monthly prices measured in Russian rubles per liter.

The influence of farm-gate (retail) price on retail (farm-gate) price is investigated using multiple linear regressions. Initially, we consider P_{1t} to be the (natural) logarithm of retail price and P_{2t} to be the (natural) logarithm of farm-gate price.

Then we specify the model (Ansah, 2012)

$$P_{1t} = \alpha + \beta P_{2t} + \gamma G_t + \varepsilon_t \qquad (1)$$

where t - index of time, α - constant term (the log of a proportionality coefficient), β - the elasticity (magnitude) that measures the percentage change in price P_1 (retail) due to a one percentage change in price P_2 (farm-gate), G_t – government policy variable.

If there is a stationarity in the data, then equation 1 can be estimated with ordinary least squares (OLS) regression. Stationarity represents a process in which the mean and standard deviation does not change over time. But mostly price time series are non-stationary that generally leads to spurious regression. A spurious regression has significant relationship between variables but the results are in fact without any economic meaning. In the presence of non-stationary data, it is required to carry out some transformation such as differencing (or detrending) to make them stationary. Thus, equation 1 cannot be estimated correctly with OLS. However, pairs of non-stationary price series can have a long-term relationship between them. If a price series is differenced once (by subtracting Pt-1 from Pt) and the differenced series is stationary, the time series is then "integrated of order 1", denoted by I (1). Non-stationarity means presence of unit roots. A variable contains a unit root if it is non-stationary.

$$P_t = \beta P_{t-1} + \varepsilon_t \qquad (2)$$

In the equation 2 if β =1 the model is characterised by unit root, stationarity requires that $-1<\beta<1$. In testing for the presence of unit roots, several methodological options are available. Widely used among them are the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) as well as the Phillips-Perron test (Phillips and Perron, 1988).

As a standard procedure to test the non-stationarity of price series the ADF test uses following regression:

$$P_t = c + \beta t + \alpha P_{t-1} + \sum_{i=1}^{k} \psi_i \Delta P_{t-i} + \varepsilon_t \qquad (3)$$

where P_t - natural logarithm of the price, c - intercept, t - linear time trend. This regression includes k lagged first differences to account serial correlation.

Phillips-Perron test builds on ADF test. While the ADF test uses a parametric autoregression, a great advantage of PP test is that it is non-parametric, i.e. it does not require to select the level of serial correlation as in ADF. The main disadvantage of the PP test is that it works well only in large samples. And it also shares disadvantages of ADF tests: sensitivity to structural breaks, poor small sample power resulting.

The Phillips-Perron and ADF tests specify the null hypothesis that a time series is non-stationary, i.e. unit root is present. In small samples, the general observation is that the Augmented Dickey-Fuller and Phillips-Perron tests have low power.

Often structural breaks present in time series (for instance, change in government policy which is denoted with G_t in equation 1). Structural breaks can result in wrong conclusion about the presence of unit root. Therefore, we should apply unit root test taking into account the presence of structural breaks.

Zivot-Andrews (1992) test is an Augmented Dickey-Fuller (ADF) based unknown structural break test which estimates the model assuming a possible break at each point and chooses the break date where the t-statistic from ADF test of unit root is at minimum. In our case, ZA test is more preferable as we do not know the exact date of structural break (in comparison with other unit root tests for structural breaks).

The test runs the following three regression models:

1. model A which allows for a one-time change in the intercept of the series;
2. model B which permits a one-time change in the slope of the trend function;
3. model C which combines a one-time structural break in the intercept and trend.

The models are given below:

$$P_t = a + \varphi P_{t-1} + \sum\theta_i \Delta P_{t-i} + \beta_t + \gamma D_t + \mu_t \quad \text{(Model A)} \qquad (4)$$

$$P_t = a + \varphi P_{t-1} + \sum\theta_i \Delta P_{t-i} + \beta_t + \gamma DT_t + \mu_t \quad \text{(Model B)} \qquad (5)$$

$$P_t = a + \varphi P_{t-1} + \sum\theta_i \Delta P_{t-i} + \beta_t + \gamma D_t + dDT_t + \mu t \quad \text{(Model C)} \qquad (6)$$

where D_t is a dummy variable to capture an intercept shift occurring at each possible break date (T_B), and DT_t is a trend shift dummy variable. D_t equals 1 if $t > T_B$, and 0 otherwise; and DT_t equals $t - T_B$ if $t > T_B$, and 0 otherwise.

The null hypothesis in all the three models is that the series contains a unit root with a drift that excludes any structural break, while the alternative hypothesis implies that the series are a trend-stationary with a one-time break occurring at an unknown point in time.

Co-integration means that prices move closely together in the long-run, while in the short-run they may drift apart. There might be a linear combination of same integrated price series that is stationary. Co-integration analysis is used to estimate long-run price relations between non-stationary and same integrated variables.

Given that some of price series will be non-stationary, we will apply conventional Granger-Engle approach to test for co-integration. Engle and Granger (1987) used a technique to test for co-integration which included the static following regression estimated with OLS:

$$\tilde{P}_{1t} = a + \beta\tilde{P}_{2t} + \varepsilon_t \qquad (7)$$

If $\tilde{P}_{1t}$ and $\tilde{P}_{2t}$ are I(1) price series, then the residuals v_t from the regression would be I(0) if they are co-integrated. So, if the residuals are I(1) we accept the null hypothesis of non-cointegration, otherwise, if the residuals are stationary, I(0), we reject the null hypothesis and accept that $\tilde{P}_{1t}$ and $\tilde{P}_{2t}$ are co-integrated.

ADF test for unit roots is applied to residuals from the co-integrating regression. First, we should test whether the price series have the same order of integration using unit root tests. If both price series have the same order of integration, we will carry out test for co-integration between the prices.

However, the power of Engle-Granger test is decreased if there is a structural break in co-integrating relationship. To avoid this problem, Gregory and Hansen (1996) improved the Engle-Granger regression in order to take into account structural breaks in the intercept or in the intercept and trend. These models are specified as follows:

Model C: Level shift

$$P_{1t} = \mu_0 + \mu_1 \varphi_t + \alpha P_{2t} + \varepsilon_t \qquad (8)$$

Model C/T: Level shift with trend

$$P_{1t} = \mu_0 + \mu_1 \varphi_t + \beta_t + \alpha P_{2t} + \varepsilon_t \qquad (9)$$

Model C/S: Regime shift

$$P_{1t} = \mu_0 + \mu_1 \varphi_t + \alpha_1 P_{2t} + \alpha_2 \varphi_t P_{2t} + \varepsilon_t \qquad (10)$$

where φ_t – dummy variable equals 1 if t >T, 0 otherwise; T = $[n\tau]$ point at which a break occurs (n – sample size, $\tau \in (0,1)$).

Gregory and Hansen (1996) suggested three statistics for aforementioned models: ADF*, Z_a^*, Z_t^*. They are corresponding to the traditional ADF test and Phillips type test of unit root on the residuals.

First, for each possible breakpoint T, estimate the models (8)-(10) by OLS, obtaining the residual series (ε_t) from which we can get the values of ADF, Z_t, Z_a test statistics. Z_t and Z_a test statistics were suggested by Phillips (1987). According to Gregory and Hansen, we compute the test statistics for each possible break point in the interval [0.15n, 0.85n]. The statistic of the cointegration test with breaks (ADF*, Z_a^*, Z_t^*) is the smallest value of the conventional ADF, Zt and Za test statistics across all values of every possible breakpoint.

Second, compare the value of ADF*, Z_a^*, Z_t^* test statistics and the critical value given by Gregory and Hansen (1996). The single break date in these models is endogenously determined. The null hypothesis of non-cointegration with structural breaks is tested against the alternative of cointegration by Gregory and Hansen approach. The null hypothesis is rejected if the statistics ADF*, Z_a^*, $Z_t^*$are less than critical values.

After testing for co-integration we will apply the Granger Causality test (1969) to evaluate the possible direction of the price transmission. The basic principle of Granger causality is that two variables P_1 and P_2 can have influence on one another. The starting point of the method is that P_1 variable Granger causes P_2 variable but P_2 does not Granger cause P_1.

$$P_{2t} = \sum_{i=1}^{n} \alpha_i P_{2t-i} + \sum_{j=1}^{q} \beta_j P_{1t-j} + \upsilon_t \qquad (11)$$

where υ_t – the white noise, n,q – the lag order of P_2 and P_1 variables respectively.

In our study, P_2 and P_1 is the retail and farm-gate prices, the α's and β's are parameters. We test for the significance of the β's and if they are jointly significant, then we conclude that P_1 Granger causes P_2. We assume that there is a linear relationship between the farm-gate and retail prices. The Granger causality test needs that the variables should be stationary.

In order to determine the optimum lags in the models, the Akaike (1973) information criterion [AIC] and the Schwarz-Bayesian (1978) information criterion [BIC] are used. Serena and Perron (2001) proposed the modified versions of AIC (mAIC) and BIC (mBIC) as a model selection criterion which are based on quasi-likelihood function.

If the price series are co-integrated we estimate a Vector Error Correction model (VECM), otherwise, we build Vector Autoregression model (VAR) for farm-gate and retail prices in order to investigate price dynamic relationships.

The Vector Autoregression (VAR) models has been widely used for modelling and forecasting since the paper of Sims (1980). A VAR model is a system of multivariate models in which each variable is explained by its own past values and the past values of all other variables in the system. A VAR model is vector of price series. It comprises one equation per price variable considered in the system.

The VECM is a special case of VAR models that takes into account co-integration relationships between price series. If our tests reveal non-cointegration, we can specify and estimate VAR model. The VAR model includes two equations and can be written as equations 12, 13. The right hand side of each equation includes a constant (α_0, β_0), lags of all the variables in the system and an error term. All variables must be of the same order of integration.

$$P_{1t} = \alpha_0 + \alpha_1 P_{1t-1} + \ldots + \alpha_k P_{1t-k} + \gamma_1 P_{2t-1} + \ldots + \gamma_k P_{2t-k} + \varepsilon_t \qquad (12)$$

$$P_{2t} = \beta_0 + \beta_1 P_{2t-1} + \ldots + \beta_k P_{2t-k} + c_1 P_{1t-1} + \ldots + c_k P_{1t-k} + \varepsilon_t \qquad (13)$$

where P_{1t} and P_{2t} - farm-gate and retail prices, P_{1t-k} and P_{2t-k} - lagged farm-gate and retail prices.

If the price series are stationary we model them by directly fitting a VAR to the data. If the series are non-stationary we take differences to make them stationary and then we fit a VAR model. In both cases, the models are estimated equation by equation using the method of least squares. For each equation, the parameters are estimated by minimising the sum of squared εt values.

The VAR model includes the Granger causality results (testing whether one price variable is useful in forecasting another). As a drawback, individual coefficients in the estimated VAR models are often difficult to interpret, users of this technique often estimate the impulse response function (the response of one price variable to a sudden and temporary change in another price variable). The VAR model generates the impulse response function that indicates us about how fast a price shock at one price transmits towards another price. It describes the response of one variable to an impulse of another variable.

Results and discussion

Stationarity of the price series was checked with the conventional ADF test and Phillips-Perron test. The number of optimal lags was determined using mBIC. Our preliminary visual examination of price series graphs gives us the insight that model for unit-root test should contain constant and a time trend. The null hypothesis H0 is rejected if the critical value is greater than test statistic (p-value is less than level of significance). The results are summarized in table 1.

The output presented in table 1 shows that null hypothesis of stationary price series in levels was rejected for all variables except for farm prices for whole milk. The lag length was 6. However, at higher lag length the null hypothesis of stationarity for farm price series was rejected as well. Tests based on first differences show that all

Price variable (log price)	Model	ADF test				Phillips-Perron test			
		Lag	Levels	Lag	First difference	Lag	Levels	Lag	First difference
Farm-gate price	Trend & intercept	6	-2.3758 (0.3923)	1	-6.049*** (8.79e-07)	6	-3.807**	1	-5.2149***
	Intercept only	6	-0.3549 (0.9143)	1	-6.074*** (7.94e-08)	6	-0.74	1	-4.894***
Retail price	Trend & intercept	7	-1.227 (0.9041)	1	-6.899*** (4.84e-09)	7	-1.8498	1	-7.4852***
	Intercept only	1	-0.6161 (0.8648)	1	-6.91*** (5.865e-10)	7	-0.5805	1	-7.1594***

Notes: ** - null hypothesis of non-stationarity rejected at 5% of significance; *** - null hypothesis of non-stationarity rejected at 1 % of significance; the value in parentheses indicates p-value.
Source: own calculations

Table 1: Unit root test results in levels and first differences.

the test statistics are significant at 1% critical level. Hence, we can conclude that all price variables are integrated of the order one, I (1). Our findings allow us to assume that there is co-integration between farm and retail dairy prices which is required to be investigated.

As we were saying above, the presence of structural breaks can lead to wrong conclusions concerning time series stationarity. To solve this problem, we investigated the stationarity using Zivot-Andrews (1992) approach. The results are presented in table 2.

From the table 2, we can see that we cannot reject null hypothesis of non-stationarity at 1% and 5% of significance. Therefore, structural breaks are insignificant and we will not take them into account. Hence, we can sum up that our price series are I (1) and we first will run the conventional test of Engle and Granger and then Gregory-Hansen tests.

Within this test for co-integration the static equation is first estimated with OLS and then the stationarity of the residuals of the relationship (between farm and retail prices for whole milk) is tested with the ADF test using the critical values proposed by MacKinnon (1991). If the residuals are revealed to be stationary, the price pair is identified to be cointegrated. We set the maximum lag in accordance with Schwert (1989) rule and used the information criterions to select appropriate lag lengths. ADF test statistics for Engle-Granger test are shown in table 3.

As we can see, we cannot reject the null hypothesis of non-cointegration in the milk farm-retail chain.

According to the findings in the table 4, we also can not reject the null hypothesis of Gregory-Hansen cointegration test since two or more test statistics exceed critical values at 1% and 5% level of significance. When we select a significance level, one should pay attention to the sample size. With a small sample size, it is more likely to get a random result. Therefore, we can apply a higher probability of Type I error. If we increase a sample size, random deviations compensate for each other, and it is less likely to obtain a significant difference in homogeneous samples. Therefore, it is necessary to apply a lower significance level. If the sample size is small (less than 100 variables), it is possible to reject the null hypothesis at a significance level of 5 % or even 10 %. Our price series are more than 100 variables. Bross (1971) points out that the continuing usage of the 5% level is indicative of another important practical point: it is a feasible level at which to do research work.

Hence, we found that both price pairs are not co-integrated and we will specify and estimate VAR model in first differences. According to our findings, we can specify VAR model in first differences and estimate dynamic effects in farm-retail price relationships via Impulse Response Function graphs (table 5 and figure 1).

Then we should implement Granger causality F-tests of zero restrictions within the framework of VAR. In order to estimate the possible direction of price transmission, we carried out Granger causality test. The appropriate lag length was selected in accordance with BIC. In order to avoid autocorrelation problem we computed HAC (heteroskedasticity and autocorrelation-consistent) standard errors within the model. As shown in table 6, the direction of price transmission goes from retailers to farmers and vice versa.

Price variable (logarithm in levels)		Zivot-Andrews test		
		break in intercept only	break in trend only	break both in intercept & trend
Farm-gate prices	Test statistic	-3.659	-3.3902	-3.7944
	Break date	July 2007	November 2007	September 2007
Retail prices	Test statistic	-4.0569	-4.3724	-4.9386
	Break date	September 2007	September 2010	September 2007

Critical values for: 1) break in intercept only – 1% (-5.34), 5% (-4.8); 2) break in trend only – 1% (-4.93), 5% (-4.42); 3) both in intercept & trend – 1 % (-5.57), 5% (-5.08)
Source: own calculations

Table 2: Unit root test with one structural break.

Price pair (in logarithms)	Test value	
	Intercept only	Trend & intercept
Dairy prices (farm-retail)	-1.7854 (0.6384)	-2.1404 (0.6984)

Notes: the value in parentheses indicates p-value (level of significance)
Source: own calculations

Table 3: Cointegration test (Engle-Granger test).

Model		ADF*		Zt*		Za*	
		Breakpoint	Test statistic	Breakpoint	Test statistic	Breakpoint	Test statistic
C		0.78 (November, 2011)	-4.175	0.48 (January, 2008)	-4.507	0.48 (January, 2008)	-36.437
Critical value	1%	-5.13		-5.13		-50.07	
	5%	-4.61		-4.61		-40.48	
C/T		0.41 (March, 2007)	-4.258	0.5 (April, 2008)	-4.597	0.5 (April, 2008)	-36.537
Critical value	1%	-5.45		-5.45		-57.28	
	5 %	-4.99		-4.99		-47.96	
C/S		0.52 (July, 2008)	-8.577***	0.5 (April, 2008)	-4.943	0.5 (April, 2008)	-45.43
Critical value	1%	-5.47		-5.47		-57.17	
	5%	-4.95		-4.95		-47.04	

Notes: critical values have been taken from Gregory-Hansen (1996)
Source: own calculations

Table 4: Cointegration test with structural break for farm-retail chain (Gregory-Hansen test).

Dependent variable Regressors	ΔlnFarm_milkt	ΔlnRetail_milkt
Intercept	-0.003463 (0.004098) [-0.8451]	0.006173*** (0.001785) [3.457]
Δln_Retail_milkt-1	0.646567*** (0.176087) [3.672]	0.377215*** (0.056886) [6.631]
Δln_Farm_milkt-1	0.588054*** (0.072582) [8.102]	0.069011** (0.029513) [2.338]
R^2	0.5896	0.2356
Adjusted R^2	0.584	0.2253
S.E. of regression	0.037924	0.021693
Sum sq.resid	0.212859	0.069645
Mean dependent	0.008834	0.010858
S.D. dependent	0.0588	0.024646
F-statistic	147.22	46.7

Notes:
1. Estimates are given, taking into account HAC standard errors;
2. values in (),[] are standard errors and t-statistics respectively;
3. *** - 1 % significance level; ** - 5% significance level;
4. ΔlnFarm_milk –farm log-price for whole milk (in first difference); ΔlnRetail_milk – retail log-price for whole milk (in first difference);
5. Lag order has been selected in accordance with information criteria (SBIC);
6. Since time trend is statistically insignificant and also have not significant effect on the whole regression model, this variable was eliminated from the model.

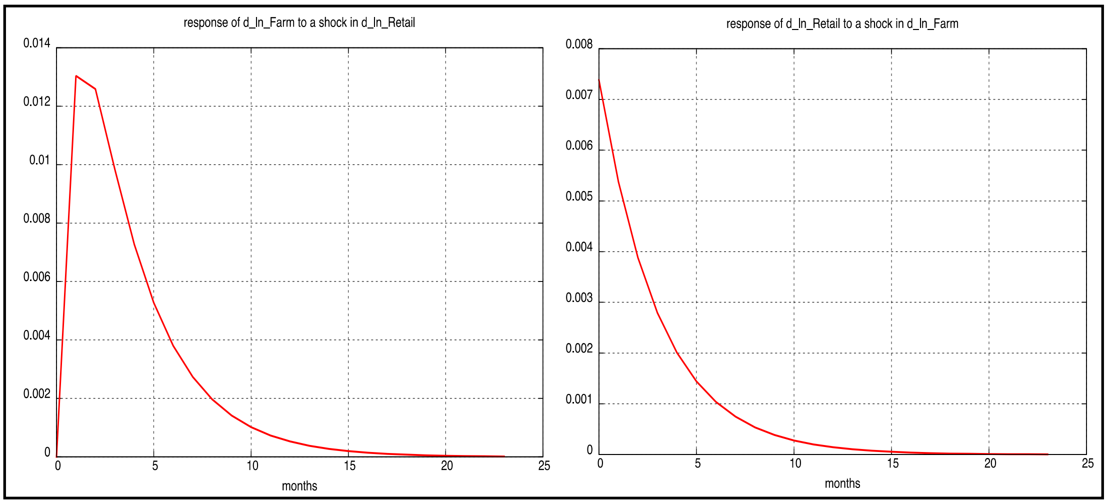
Source: own calculations

Table 5: Vector Autoregression Estimates.

Null Hypothesis	F-statistics (p-value)
ΔlnFarm_milk does not cause ΔlnRetail_milk (lag 1)	5.4677** (0.0207)
ΔlnRetail_milk does not cause ΔlnFarm_milk (lag 1)	13.483*** (0.0003)

Notes: ΔlnFarm_milk –farm log-price for whole milk (in first difference); ΔlnRetail_milk – retail log-price for whole milk (in first difference); *** 1 % significance level; ** 5% significance level;
Source: own calculations

Table 6: Granger causality F-test.



Source: own calculation

Figure 1: The impulse response of variables to each other.

Hence, the results of the VAR indicate that there is a positive and significant relationship between the farm-gate price for whole milk and the retail price. Further from the analysis of the impulse response function (figure 1) we revealed that a one-standard deviation shock to retail price causes an increase in farm price, followed by a gradual decrease until the effect dies out after 16 months. Farm price change reaches a maximum on the second month after the initial retail price change shock to the economy. A one-standard shock to farm price causes retail price to peak immediately, then it begins to decrease until the effect dies out after 14-15 months. The responses are all positive at each period of responsive period.

Conclusion

In this study we have investigated relationship between the farm-gate and retail prices for milk in Russia. Structural break tests revealed breaks but they were insignificant and have not been taken into account. Vertical price transmission was evaluated in the co-integration framework, using classical Engle-Granger and Gregory-Hansen approaches. The results have shown that a long-run co-integration relationship does not exist between farm and retail prices, that is, they do not move together. That is quite surprising that this finding is not in line with most studies on price transmission on the East European milk markets which found price series co-integration (Kharin et el., 2017; Lajdova and Bielik, 2015; Falkowski, 2010).

We have found evidence that change in one price has a significant effect on another one, that is, Granger test established bidirectional Granger causality from farm to retail prices and vice versa. However, response of the farm-gate price to a change in retail price is greater and slightly longer than price response of the retail price to a change at the farm level. One of the factor, underlying the fact that retailers have more market power than farmers. However, the argument about asymmetric price transmission goes further. The assertion is that, due to imperfect price transmission (especially caused by market power), a price reduction at the farm level is only slowly, and possibly not fully, transmitted through the supply chain. The implication is that the profit margins of the oligopolistic actors (those with the market power) will be higher than normal.

The absence of market integration in our study and complete pass-through of price changes from farmers to retailers has important implications for economic welfare (Rapsomanikis et el., 2003). Imperfect price transmission arising either due to trade and other policies, or due to transaction costs (poor transport and communication infrastructure), results in a reduction in the price information available to economic agents and consequently may lead to decisions that contribute to inefficient outcomes.

Our study will help the Russian authorities that need to have a transparent picture in the price transmission on the milk market, and support the rural sector in the aspect of distribution and balancing of subsidies in the dairy chain. This study can be extended with including wholesale level in the analysis as well as using a wider range of advanced unit root and co-integration tests under multiple structural breaks.

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System Macromodel of Agricultural Building with Aim to Energy Consumption Minimization

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Abstract

Economizing on energy intended for heating of agricultural buildings is correlative with their convenient construction from the viewpoint of both thermal and mechanical properties. Therefore, knowledge of temperature time characteristics enables building construction optimizing. This paper deals with process of recognizing elements and parameters of some particular building object, assembling its system macromodel, and analysing temperature time characteristics on its base using appropriate mathematic tools (Laplace and Fourier transformation, matrix characterizing of model parameters) and special software (ANATH). Finally, the resulting temperature time characteristics can be used for an optimal design of some planned agricultural object or for reconstruction of some existing one.

Keywords

Economy of agricultural engineering, heating energy economy, system analysis, temperature time characteristics, expenses optimizing, ambient temperature well-being.

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Introduction

Nowadays, significance of heating energy economy constantly increases. On that account, it is need to lay enhanced emphasis on building constructions design in consideration of energy consumption minimization. To process the most heat-economic building project possible, system designers must carry out a careful structural analysis from the viewpoint of active zones origin induced by floating temperature differences.

By help of a mathematic model of a building construction, it is possible to simulate and study heat behaviour of each structural element in response to time changes caused by both outdoor temperature and indoor heating system. This method is applicable for indoor non-stationary heat processes analysis as well as for computer-controlled heating optimization. (Mehta and Woods, 1981)

The idea is based on analogy between electronic and heat circuits and, therefore, the rules used for resolving electronic circuits can be analogically used for resolving heat circuits represented by the building construction mathematic model. For easy computer algorhitmizing, characteristics of the time heat responses are "harmonized" by use of the Fourier transformation (Bracewell, 1999). The model environment is described by help of the finite element method with composed parameters (thermal conductivity, thermal capacity, temperature controlled heat flow sources) and elements with spread parameters (where geometric dimensions do not allow to consider insulation resistance and thermal capacity as separate parameters) (Dong et al., 2015).

First time, this method was introduced by Professor Jiří Pánek, the former dean of the Faculty of Civil Engineering at CTU in Prague and, afterwards, it was enhanced by Professor Petr Moos and Associate professor Dalibor Vytlačil, both of them of the same institute. Later (in 1993), senior lecturer Vít Malinovský worked up a method and carried out its application on particular building constructions together with a comparative analysis of the obtained results. At the Department of Building Equipment at CTU, the team led by Professor Miroslav Jokl developed the special application ANATH for analysis and synthesis intended for calculating heat responses at different building structural configurations (Jokl, 1989).

Materials and methods

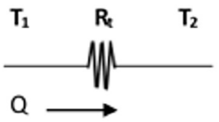
Mathematic model construction

To be able to perform matrix analysis of heat sources inside a building object, it is necessary to design an appropriate model of a building construction. The first step includes using some applicable tools from the field of system projecting determined for identification an existing or planned system within the real world and, consequently, transforming the identified system into a mathematic model form (Sangi et al., 2016). This form should take into consideration the above mentioned analogy between electronic and heat circuits for physical parameters to be definitely assigned and processed by the analytic software.

Description of model with concentrated elements

Description of model with concentrated elements deals with characterizing system properties by means of discrete (discontinuous) elements. The method proceeds from analogy between heat and electric current flow. The system consist of the following elements:

a) *Thermal resistance* is a point through which a heat flow *Q* passes. The *Q* heat flow replaces an integral representation with the Laplace image form.



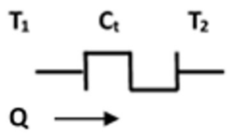
$$Q = \frac{T_1 - T_2}{R_t} \quad (1)$$

Q heat flow [W];

T_1, T_2 temperatures before and behind a point of resistance [°C];

R_t thermal resistance [W.m^{-1}.K^{-1}].

b) *Thermal capacity* is an element simulating the system accumulation properties.



$$\delta T = \frac{1}{C_t} \cdot \int q(t) \cdot dt = \frac{1}{C_t \cdot p} \cdot Q \quad (2)$$

Q heat flow [W];

T_1, T_2 temperatures before and behind a point of resistance [°C];

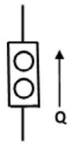
δT difference of temperatures after heat passing through an element [°C];

C_t thermal capacity [J.m^{-1}.K^{-1}];

p Laplace operator [–];

t, dt time and time increase [s],

c) *Heat flow resource* is an element representing a regulated or unregulated heating system.



where

Q heating flow [W].

A heat flow resource can be regulated or unregulated. The regulated resource is characterized by the regulation factor g determining a change of temperature by 1 °K in a point of a sensor (controlling temperature point).

Description of model with spread elements

Description of model with spread elements solves inaccuracies of the previous description caused by assumption that only condition of all materials predominates (i.e. polystyrene – thermal resistance, concrete and stone – thermal capacity, etc.). However, other conditions of the most of materials cannot be omitted because both heat resistance and thermal capacity are functions of the element´s thickness and, that is why, it is not possible to consider each condition separately and compile the result afterwards (Moziraji et al., 2014).

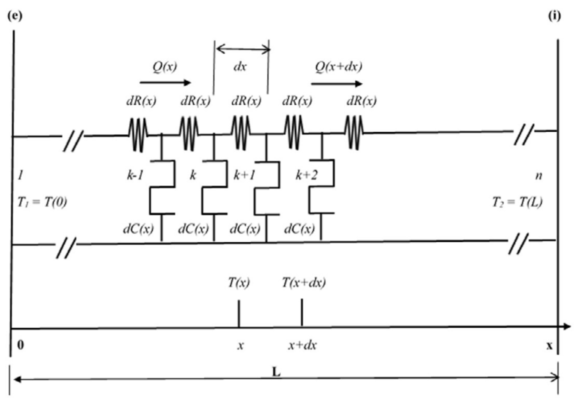


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Figure 1: Scheme of model with spread elements.

Q heat flow [W];

(e), (i) exterior, interior;

x variable of thickness ($x = 0$ outer surface; $x = L$ inner surface) [m];

L thickness of the whole perimeter construction [m];

$dR(x)$ increase of thermal resistance within the distance element dx [W.m^{-1}.K^{-1}];

$dC(x)$ increase of thermal capacity within the distance element dx [J.m^{-1}.K^{-1}];

$T(x)$ temperature in the point x [°C];

$Q(x)$ heating flow in the point x [W].

Mathematic definition of model with spread elements

The relations between quantities characterizing the model with spread elements is based on the following formulas:

$$\frac{\sigma T(x,t)}{\sigma x} = R(x) \cdot Q(x,t) \tag{3}$$

and

$$\frac{\sigma Q(x,t)}{\sigma x} = C(x) \cdot \frac{\sigma T(x,t)}{\sigma t} \tag{4}$$

where

T temperature [°C];

Q heating flow [W];

R thermal resistance [W.m^{-1}.K^{-1}];

C thermal capacity [J.m-1.K-1];

x position of examined point [m];

t time [s].

The temperature equation results from deriving the formula (3) and substituting the result into the formula (4).

$$\frac{\sigma^2 T(x,t)}{\sigma^2 x} - \frac{1}{R(x)} \cdot \frac{\sigma R(x)}{\sigma x} \cdot \frac{\sigma T(x,t)}{\sigma x} - R(x) \cdot C(x) \cdot \frac{\sigma T(x,t)}{\sigma t} = 0 \tag{5}$$

The heating flow results again from derivate the formula (3) and substituting the result into the formula (5).

$$\frac{\sigma^2 Q(x,t)}{\sigma^2 x} - \frac{1}{R(x)} \cdot \frac{\sigma R(x)}{\sigma x} \cdot \frac{\sigma Q(x,t)}{\sigma x} - R(x) \cdot C(x) \cdot \frac{\sigma Q(x,t)}{\sigma t} = 0 \tag{6}$$

The formulas (5) and (6) create a matrix differential equation with three variables. The time equation is transformed by means of Laplace transformation to the following form:

$$T(x,p) = A_1.e^{-\tau x} + A_2.e^{-\tau x} \tag{7}$$

and

$$Q(x,p) = B_1.e^{-\tau x} + B_2.e^{-\tau x} \tag{8}$$

where

$\tau^2 = p.C_t.R_t$ heating constant;

R_t specific thermal resistance [W.m^{-1}.K^{-1}];

C_t specific thermal capacity [J.m^{-1}.K^{-1}];

and contains two linearly dependent constants:

$$B_1 = \tau_0.A_1 \tag{9}$$

and

$$B_2 = \tau_0.A_2 \tag{10}$$

where the specific heating constant is of the following form:

$$\varrho_0 = \sqrt{\frac{R_t}{p \cdot C_t}} \tag{11}$$

For the model, the boundary conditions are determined: temperature T_2 on the inner surface ($x = L$) and heating flow Q_2, and temperature T_1 on the outer surface ($x = 0$) and heating flow Q_1. After substitution of (9), (10), and (11) to the equations (07) and (08) and examining the boundary conditions, the following matrix form arises (Draghici at al., 1998):

$$\begin{bmatrix} T_1(p) \\ Q_1(p) \end{bmatrix} = \begin{bmatrix} \cosh \tau d & \varrho_0 \sinh \tau d \\ \frac{1}{\varrho_0} \sinh \tau d & \cosh \tau d \end{bmatrix} \cdot \begin{bmatrix} T_2(p) \\ Q_2(p) \end{bmatrix} \tag{12}$$

The middle matrix [A] contains all information on heating change of a layer with L, C, and R parameters. For multilayer constructions, the resulting matrix [A] can be obtained by multiplying particular matrixes of individual construction layers from the outer surface to the inner one. For a construction consisting of n layers, the aggregate matrix is of the form (Pöttgen et al., 2016):

$$[A] = [A_1] \cdot [A_2] \cdot [A_2] \cdot \ldots \cdot [A_n] \tag{13}$$

For computer processing, performing Fourier transformation ($p = j.\Omega$) is very useful because it can transform time courses to harmonic ones (Sonderegger, 1977).

$\tau^2 = j\ \Omega\ C_t.R_t$ heating constant:

complex unit j [–]; angular frequency Ω [s^{-1}];

specific thermal resistance related to 1 m′ R_t [W.m^{-1}.K^{-1}];

specific thermal capacity related to 1 m′ C_t [J.m^{-1}.K^{-1}];

$\varrho_0 = \frac{R_t}{j \cdot \Omega \cdot C_t}$ specific heating constant;

$\Omega = \frac{2\Pi}{T}$ angular frequency [s^{-1}]; period T [s];

$\Theta = \Omega\ C_t \cdot R_t\ L^2$ heating flow;

thickness of spread parameter L [m];

total thermal resistance $R_t\ L$ [W K^{-1}];

total thermal capacity $C_t L$ [J K-1]

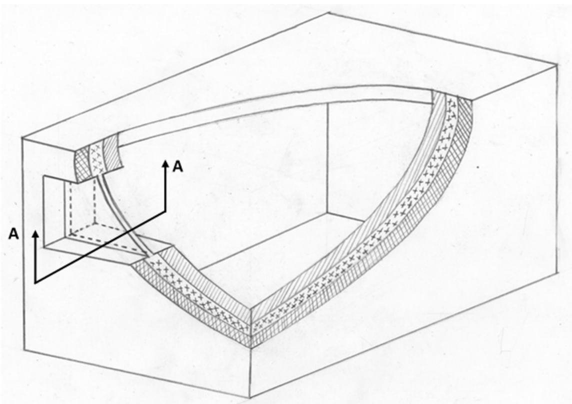
By dividing (12) according to the De Moivre´s formula to a real and complex part, the coefficients of the complex matrix [A] arise. The real part describes a module (maximum deviations of heating cycle) while the complex part describes a phase (time delay from exciting change) (Moos, 1989).

Analysis of barn building model

The following procedure consists of processing expected data of exterior time temperature courses by means of Fourier transformation representing independently variable quantities causing temperature changes inside the building constructions (Stupka et al., 2014). Next, important inner and outer points of around the construction – so called thermal nodes – are assigned by unique numerals. These numerals create the building construction heat model including heat relations to the monitored subjects inside the building construction (Wachowicz et al., 2016).

Barn model construction

First, for easier projection, a simplified barn building 3D-model (see Figure 2) is designed. For this purpose, a single-space building object of three-layer perimeter wall was chosen to represent an initial base for a particular scheme creation (Svoboda, 2012). The spatial projection contains marking of a typical wall cross-section *A-A* that is shown on the upper part of Figure 2. Also a glass-walled part is taken into the account for temperature changing calculation (Malinovský, 1993).



Source: Author´s own work

Figure 2: Simplified barn building 3D-model.

This 3D-model allows to create the particular scheme of a thermal circuit (shown on the bottom part of Fig. 2) representing a construction part of the barn building. The thermal circuit is used for entering input parameters for calculation processed by the ANATH application (Zajicek and Kic, 2014).

The ANATH application serves for calculating thermal responses of the system (object model) for changes of the outdoor temperature and, concurrently, for simulating situations when the elements and their parameters affecting the global thermal system behaviour are changing. It results from data containing recorded temperature values in the course of 24 hours. The curves representing temperature courses within the given time unit are not harmonic and are not in accordance with goniometrical functions. However, by help of Fourier transform, these non-harmonic but periodical curves can be replaced by a sum of goniometrical functions (Moos and Vytlačil, 1991):

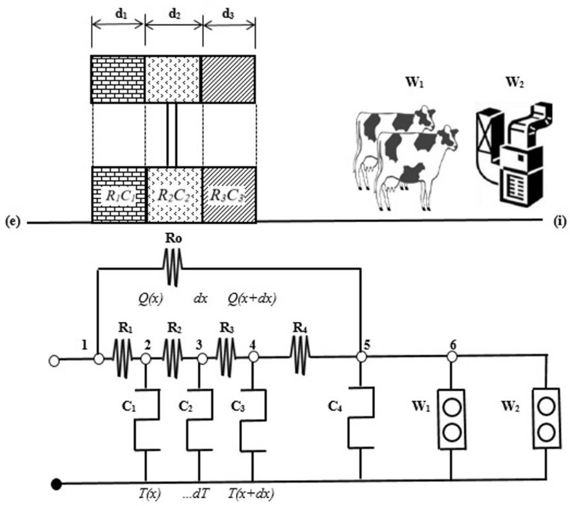
$$T_i(\Omega \cdot t) = |M_i| \cdot e^{j \cdot \Phi_i} \quad (14)$$

where

M_i modules of individual harmonic items Ω, 2Ω, 3Ω … nΩ (frequency functions);

j complex unit;

Φ_i argument of harmonic item



Notes:

d_i individual construction layers´ thicknesses;

W_1 unregulated heating source – cattle (Chloupek, 1992);

W_2 regulated heating source – heating system;

C_i individual construction layer thermal capacities;

R_i individual construction layer thermal resistances;

T(x) temperature as function of distance x [°C];

Q(x) heating flow as function of distance x [W]

Source:

Figure 3: Barn building heating scheme.

Calculation procedure

For describing the barn building thermal system, the system matrix equation has to be created. The presence of the heat q within the barn construction is represented predominantly in the form of the heating flow Q considered as an agent. For this quantity, the principle of agents conservation states can be expressed as following (Price and Smith, 1995):

$$\sum_{i=1}^{n} \Delta Q_i = 0 \tag{15}$$

where

ΔQ_i increases of individual heating flows components inside barn construction.

This equation can be expressed in the developed form:

$$[Q] - [h] \cdot [T] = 0 \tag{16}$$

where

$[Q]$ matrix of external heating flows;

$[h]$ system matrix;

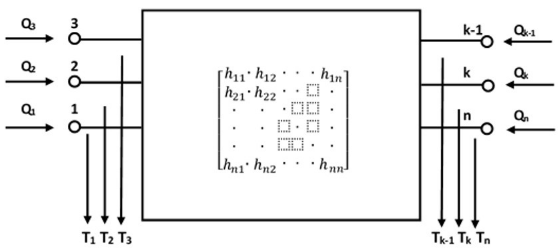
$[T]$ matrix of temperatures in heating nods.

The matrices $[Q]$, $[h]$, and $[T]$ contain Laplace images of the corresponding time functions.

After separating the external heating flows matrix $[Q]$ to the left, the following matrix equation (in full form) origins:

$$\begin{bmatrix} Q_1 \\ Q_2 \\ \cdot \\ \cdot \\ \cdot \\ Q_n \end{bmatrix} = \begin{bmatrix} h_{11} \cdot h_{12} & \cdot & \cdot & \cdot & h_{1n} \\ h_{21} \cdot h_{22} & \cdot & \cdot & \square & \cdot \\ \cdot & \cdot & \cdot & \square\square & \cdot \\ \cdot & \cdot & \square & \cdot & \square \\ \cdot & \cdot & \square\square & \cdot & \cdot \\ h_{n1} \cdot h_{n2} & \cdot & \cdot & \cdot & h_{nn} \end{bmatrix} \cdot \begin{bmatrix} T_1 \\ T_2 \\ \cdot \\ \cdot \\ \cdot \\ T_n \end{bmatrix} \tag{17A}$$

This matrix can be seen as the following scheme representing the construction heating system exposed by the external heating flows Q_1, Q_2 ... Q_n in the heating nods T_1, T_2 ... T_n.



(17B)

The temperature values and their time courses are the most important quantities for state changes examining in the given points and, therefore, the equation (17) must be adjusted so that the heating nods matrix would be in the left side:

$$[T] - [h]^{-1} \cdot [Q] \tag{18}$$

or in the full form:

$$[h]^{-1} = \frac{1}{\Delta} \begin{bmatrix} \Delta_{11} \cdot \Delta_{21} & \cdot & \cdot & \cdot & \Delta_{n1} \\ \Delta_{12} \cdot \Delta_{22} & \cdot & \cdot & \square & \Delta_{1n} \\ \cdot & \cdot & \cdot & \square\square & \cdot \\ \cdot & \cdot & \square & \cdot & \square \\ \cdot & \cdot & \square\square & \cdot & \cdot \\ \Delta_{1n} \cdot \Delta_{2n} & \cdot & \cdot & \cdot & \Delta_{nn} \end{bmatrix} \tag{19}$$

where

Δ determinant of $[h]$ matrix;

Δ_{ij} algebraic complements to appropriate $[h]$ matrix elements.

Supposing only exterior represents a source of the heating flow Q_1 and this environment is characterized by the T_1 temperature, another heating flows Q_2, Q_3 ... Q_n are of zero value, nevertheless, inner heating flows within the construction are time dependent values in relation to both Q_1 and T_1 changes. Further, a course of temperature changing in the k point (k heating nod) is of essential importance. Dependence between temperatures T_1 and T_k is arises from the following equation system (Moos, Vytlačil 1991):

$$\begin{aligned} T_1 &= \frac{1}{\Delta}(\Delta_{11} \cdot Q_1 + \Delta_{21} \cdot Q_2 + \cdots + \Delta_{n1} \cdot Q_n) \\ T_2 &= \frac{1}{\Delta}(\Delta_{12} \cdot Q_1 + \Delta_{22} \cdot Q_2 + \cdots + \Delta_{n2} \cdot Q_n) \\ &\dots \qquad \dots \qquad \dots \\ &\dots \qquad \dots \qquad \dots \\ T_k &= \frac{1}{\Delta}(\Delta_{1k} \cdot Q_1 + \Delta_{2k} \cdot Q_2 + \cdots + \Delta_{nk} \cdot Q_n) \\ &\dots \qquad \dots \qquad \dots \\ &\dots \qquad \dots \qquad \dots \\ T_n &= \frac{1}{\Delta}(\Delta_{1n} \cdot Q_1 + \Delta_{2n} \cdot Q_2 + \cdots + \Delta_{nn} \cdot Q_n) \end{aligned} \tag{19}$$

Considering the above determined conditions, only the following two adjusted equations are used:

$$\begin{aligned} T_1 &= \frac{1}{\Delta}\Delta_{11} \cdot Q_1 \\ T_k &= \frac{1}{\Delta}\Delta_{1k} Q_1 \end{aligned} \tag{20a; 20b}$$

The impulse heating response are given as a fraction of both the equations (20a; 20b).

$$L\{f(t)\} = \frac{T_k(p)}{T_1(p)} = \frac{\Delta_{1k}}{\Delta_{11}} \tag{21}$$

The time course of the temperature $T_k(t)$ in the k point depend on external temperature course $T_1(t)$ can be determined either by means of Laplace transformation:

$$T_1(t) = \mathcal{L}^{-1}\left\{\frac{\Delta_{1k}}{\Delta_{11}} \cdot T_1(p)\right\} \tag{22}$$

or, after substituting the Laplace operator for $p = J\omega_i$, by means of the Fourier transformation:

$$T_1(t) = \widetilde{f^{-1}}\left\{\frac{\Delta_{1k}}{\Delta_{11}} \cdot T(j\omega_t)\right\} \tag{23}$$

as a sum of harmonic components from the heating Fourier spectre. (Lloyd et al., 1978)

If the $[h]$ system matrix is known then determining a time dependent temperature course in some selected heating nod is possible from the equations (20a; 20b). The $[h]$ matrix can be compiled with a help of the heating model. Such the model with concentrated elements is shown on Figure 3. The requested $[h]$ matrix is of the table form consisting of n rows and n columns where the n variable represents a number of the system heating nods. These heating nods are coupled through the thermal resistances R_{t1}, R_{t2}… and thermal capacities C_{t1}, C_{t2} in the model. The main diagonal elements of the $[h]$ matrix create sums of reciprocal values of thermal resistances coupled to numerically appropriate heating nods (Evola and Marletta, 2013). The other elements are created by reciprocal values of thermal resistances with minus signs coupling individual heating nods. Since also inertial construction properties are considered in the system due to thermal capacities, the Laplace images of heating flows and temperatures fractions are added to the reciprocal values of thermal resistances in the i[th] nod with the attached thermal capacity (Moos, 1989):

$$\frac{Q_i(p)}{T_i(p)} = pC_{ti} \tag{24}$$

The partial $[h]$ system matrix is of the following form (25):

		1	2	3
	1	$1/R_{t2}$	$-1/R_{t2}$	
$[h]$ =	2	$-1/R_{t2}$	$1/R_{t2} + 1/R_{t1} + p\cdot C_{t1}$	$-1/R_{t1}$
	3		$-1/R_{t1}$	$1/R_{t1} + \ldots$

(25)

Sources of the heating flow in the i^{th} nod – Q_i controlled by the temperature T_j in the j^{th} nod can be expressed by the linear equation:

$$Q_i = g.T_j \tag{26}$$

where g is a regulation factor – are in the $[h]$ matrix represented so that the transfer heating conductivity g performing the regulation factor function is added to the element in the i^{th} row and j^{th} column of the $[h]$ system matrix.

Between each pair of heating nods i and j, there is a construction element described as the system with spread parameters and, from that, a partial matrix of the second-order (its compact form in 26)

$$\begin{bmatrix} Q_i \\ Q_j \end{bmatrix} = \begin{bmatrix} h_{ii} & h_{ij} \\ h_{ij} & h_{jj} \end{bmatrix} \cdot \begin{bmatrix} T_i \\ T_j \end{bmatrix} \tag{27}$$

is derived and its partial parameters h_{ii}, h_{ij}, h_{ji}, and h_{jj} also being functions of Laplace operator p and, further, functions of the construction geometrical dimensions (wall thickness for example) are added to appropriate elements of the $[h]$ matrix.

The partial section of the construction described by the equation (27) can consist of several layers (see Fig 3). The partial layers can be suitably characterized by the following matrix equation:

$$\begin{bmatrix} T_1(p) \\ Q_1(p) \end{bmatrix} = \begin{bmatrix} \cosh \gamma d & \varrho_0 \sinh \gamma d \\ \frac{1}{\varrho_0} \sinh \gamma d & \cosh \gamma d \end{bmatrix} \cdot \begin{bmatrix} T_2(p) \\ Q_2(p) \end{bmatrix} \tag{28}$$

where

$\gamma = \sqrt{p \cdot R_i \cdot C_i}$ heating constant;

$\varrho_0 = \sqrt{\dfrac{R}{pC_i}}$ specific heating constant;

R_i specific thermal resistance [W.m^{-1}.K^{-1}];

C_i specific thermal capacity [J.m^{-1}.K^{-1}].

The resulting function

$$\begin{bmatrix} \cosh \gamma d & \varrho_0 \sinh \gamma d \\ \frac{1}{\varrho_0} \sqrt{pR_iC_i} & \cosh \gamma d \end{bmatrix} \cdot \begin{bmatrix} A & B \\ C & D \end{bmatrix} \tag{29}$$

can be obtained as a product of partial matrices (28) for separate construction layers:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \cdot \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \cdot \begin{bmatrix} A_3 & B_3 \\ C_3 & D_3 \end{bmatrix} \tag{30}$$

The matrix (29) is transformed on the form compatible with the system matrix according to the following transformation function:

$$[h]_{ij} = \frac{1}{B} \cdot \begin{bmatrix} A & -1 \\ -1 & D \end{bmatrix} \quad (31)$$

The triple layer construction according to Figure 3 (lower scheme) includes the resulting thermal resistance of separate layers ΣR_i; $i = 1, ..., 4$ (R_1 includes heating properties of heat transfer from exterior and R_4 heating transfer from the wall to interior) and thermal resistance of the window R_O. Further, the construction includes the resulting thermal capacities of separate layers ΣC_i; $i = 1, ..., 4$ (C_4 represents thermal capacity of interior). The unregulated heating source heating system W_1 (cattle) supplies the interior by the heating flow Q_5 and the regulated heating source W_2 (heating system regulated by the temperature T_4 measured on the inner surface of the perimeter wall; Q_6 is equal to regulation factor g) supplies the interior by the heating flow Q_6. According to the described procedure, the following system matrix $[h]$ can be compiled (equation 32, this page below) (Moos and Vytlačil 1991):

where:

- k sum of heat transfer coefficients Σk_i; $i = 1, 2, 3$ of all layers;
- k_0 heat transfer coefficients of window.

The Laplace image of impulse characteristic is expressed as the fraction of the algebraic complements Δ_{11} and Δ_{15} (question 33, this page below):

If the temperature T_1 suddenly decreases in the time $t = t_0$ by x °C the change can be expressed by means of the Laplace image:

$$T_5(p) = \frac{\Delta_{15}}{\Delta_{11}} \cdot \frac{X}{p} \quad (34)$$

so that the temperature course T_5 within the interior can be computed by the help of the reversal Laplace transformation of the following equation:

$$T_1(t) = \mathcal{L}^{-1}\left\{\frac{\Delta_{15}}{\Delta_{11}} \cdot \frac{X}{p}\right\} \quad (35)$$

The course of the temperature response is shown in the Figure 4.

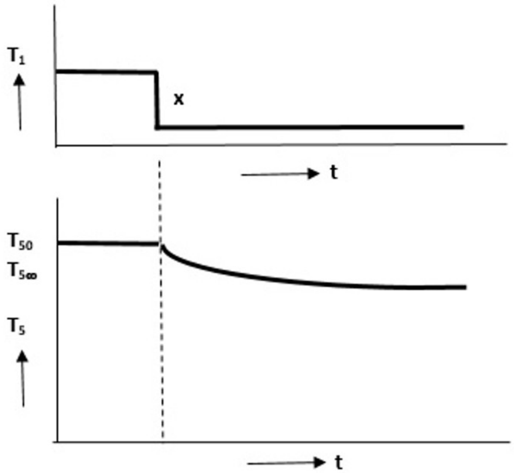


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Figure 4:Time characteristics of temperature changes.

Results and discussion

Analysis of computed outputs

For analysis, the barn whose construction heating scheme is shown on Fig. 3 was used. As input data, the following set of input information was entered (Veverka et al., 1992):

- exterior temperature values was adopted from the temperature standard for a clear winter day (Figure 5).
- thermal resistances of individual materials R_i [$W.m^{-1}.K^{-1}$] (see Table 1);
- thermal capacities of individual materials C_i [$J.m^{-1}.K^{-1}$] (see Table 1);

$$[h] = \begin{bmatrix} k + k_0 & -k_1 & -k_2 & -k_3 & -k_0 \\ -k_1 & k + 1/R_1 + p \cdot C_1 & -1/R_2 & -1/R_3 & -1/R_4 \\ -k_2 & -1/R_1 & k + 1/R_2 + p \cdot C_2 & -1/R_3 & -1/R_4 \\ -k_3 & -1/R_1 & -1/R_2 & k + 1/R_{13} + p \cdot C_3 & g - 1/R_4 \\ -k_0 & -1/R_1 & -1/R_2 & g - 1/R_3 & k_0 + 1/R_4 + p \cdot C_4 \end{bmatrix} \quad (32)$$

$$\frac{T_5}{T_1} = \frac{\Delta_{15}}{\Delta_{11}} = \frac{\frac{k_0}{C_4} \cdot \left[\frac{k}{k_0 C_1} \cdot (1/R_4 - g) + \frac{k + 1/R_4}{C_4} + p\right]}{p^2 + p + \left(\frac{k_0 + 1/R_4}{C_4} + \frac{k_0 + 1/R_4}{C_1}\right) + \frac{1/R_4 \cdot g + k \cdot k_0 + 1/R_4 \cdot k + 1/R_4 \cdot k_0}{C_1 \cdot C_4}} \quad (33)$$

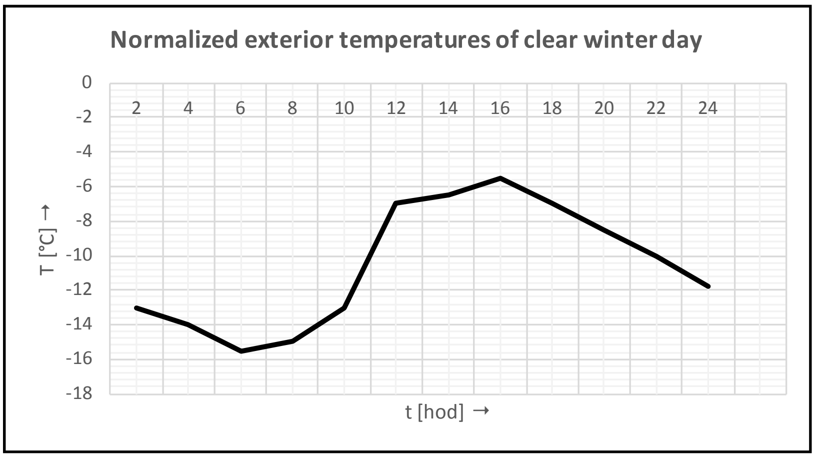

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Figure 5: Normalized exterior temperatures of clear winter day.

Material	**Thickness [m]**	**Thermal resistance R_i [W.m^{-1}.K^{-1}]**	**Thermal capacity C_i [J.m^{-1}.K^{-1}]**
A) Reinforced concrete cladding			
Reinforced concrete	0.225	0.059	840
Polystyrene	0.145	2.5	1550
Heraklit	0.115	0.357	1590
B) Ceramic cladding			
CD-IVA-C	0.14	0.238	690
Polystyrene	0.04	2.5	1550
CD-IVA-C	0.14	0.238	690
C) Plasterboard cladding (no supporting structure; used with any other construction)			
Plasterboard	0.03	0.625	1380
Prefizol	0.10	2.0	920
Eternit boards	0.02	0.2	960

Source: Rochla (1983)

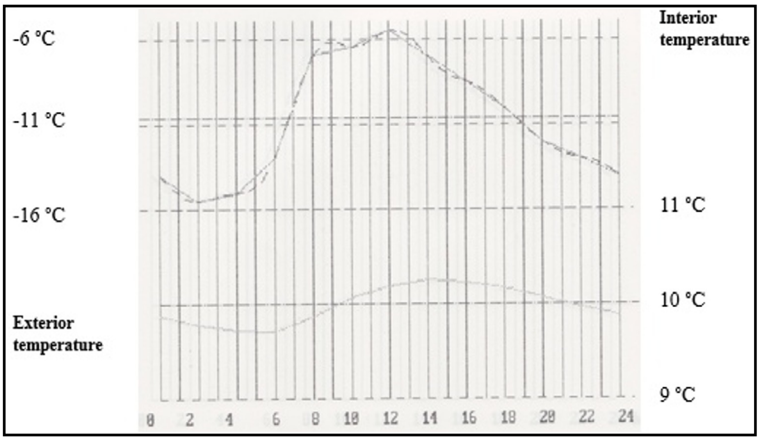
Table 1: Cladding configurations.

- thermal resistances of window R_i [0.04 W.m^{-1}.K^{-1}];
- unregulated heating source W_1 [cattle; constant 125 W.K^{-1}];
- regulated heating source W_2 [heating system; constant 100 W.K^{-1}];

Processing the input data using ANATH application is carried out in several steps:

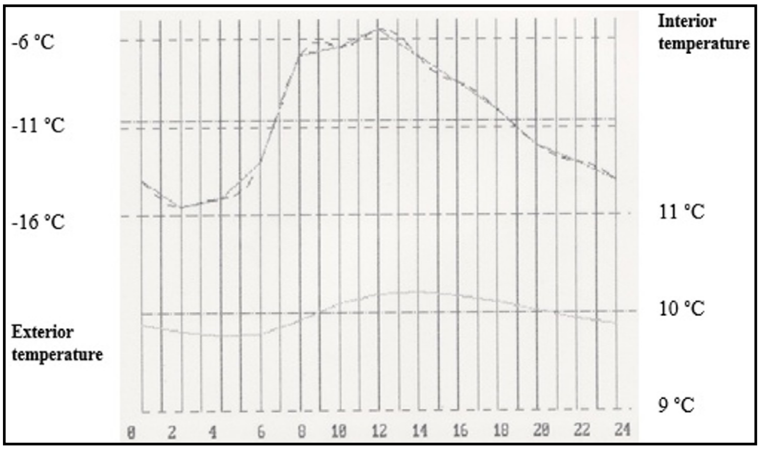
1) Fourier transformation of temperature time course being an independent variable causing temperature changes within the construction.
2) Assigning numbers to individual points – or heating nods – within and out of the construction whose temperature should be examined.
3) Creating a heating model of the building construction and its couplings to the examined object within the building´s interior.
4) Forming a matrix of heat penetration and heating absorbability through given parts of the construction. Completing the elements representing the heating system and adding the submatrices characterizing the system with spread parameters. The result is the system matrix.
5) Obtaining the image of the system´s heat impulse responses in the nods important from the viewpoint of heating gradients by the help of quotients of the system matrix algebraic complements and optimizing the function of the heating system.
6) Determining the temperature course in the examined points by reverse transformation of the Fourier convolution image of exterior temperature time course with the system impulse response (Moos and Vytlačil 1991).

The resulting graphs consist of two parts. The first ones (situated in upper halves) represent rough (continuous lines) curves (according to Figures 6-8) and smooth interpolated (dashed lines) curves of exterior temperatures. The second ones (situated in lower halves) represent responses of interior temperature on the exterior temperatures shown above.



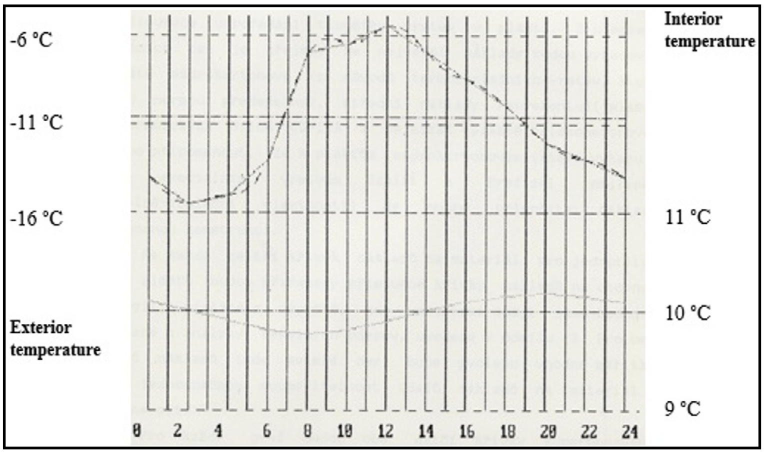
Source: authors´ own processing in ANATH

Figure 6: Heating responses of Cladding A.



Source: authors´ own processing in ANATH

Figure 6: Heating responses of Cladding B.



Source: authors´ own processing in ANATH

Figure 6: Heating responses of Cladding C.

Conclusion

Knowledge of time temperature characteristics enables expecting values of mechanical tension inside constructions given by thermal dilatations of structural parts in the course of non-stationary thermal processes and, afterwards, building construction optimizing. The complex analysis of temperature time characteristics can be applied for examining thermal bridges within interiors of building objects with humid ambient and with light cladding (Cooke 1975). The results provided in the form of graphs and temperature data files by the ANATH application can be used by various manners. For example, they can serve for simulating inner temperatures of agricultural buildings (cow barn, in our case) and following setting the appropriate heating plan via programming heat regulation systems – provided the existing building objects or for designing optimal construction configuration (system of cladding layers arrangement) in case of planned objects (Hoffman and Feldman, 1981). A specific task was solved by Malinovský in 1993, when a cost curve (material costs versus heating costs) had been built on the basis of analysing heating responses at different cladding material configurations an standardized exterior temperatures. Of course, analysing thermal behaviour of building object interiors on the basis of multi-factors (temperature responses, cladding material configuration, heating system configuration, construction type, ventilation system and mode, etc.) can be used for lot of different purposes in the field agriculture engineering.

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Effects of Natural Disaster on Rice Production at Farm Level: New Evidence from Vietnam

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Abstract

The current study uses a unique balanced panel of 3,922 households between 2008 and 2010 to examine the extent to which rice production in Vietnam is affected by natural disasters and how coping strategies lessen the negative effects of natural disaster, using a fixed effects model that controls for time invariant farm heterogeneity. With regard to natural disaster, we find evidence of the negative inter-temporal occurrence and negative inter-temporal severity effects, and the negative current occurrence one as well. With regard to coping strategies, we find various evidence of current, inter-temporal coping-occurrence and coping-severity effects, depending on kinds of coping strategies.

Keywords

Current and inter-temporal occurrence effects, current and inter-temporal severity effects, current and inter-temporal coping-occurrence effects, current and inter-temporal coping-severity effects, natural disaster, rice production, Vietnam.

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Introduction

Agriculture is inherently sensitive to climate conditions and is among the sectors most vulnerable to natural disaster. In simple terms, according to Sivakumar (2005), a natural disaster is a natural event with catastrophic consequences for living things in the vicinity. Natural disasters can be classified into hydro-meteorological and geophysical disasters (Sivakumar, 2005), in which the former includes landslides, droughts, extreme temperatures and heat waves, floods, tropical cyclones, windstorms; and others (insect infestation and waves/surges), and the latter include earthquakes and volcanic eruptions (IFRC/RCS, 2003).

In this paper, we explore the extent to which rice production in Vietnam is affected by natural disasters such as flood, drought, typhoon and landslides and how coping strategies lessen the negative effects of natural disaster. Our primary hypothesis is that natural disasters have negative impacts on rice production and coping strategies can lessen the negative effects of natural disaster to a certain extent. While many empirical studies have done so far on the effects of natural disaster, either at nation, region, community, household, and individual level or sector and crop level, such as Blaikie et al. (2014), Loayza et al. (2012), Kaplan (2010), Ludwig et al. (2007), De Haen and Hemrich (2007), Sawada (2007), Alderman et al. (2006), Toya and Skidmore (2005), Sivakumar (2005), Fothergill and Peek (2004), Das et al. (2003), Pelling et al. (2002), Jacoby and Skoufias (1997), Deaton (1997), Benson (1997), and Long (1978), and coping strategies as well such as Davies et al. (2013), Briguglio et al. (2009), Fafchamps (2009), Greiving et al. (2006), Rose (2004), Bruneau et al. (2003), and Rosenzweig and Wolpin (1993), little is known about the effects of natural disaster on rice production at the farm level (with an exceptional research of Israel and Briones (2012) for the case of the Philippnies at the provincial level). This is mainly due to a lack of suitable information.

The study focuses on the impact of natural disaster on rice production at the farm level in Vietnam for several reasons: Firstly, paddy rice (referred as rice in this paper for simplification) has played an important role in food security, agriculture, and rural development in the world in general and in Vietnam in specific. In Vietnam, rice accounts for more than three-quarters of the country's total annual harvested agricultural area and employs about two-thirds of the rural labor force. Because the scope of expanding arable land to increase production is limited (as a consequence of such as rapid industrialization and urbanization), natural disaster impacts and declining agricultural productivity could compound the risk of food insecurity and agricultural growth in Vietnam. Secondly, Vietnam is considered as one of the most affected countries in the world by climate change (World Bank, 2009). Thirdly, our data come from the Vietnamese Access to Resources Household Survey (VARHS) for 2008 and 2010 and include uniquely detailed information on farm-level rice production, and the various types of natural disaster, their time of occurrences, and their levels of severity on rice plots and these allow for the analysis of farm-level rice production and natural disaster.

Findings from the study can provide useful information for policy makers on the adverse effects of natural disaster on rice production and coping strategies in developing countries. If natural disaster results in the depletion of rice productivity, the government should have strong and effective policies and programs to reduce the adverse effects of natural disaster. Moreover, effective coping strategies to deal with the negative effects from natural disaster should be promoted and tailored more in a national framework to fight against natural disaster.

The study is expected to contribute to the literature of environmental economics and development economics in some ways. Firstly, it provides empirical findings on the impacts of natural disaster and of coping strategies on rice production that is still silent in most empirical literature so far. Secondly, it distinguishes between current and inter-temporal effects and occurrence and severity effects as well.

Materials and methodology

Data

The data are taken from VARHS for 2008 and 2010, which are results of a joint project conducted by the Central Institute for Economic Management (CIEM) of the Ministry of Planning and Investment (MPI), the Centre for Agricultural Policy Consulting (the Institute of Policy and Strategy for Agriculture and Rural Development - CAP-IPSARD), which is belonged to the Ministry of Agriculture and Rural Development (MARD), the Institute of Labor Science and Social Affairs (ILSSA) (Ministry of Labour, Invalids and Social Affairs - MoLISA), and the Development Economics Research Group (DERG) of the University of Copenhagen, together with Danida.

The VARHS was carried out in rural areas of 12 provinces of Vietnam in the summer of each year. The survey was conducted during the same three-month period each year to ensure consistency and facilitating reasonable comparisons across time. The VARHS explores issues surrounding Vietnamese rural households' access to resources and the constraints that these households face in managing their livelihoods. Along with detailed information on farm-level rice production, the survey includes sections on natural disasters. After refining the dataset between 2008 and 2010, we obtain a balanced two-wave panel of 1,961 households involved in rice production.

Information on natural disaster are gathered by asking farms to name specific natural disasters from a list of natural disasters on each plot cultivated. The list of natural disasters includes flood, drought, typhoon, land slide. The questionnaire also includes an estimation of the loss that farm suffered from the natural disasters with respect to values of output lost on the plot in terms of Vietnamese Dong (VND). Table 1 provides a more detailed breakdown of natural disasters and their sub-categories among rice producers.

We find that that 4.03 per cent of farms faced a natural disaster on their rice plots in 2008 and 5.2 percent in 2010, in general. At a disaggregated level, in 2010 we find that 0.46 per cent of farms suffered a flood (down from 2.35 per cent in 2008) while 4.28 per cent suffered a drought (up from 1.22 per cent in 2008). In 2010, typhoon also increase to 0.31 per cent from 0.15 per cent in 2008.

Farms can cope with natural disasters in a variety of ways. Table 2 provides a brief description of each type of coping. While over time farms tend to be dependent more on selling land, livestock, assets, getting assistance from relatives or friends, government, NGO, borrowing from banks or relatives and using savings between 2008 and 2010, the less proportion of farms choose to reduce consumption in 2010 compared with 2008.

Table 3 presents the crops of farmers in the 2008-2010 VARHS survey. Information collected on annual and perennial crop plots of 2008 indicates that rice is the highest frequency

Disaster type	2008		2010		Total	
	Obs.	Percent (%)	Obs.	Percent (%)	Obs.	Percent (%)
No disaster	1,882	95.97	1,859	94.8	3,741	95.39
Flood	46	2.35	9	0.46	55	1.40
Drought	24	1.22	84	4.28	108	2.75
Typhoon	3	0.15	6	0.31	9	0.23
Land slide	6	0.31	3	0.15	9	0.23
Total	**1,961**	**100**	**1,961**	**100**	**3,922**	**100**

Source: Author' calculation from VARHS 2008-2010

Table 1: Disasters by types, 2008-2010.

Coping strategies	2008		2010		Total	
	Obs.	Percent (%)	Obs.	Percent (%)	Obs.	Percent (%)
Doing nothing	1,237	63.08	1,202	61.3	2,439	62.19
Reduce consumption	558	28.45	416	21.21	974	24.83
Sold land, livestock, assets	27	1.38	48	2.45	75	1.91
Got assistance from relatives or friends	22	1.12	29	1.48	51	1.30
Got assistance from Government	19	0.97	37	1.89	56	1.43
Got assistance from NGO	2	0.10	3	0.15	5	0.13
Borrowed money from bank, others	51	2.60	64	3.26	115	2.93
Use savings	45	2.29	162	8.26	207	5.28
Total	**1,961**	**100**	**1,961**	**100**	**3,922**	**100**

Source: Author' calculation from VARHS 2008-2010

Table 2: Coping strategies by types, 2008-2010.

Crop	2008				2010			
	Obs.	Percent (%)	Mean (thous. VND)	Std. dev. (thous. VND)	Obs.	Percent (%)	Mean (thous. VND)	Std. dev. (thous. VND)
Rice	2,470	43.97	12739	29446	2,386	30.62	13472	32082
Maize	1,286	22.89	4213	7551	1,243	15.95	5004	8560
Potato (non-sweet)	12	0.21	1306	1264	27	0.35	1715	1793
Sweet potato	104	1.85	840	1394	81	1.04	2440	4614
Cassava	652	11.61	3464	5273	639	8.20	3166	7339
Peanuts	226	4.02	4077	10039	212	2.72	4006	13178
Vegetables	na	na	na	na	664	8.52	2551	6201
Other annual crops	na	na	na	na	476	6.11	6299	22180
Fruits	44	0.78	3333	4332	949	12.18	1662	4304
Coffee	394	7.01	52956	63287	435	5.58	51504	64727
Tea	101	1.80	4982	7089	111	1.42	5184	7621
Cocoa	na	na	na	na	16	0.21	8250	9546
Cashew nuts	154	2.74	4511	7067	182	2.34	10752	15606
Sugar cane	42	0.75	15302	24191	51	0.65	19567	39732
Pepper	116	2.07	30165	55930	88	1.13	35701	50698
Rubber	16	0.28	40289	57807	41	0.53	75225	62585
Medicinal trees/ plants	na	na	na	na	67	0.86	8844	11206
Other perennial crops	na	na	na	na	124	1.59	8362	14031
Forestry	na	na	na	na	1	0.01	500	na
Total	**5,617**				**7,793**			

Note: na: no information

Source: Author' calculation from VARHS 2008-2010

Table 3: Cultivation activities by types and crop values (thousand VND), 2008-2010.

crop, followed by maize, cassava and coffee. Data for 2010 show that rice is still the most frequently planted crop, followed by maize, fruit trees, vegetables and cassava. There is a big difference in fruit trees between the two years of the survey, possibly because farmers responded to the food price decline in 2008.

Table 3 also presents the value of crop production of farmers in the two years 2008-2010. In 2008, among the short-term crops, rice had the highest average farmer production value, about 13 million VND per year, followed by maize, and peanut. In 2010, the average production value of rice farmers is over 13 million VND per year, followed by maize and peanut. In general, in the two years 2008-2010, there was no significant change in the value of production and the hierarchy of short-term crops.

Review of related literature and empirical approach

Most of related empirical works so far are on the impacts of natural disasters on agriculture in general, for example: Loayza, et al. (2009), Sivakumar (2005), and Long (1978). Loayza, et al. (2009) find that droughts and storms have negative impacts on agriculture while floods have a positive effect. Sivakumar (2005) argues that the predominant impacts of natural disasters on agriculture are negative. Long (1978) indicates that the negative effects are a powerful partial explanation of the lack of agricultural self-sufficiency in a large number of low income countries.

An exception is Israel and Briones (2012), who use the Agricultural Multi-market Model for Policy Evaluation (AMPLE) to examine the impacts of natural disasters such as typhoons, floods and droughts on agriculture at the provincial level in the Philippines. They find that typhoons have a significant negative impact on paddy rice production at the provincial level.

Our empirical investigation focuses on: the extent to which natural disaster affects farm-level rice productivity and the extent to which farms manage to cope with adverse effects of natural disaster within the framework of traditional Cobb-Douglas production function as illustrated by Te'o (1997). We follow two stages of empirical investigations to explore these issues. First, we analyses the impacts of natural disaster on farm-level rice productivity. The relationship between natural disaster and the depletion of the farm productivity can be identified using a panel fixed-effects approach under certain assumptions. We exploit the panel dimension to our data by using a fixed effects model that controls for time invariant farm heterogeneity. Time varying farm characteristics are also included as control variables. The key explanatory variables of interest are the different types of natural disaster and the severity and persistence of these natural disasters. Our data facilitate the disaggregation of overall natural disaster into specific natural disasters, which are all exogenous to the model. Using a fixed effects estimation procedure will eliminate any time invariant unobserved heterogeneity while the inclusion of control variables for inputs to capture any remaining time varying heterogeneity. The full farm level fixed effects model we estimate is given by:

$$\begin{aligned} Y_{it} &= \left(\alpha_1 LAB_{it} + \alpha_2 LAND_{it} + \alpha_3 CAP_{it} + \alpha_4 MATE_{it}\right) \\ &+ \beta\sum_1^3 NAT_{it}^j + +\chi\sum_1^3 LOSS_{it}^j + \delta\sum_1^3 NATLOSS_{it}^j \\ &+ \delta_4 NATLOSS21_{it} + +\delta_5 NATLOSS31_{it} \\ &+ \delta_6 NATLOSS32_{it} + \tau_i + u_i + \varepsilon_{it} \qquad \text{(A)} \end{aligned}$$

Where:

Y_{it} is rice productivity (measured by tons per hectare and in natural logarithm form as used in, for example, Yu et al. (2010));

LAB_{it}, $LAND_{it}$, CAP_{it}, $MATE_{it}$ represents a vector of farm production inputs (such as labor (total of working days), land (arable land for rice cultivation), capital (annual capital investment), and intermediate costs for rice cultivation. These variables are in natural logarithm form. Economic theory said that higher rice yields are characterized by higher input usage (labor, land, capital, and intermediates such as fertilizer) during the production process;

NAT^j_{it} (j=1,2,3) are zero-one dummy variables indicating natural disaster occurred in survey year (*t*), one year before (*t* - 1) and two years before (*t* - 2), respectively. If the current natural disaster resulted in a loss in yield of rice, we would expect the coefficient on this term to be negative and statistically significant (the current occurrence effect); and if the past natural disaster resulted in a loss in yield of rice, we would expect the coefficient on these terms to be negative and statistically significant (the inter-temporal occurrence effect);

$LOSS^j_{it}$ (*j*=1,2,3) are variables indicating total loss from natural disaster on rice plots occurred in survey year (*t*), one year before (*t* - 1) and two years before (*t* - 2), respectively. These variables are in natural logarithm form;

$NATLOSS^j_{it}$ (j=1,2,3) are variables indicating interactions between natural disaster and total loss (in natural logarithm form) from natural disaster on rice plots occurred in survey year (t), one year before (t - 1) and two years before (t - 2), respectively. If natural disasters are severe, resulted in a loss in yield of rice, we would expect the coefficient on these above interaction terms to be negative and statistically significant (the current severity effects, respectively);

$NATLOSS21_{it}$, is interaction between natural disaster at last year (t - 1) and total loss (in natural logarithm form) from natural disaster on rice plots occurred at current year (t); and $NATLOSS31_{it}$ and $NATLOSS32_{it}$ are interactions between natural disaster occurred two years ago (t - 2) and total loss (in natural logarithm form) from natural disaster on rice plots occurred at current year (t) and last year (t - 1), respectively. If natural disasters are severe, resulted in a loss in yield of rice, we would expect the coefficient on these above interaction terms to be negative and statistically significant (the inter-temporal severity effects);

τ_t represents time dummies, u_i is a farm specific fixed effect and ε_{it} is the farm random error term. We assume that regional differences which control for rice productivity variations and across regions are subsumed within the farm fixed effect while the time dummies control for changes in technology over time.

We explore model (A) into four sub-models: (a) Model 1a with natural disaster, (b) Model 2a with natural disaster, loss, and interactions between natural disaster and loss, (c) Model 1b with specific natural disasters such as flood, drought, typhoon and land slide, (d) Model 2b with specific natural disasters such as flood, drought, typhoon and land slide, their respective losses, and their interactions between specific natural disasters and their respective losses.

At the second stage, our analysis is further extended to consider the extent to which coping strategies may serve to lessen the depletion of farm productivity. We consider seven types of coping strategies, namely: (1) 'reduced consumption', (2) 'sold land, livestock, assets', (3) 'got assistance from relatives or friends', (4) 'got assistance from Government', (5) 'got assistance from NGO', (6) 'borrowed money from bank, others', and (7) 'used savings'. A specified model is as follows:

$$\begin{aligned} Y_{it} = {} & \left(\alpha_1 LAB_{it} + \alpha_2 LAND_{it} + \alpha_3 CAP_{it} + \alpha_4 MATE_{it}\right) \\ & + \beta\sum_1^3 NAT^j_{it} + + \chi\sum_1^3 LOSS^j_{it} + \delta\sum_1^3 NATLOSS^j_{it} \\ & + \delta_4 NATLOSS21_{it} + + \delta_5 NATLOSS31_{it} \\ & + \delta_6 NATLOSS32_{it} + \phi_1\sum_1^7 COP^j_{it} + \phi_2\sum_1^7 COPLG1^j_{it} \\ & + \phi 3\sum_1^7 COPLG2^j_{it} + \varphi 1\sum_1^7 COPNAT^j_{it} + \varphi 2\sum_1^7 COPNATLG1^j_{it} \\ & + \varphi 3\sum_1^7 COPNATLG2^j_{it} + \tau_i + u_i + \varepsilon_{it} \end{aligned} \qquad \text{(B)}$$

Where:

COP^j_{it}, $COPLG1^j_{it}$, and $COPLG2^j_{it}$ (j=1,2,3,4,5,6,7) are zero-one dummy variables indicating seven specific coping strategies conducted in survey (t), one year before (t - 1) and two years before (t - 2), respectively. If copping strategies help to lessen the depletion of rice productivity in the event of a natural disaster, we would expect the coefficient on these interaction terms to be positive and statistically significant (the positive current coping-occurrence effects); if not, the coefficients can be negative and statistically significant (the negative current coping-occurrence effects).

$COPNAT^j_{it}$, $COPNATLG1^j_{it}$, and $COPNATLG2^j_{it}$ (j=1,2,3,4,5,6,7) are interactions between natural disaster and seven specific coping strategies in survey (t), one year before (t - 1) and two years before (t - 2), respectively. If copping strategies help to lessen the depletion of rice productivity in the event of a natural disaster, we would expect the coefficient on these interaction terms to be positive and statistically significant (the positive inter-temporal coping-occurrence effects); if not, the coefficients can be negative and statistically significant (the negative inter-temporal coping-occurrence effects).

We explore model (B) into four sub-models: (a) Model 3a with natural disaster, coping strategies, and interactions between natural disaster and coping strategies, (b) Model 4a with natural disaster, loss, their interactions, coping strategies, and interactions between natural disaster and coping strategies, (c) Model 3b with specific natural disasters, coping strategies, and interactions between specific natural disasters and coping strategies, (d) Model 4b with specific disasters, loss, their interactions, coping strategies, and interactions between specific disasters and coping strategies.

Outliers are always hidden in the questionnaire survey. In this study, we suspected outlier observations on the variables of rice area, rice yield, and rice yield of farmers. With these three variables we cannot apply the conventional method to identify and eliminate outlier observations, so we use *bacon* command in Stata to identify multivariate outliers (Weber, 2010). After removing outliers, we obtain a two-wave panel dataset of 3922 observations.

During the regression analysis, multi-collinearity and heteroskedasticity are examined and the results show that there is no multi-collinearity and no evidence of unequal variance. In addition, we present the regression results after the procedure for eliminating natural disasters related variables that do not pass the statistical significance test at the common levels.

Results and discussion

The summary statistics presented in Materials and methods help to motivate the central research questions of this paper concerning the impact of natural disaster on farm-level rice production. As discussed in Section 3, there are two parts to our empirical investigation of these issues. First, we estimate a fixed effects model of the impact of natural disaster on farms' rice productivity. Second, we focus on the impacts of coping strategies to farms' rice productivity under natural disaster to gain an understanding of the extent to which coping strategies are effective.

1. Statistic description

Table 4 presents descriptive statistics for the years 2008 and 2010 on the annual sample. There is no significant change in the average annual production of rice between 2008 and 2010, at about 1.8 tones. However, there is a significant change in paddy yield between 2008 (4.22 tons per ha) and 2010 (4.48 tons per ha). Labor size has not changed between two years (approximately 3 labors in 2008 and 2010). However, the number of working days devoted to rice cultivation has changed much: 125 days in 2008 and 101 days in 2010. Rice cultivation area remains unchanged in 2008 and 2010, at about 0.45 hectares. There is an increase in investment between 2008 and 2010, about 928 thousand VND in 2008 to about 1.3 million VND in 2010. The cost of production also increased about 2.5 million VND in 2008 to nearly 6.0 million VND in 2010.

Table 5 also shows that that from less than 1 per cent to 18 per cent of rice cultivating firms suffered natural disaster between 2007 and 2010. At a disaggregated level, in 2007 we find that

Variable	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
	2008 (N = 1969)				2010 (N = 1969)			
Rice output (tons)	1.80	1.36	0.03	10.80	1.73	1.31	0.05	10.50
Rice productivity (Tons/ha)	4.48	1.50	0.20	10.00	4.22	1.44	0.25	11.43
Number of labor	3.08	1.46	1.00	10.00	3.17	1.48	1.00	9.00
Number of working days for rice (days)	124.59	87.85	2.00	660.00	101.25	64.51	3.00	520.00
Arable land for rice (hectare)	0.45	0.36	0.01	2.9	0.46	0.39	0.01	3.80
Total investment (thousand VND)	928.54	3674	0.00	70035	1287.41	4240.63	0.00	45100
Input costs (thousand VND)	2518	2722	0.00	35500	5947.27	9257	0.00	128230

Source: Authors' calculation from VARHS 2008-2010

Table 4: Statistic summary on factor variables, 2008-2010.

Variable	2008		2010		Variable	2008		2010	
	Mean	Std. Dev.	Mean	Std. Dev.		Mean	Std. Dev.	Mean	Std. Dev.
Natural disaster at year t (Yes=1)	0.0331	0.1791	0.0495	0.2169	Got assistance from relatives or friends at year t (Yes=1)	0.0112	0.1053	0.0214	0.1448
Natural disaster at year (t – 1) (Yes=1)	0.1260	0.3319	0.1836	0.3872	Got assistance from Government at year t (Yes=1)	0.0102	0.1005	0.0224	0.1481
Natural disaster at year (t – 2) (Yes=1)	0.0041	0.0638	0.0617	0.2407	Got assistance from NGOs at year t (Yes=1)	0.0010	0.0319	0.0015	0.0391
Flood at year t (Yes=1)	0.0235	0.1514	0.0066	0.0812	Borrowed money from bank, others at year t (Yes=1)	0.0265	0.1607	0.0403	0.1967
Flood at year (t – 1) (Yes=1)	0.0796	0.2707	0.0637	0.2444	Used savings at year t (Yes=1)	0.0229	0.1498	0.0826	0.2754
Flood at year (t – 2) (Yes=1)	0.0036	0.0597	0.0566	0.2311	Reduced consumption at year (t – 1) (Yes=1)	0.3177	0.4657	0.2743	0.4463
Drought at year t (Yes=1)	0.0122	0.1100	0.0444	0.2060	Sold land, livestock, assets at year (t – 1) (Yes=1)	0.0127	0.1122	0.0454	0.2082

Source: Authors' calculation from VARHS 2008-2010

Table 5: Statistic summary on natural disaster and coping strategies, 2008 -2010 (to be continued).

Variable	2008		2010		Variable	2008		2010	
	Mean	Std. Dev.	Mean	Std. Dev.		Mean	Std. Dev.	Mean	Std. Dev.
Drought at year (t – 1) (Yes=1)	0.0352	0.1843	0.0938	0.2917	Got assistance from relatives or friends at year (t – 1) (Yes=1)	0.0122	0.1100	0.0224	0.1481
Drought at year (t – 2) (Yes=1)	0.0005	0.0226	0.0056	0.0747	Got assistance from Government at year (t – 1) (Yes=1)	0.0102	0.1005	0.0245	0.1546
Typhoon at year t (Yes=1)	0.0015	0.0391	0.0031	0.0552	Got assistance from NGOs at year (t – 1) (Yes=1)	0.0020	0.0451	0.0031	0.0552
Typhoon at year (t – 1) (Yes=1)	0.0087	0.0927	0.0311	0.1737	Borrowed money from bank, others at year (t – 1) (Yes=1)	0.0286	0.1666	0.0428	0.2025
Typhoon at year (t – 2) (Yes=1)	0	0	0.0010	0.0319	Used savings at year (t – 1) (Yes=1)	0.0316	0.1750	0.0903	0.2866
Landslides at year t (Yes=1)	0.0031	0.0552	0.0015	0.0391	Reduced consumption at year (t – 2) (Yes=1)	0.3095	0.4624	0.2458	0.4307
Landslides at year (t – 1) (Yes=1)	0.0102	0.1005	0.0143	0.1187	Sold land, livestock, assets at year (t – 2) (Yes=1)	0.0122	0.1100	0.0454	0.2082
Landslides at year (t – 2) (Yes=1)	0	0	0.0010	0.0319	Got assistance from relatives or friends at year (t – 2) (Yes=1)	0.0112	0.1053	0.0219	0.1465
Natural disaster loss at year t (thousand VND)	159	680	98	550	Got assistance from Government at year (t – 2) (Yes=1)	0.0066	0.0812	0.0250	0.1561
Natural disaster loss at year (t – 1) (thousand VND)	336	1253	304	1438	Got assistance from NGOs at year (t – 2) (Yes=1)	0.0010	0.0319	0.0015	0.0391
Natural disaster loss at year (t – 2) (thousand VND)	16	205	105	880	Borrowed money from bank, others at year (t – 2) (Yes=1)	0.0255	0.1577	0.0398	0.1955
Reduced consumption at year t (Yes=1)	0.3151	0.4647	0.2407	0.4276	Used savings at year (t – 2) (Yes=1)	0.0209	0.1431	0.0852	0.2792
Sold land, livestock, assets at year t (Yes=1)	0.0143	0.1187	0.0444	0.2060					

Source: Authors' calculation from VARHS 2008-2010

Table 5: Statistic summary on natural disaster and coping strategies, 2008 -2010 (continuation).

less than 1 per cent of farms suffered one form of natural disasters such a flood, drought, typhoon, and landslides, while in 2009-2010, flood occurred at 5-6 per cent, drought sometimes at 9 per cent, typhoon at 3 per cent, and landslides at 1 per cent.

The losses as a result of natural disaster varies considerably over time. As revealed in Table 7, the size of losses increases from 16 thousand VND in 2007 to 304 thousand VND in 2009.

With respect to coping strategies, most farms choose to reduce consumption and the percentage is increasing over time, from 31 per cent in 2007 to 43 per cent in 2010. Coping by selling productive means is also increased over time, from around 1 percent in 2007 to about 21 per cent in 2010. The proportion farms with assistance from relatives and from Vietnamese government increased between 2007 and 2010 from 1 per cent to 14 per cent of farms. As an important source of finance, farms choosing to borrow from bank increased between 2007 and 2010 from 3 per cent to 20 per cent of farms. We also find that the proportion of farms using savings increased between 2007 and 2010 from 2 per cent to 28 per cent of farms.

2. Natural disaster effects on rice productivity

The results of the fixed effects model of the effects of natural disaster on farm-level rice productivity are presented in Table 6. First, we determine whether farms suffering any type of natural disasters experience a statistically significant reduction in rice productivity (the current and inter-temporal occurrence effects). Second, we further investigate to which extend the level of severity by natural disaster affect farm-level rice productivity by taking into account the loss from natural disaster and by interacting natural disaster incidence and the loss from natural disaster (the current and inter-temporal severity effects). Third, we disaggregate the natural disaster measure into its specific forms such as flood, drought, typhoon, and landslides to explore how each specific category of natural disasters influences rice productivity over time (the current and inter-temporal occurrence effects). Four, we further examine the level of severity by specific natural disasters affecting farm-level rice productivity by taking into account the loss from specific natural disasters and by interacting specific natural disaster incidence and the loss from respectively specific natural disasters (the current and inter-temporal severity effects). In all steps, controls for traditional determinants of rice productivity such as labor, land, capital investment, and intermediate costs and other factors such as recovery from prior shocks (to control for persistence) and time dummies (to control for technology change over time) are included. Table 6 shows, in the second last row of it, that the fixed effects model is preferred than the OLS model. In addition, Hausman test in the last row of the table indicating that the random effect estimator is consistent (due to non-zero covariance between residuals and explanatory variables) is rejected. Therefore, we have to rely upon the fixed effect estimator.

Table 6 presents two main parts of estimation results. The first is related to factor variables, and the second all about natural disasters' effects. Although our main concerns are the second, we say somethings about the factor variables. Since production and inputs are measured in their logarithmic forms and are continuous, all the estimated parameters are the elasticities of these inputs. Yield elasticities with respect to household labor is about 0.09, highlighting the important role of labor in four models. An additional 1 percent working day use (proxied by working days) could increase the yield by 0.09 percent. Intermediates also have a sizable effect on rice yield, and an additional 1 percent intermediates use (proxied by intermediates costs) could increase the yield by 0.05 percent in four models. Annual capital investment is not significant in four models. Land has significantly negative effects on yield in four models. A possible explanation is the arable land size is small (on average, 0.45 ha in 2008 and 0.39 ha in 2010 in our sample and see Markussen (2015) for more description on this issue). Small land size can prevent farmers from mechanization or benefit from economies of scale. Another explanation is the fragmentation of land that also constraints the effectiveness of land use (see, for example, Markussen (2015)).

Regarding to the effect of natural disasters, Model 1a in Table 6 reveals that natural disaster within the last two years have a negative effect on rice productivity (the negative inter-temporal occurrence effect), which proves to be consistent with past studies (Israel and Briones, 2012; Sivakumar, 2005), while natural disaster at the survey year has no significant effect). Average rice yields among farms with natural disaster in last year are considerably lower than those with no natural disaster in the current year by 4.9 percent. In addition, average rice yields

Dependent variable: rice productivity (tons per hectare, log)	Model 1a	Model 2a	Model 1b	Model 2b
Factor variables				
Total of working days (days, log)	0.0847*** (0.0129)	0.0866*** (0.0128)	0.0853*** (0.0128)	0.0858*** (0.0260)
Arable land for rice cultivation (hectare, log)	-0.313*** (0.0199)	-0.314*** (0.0198)	-0.312*** (0.0199)	-0.302*** (0.0374)
Annual capital investment (thousand VND, log)	0.00189 (0.00265)	0.00213 (0.00265)	0.00164 (0.00265)	0.00255 (0.00515)
Intermediate costs for rice cultivation (thousand VND, log)	0.0558*** (0.00827)	0.0573*** (0.00823)	0.0533*** (0.00822)	0.0504*** (0.0148)
Natural disasters related variables				
Loss by disaster at year (t – 1) (thousand VND, log)		-0.00694*** (0.00267)		
Disaster at year (t – 1) (Yes=1) *Loss by disaster at year (t) (thousand VND, log)		-0.0237*** (0.00755)		
Disaster at year (t – 2) (Yes=1) *Loss by disaster at year (t – 1) (thousand VND, log)		-0.0278**(0.0116)		
Disaster at year (t) (Yes=1)	-0.0419 (0.0352)			
Disaster at year (t – 1) (Yes=1)	-0.0493** (0.0202)			
Disaster at year (t – 2) (Yes=1)	-0.0690* (0.0400)			
Flood at year (t) (Yes=1)			-0.105* (0.0575)	
Typhoon at year (t) (Yes=1)			-0.323** (0.147)	
Drought at year (t - 1) (Yes=1)				-0.574*** (0.207)
Loss by drought at year (t – 1) (thousand VND, log)				-0.0964*** (0.0318)
Landslide at year (t – 2) (Yes=1) *Loss by landslide at year (t – 1) (thousand VND, log)				-0.0869 (0.0731)
Recovery controlled	Yes	Yes	Yes	Yes
Constant	0.266** (0.106)	0.260** (0.105)	0.275*** (0.106)	0.275*** (0.206)
Observations	3,922	3,922	3,922	2,122
R-squared within model	0.118	0.129	0.117	0.115
R-squared between model	0.274	0.287	0.271	0.212
R-squared overal model	0.224	0.237	0.221	0.203
F for u_i=0	1.463***	1.459***	1.496***	1.245***
Hausman test (H_0: Difference in coefficients not systematic)	311.02***	285.39***	250.31***	46.55***

Note: Model 1a: Natural disaster; Model 2a: Natural disaster, loss, and interactions; Model 1b: Specific natural disaster; Model 2b: Specific natural disasters, loss, and interactions
Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Source: Authors' calculation from VARHS 2008-2010

Table 6: Effects of natural disaster on rice productivity, 2008-2010.

among farms with natural disaster in two years ago are considerably lower than those with no natural disaster in the current year by 6.9 percent.

Taking the total loss from natural disaster into account, we find that natural disaster with severity in all time swing of consideration (the survey year, last year and two years ago) do have a significantly negative effect on rice productivity in Model 2a (the negative inter-temporal severity effect). Specifically, a 1 percent loss due to natural disaster in the last year could decrease the yield by nearly 0.01 percent. In addition, a 1 percent loss in the current year due to natural disaster in the last year could decrease the yield by nearly 0.02 percent. Moreover, a 1 percent loss in the last year due to natural disaster in two years ago could decrease the yield by nearly 0.03 percent.

Disaggregating the natural disaster into its specific forms (Model 1b) we find that two types of natural disasters such as flood and typhoon at the survey year have a negative effect on rice productivity (the negative current occurrence effect), which appears to be consistent with past studies (Israel and Briones, 2012; Sivakumar, 2005). Average rice yields among farms with flood in the current year are considerably lower than those with no flood in the current year by 10.5 percent. In addition, average rice yields among farms with typhoon in the current year are considerably lower than those with no typhoon in the current year by 32.3 percent.

A further step to take total loss into consideration (Model 2b) by interacting specific natural disasters with their respective losses reveals that both drought and land slide with severity serve to deplete rice productivity over time (the negative inter-temporal severity effect), which appears to be consistent with the study of Israel and Briones (2012) for the Philippines. Average rice yields among farms with drought in the last year are considerably lower than those with no drought in the last year by 57.4 percent. Furthermore, a 1 percent loss in the last year due to drought could decrease the yield by nearly 0.1 percent. Last but not least, a 1 percent loss in the last year due to landslide in two years ago could decrease the yield by nearly 0.09 percent.

3. Coping strategies and rice productivity

The results of the fixed effects model of the effects of coping strategies on farm-level rice productivity are presented in Table 7. First, we determine whether coping strategies conducted by farms suffering any type of natural disasters help to reduce the negative effect of natural disaster on rice productivity (the current and inter-temporal coping-occurrence effects). Second, we further investigate whether coping strategies conducted by farms help to reduce the negative effect of natural disaster on rice productivity by` taking into account the level of severity by natural disaster (measure by the loss from natural disaster) and by interacting natural disaster incidence and the loss from natural disaster (the current and inter-temporal coping-severity effects). Third, we investigate whether coping strategies conducted by farms help to reduce the negative effect of a specific natural disaster on rice productivity by using information on specific natural disaster on rice plots (the current and inter-temporal coping-occurrence effects). Four, we further examine whether coping strategies conducted by farms help to reduce the negative effect of a specific natural disaster on rice productivity by using information on the severity of specific natural disaster (the current and inter-temporal coping-severity effects). In all steps, controls for traditional determinants of rice productivity such as labor, land, capital investment, and intermediate costs and other factors such as recovery from prior shocks (to control for persistence) and time dummies (to control for technology change over time) are included. As a step to determine whether fixed effects model or OLS one is preferred, Table 7 shows, in the second last row of it, that the fixed effects model is preferred than the OLS model. In addition, Hausman test in the last row of the table indicating that the random effect estimator is consistent (due to non-zero covariance between residuals and explanatory variables) is rejected. Therefore, we have to rely upon the fixed effect estimator.

While selling productive means such as land, livestock, assets as a coping strategy has been discussed in, for example, Fafchamps (2009) in general case, and Rosenzweig and Wolpin (1993) for the case of India, Model 3a reveals some mixed results from selling productive means. On the one hand, selling productive means such as land, livestock, assets in the last year can reduce rice productivity at current year (the negative inter-temporal coping-occurrence effect). On the other hand, selling productive means such as land, livestock, assets in the two years ago can increase rice productivity at current year (the positive inter-temporal coping-occurrence effect). This is further confirmed when taking into account the severity of natural disaster in Model 3b (both the positive and negative inter-

Dependent variable: rice productivity (tons per hectare, log)	Model 3a	Model 4a	Model 3b	Model 4b
Factor variables				
Total of working days (days, log)	0.0819*** (0.0129)	0.0843*** (0.0127)	0.0807*** (0.0128)	0.0777*** (0.0262)
Arable land for rice cultivation (hectare, log)	-0.312*** (0.0199)	-0.313*** (0.0198)	-0.312*** (0.0198)	-0.303*** (0.0372)
Annual capital investment (thousand VND, log)	0.00160 (0.00264)	0.00190 (0.00264)	0.00170 (0.00263)	0.00277 (0.00513)
Intermediate costs for rice cultivation (thousand VND, log)	0.0577*** (0.00824)	0.0594*** (0.00820)	0.0583*** (0.00829)	0.0596*** (0.0152)
Natural disasters related variables				
Loss by disaster at year (t – 1) (thousand VND, log)		-0.00632** (0.00266)		
Disaster at year (t – 1) (Yes=1) * Loss by disaster at year (t) (thousand VND, log)		-0.0253*** (0.00751)		
Disaster at year (t – 2) (Yes=1) * Loss by disaster at year (t – 1) (thousand VND, log)		-0.0269** (0.0116)		
Disaster at year (t) (Yes=1)	-0.0403 (0.0350)			
Disaster at year (t – 1) (Yes=1)	-0.0371* (0.0204)			
Disaster at year (t – 2) (Yes=1)	-0.0752* (0.0400)			
Flood at year (t) (Yes=1)			-0.110* (0.0572)	
Typhoon at year (t) (Yes=1)			-0.306** (0.147)	
Drought at year (t - 1) (Yes=1)				0.671*** (0.211)
Loss by drought at year (t – 1) (thousand VND, log)				-0.109*** (0.0321)
Landslide at year (t – 2) (Yes=1) * Loss by landslide at year (t – 1) (thousand VND, log)				-0.104 (0.0732)
Coping measures				
Got assistance from NGO at year (t) (Yes=1)	-0.284 (0.197)	-0.296 (0.196)	-0.305 (0.197)	
Sold productive means at year (t – 1) (Yes=1)	-0.705*** (0.198)	-0.711*** (0.197)	-0.665*** (0.197)	
Sold productive means at year (t – 2) (Yes=1)_	0.558*** (0.199)	0.556*** (0.197)	0.511*** (0.198)	
Used savings at year (t – 2) (Yes=1)			-0.0644** (0.0323)	-0.110** (0.0467)
Recovery controlled	Yes	Yes	Yes	Yes
Constant	0.269** (0.105)	0.250** (0.105)	0.265** (0.105)	0.246*** (0.205)
Observations	3,922	3,922	2,122	2,122
R-squared within model	0.129	0.139	0.131	0.123
R-squared between model	0.277	0.291	0.278	0.210
R-squared overal model	0.229	0.242	0.231	0.204
F for u_i=0	1.477***	1.474***	1.506***	1.256***
Hausman test (H_0: Difference in coefficients not systematic)	317.18***	292.77***	250.05***	49.50***

Note: Model 3a: Natural disaster, coping strategies, and interactions; Model 3b: Natural disaster, loss, coping strategies, and interactions; Model 4a: Specific natural disaster, coping strategies, and interactions; Model 4b: Specific natural disasters, loss, their interactions, coping strategies, and interaction
Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Source: Authors' calculation from VARHS 2008-2010

Table 7: Effects of coping strategies on rice productivity, 2008-2010.

temporal coping-occurrence effects of selling productive means).

On top of that, disaggregating the natural disaster into its specific forms, both the positive and negative inter-temporal coping-occurrence effects of selling productive means) is confirmed (Model 4b). In addition, the negative inter-temporal coping-occurrence effect from using savings at the point of two years ago is confirmed (Model 3b and 4b). Findings from theoretical models by Zeldes (1989), Kimball (1990), studies by Deaton (1992) for developing countries, and Udry (1994) in Nigeria suggest that savings (especially for poor rural households) appear to be a pre-emptive response to income shocks rather than a long-term investment decision. Thus, a plausible explanation is using savings in the past may deplete the productivity through a shortage of financial resource at the current time.

We did not find significant coping evidence of borrowing money from bank, assistances from relatives, NGOs, and government.

Conclusion

Rice production in Vietnam faces severe challenges from natural disaster. In the current paper, we examine the consequences of natural disaster on rice production of Vietnamese farms by examining the impacts of natural disaster and coping strategies as well on rice productivity. We exploit the panel dimension to the dataset of rice production with 3,922 households by using a fixed effects model that controls for time invariant farm heterogeneity. Time varying farm characteristics are also included as control variables.

When natural disaster variable in general is used, we find that natural disaster within the last two years have a negative effect on rice productivity (the negative inter-temporal occurrence effect). Taking the total loss from natural disaster into account, we find that natural disaster with severity in all time swing of consideration (the survey year, last year and two years ago) do have a significantly negative effect on rice productivity (the negative inter-temporal severity effect).

Disaggregating the natural disaster into its specific forms, we find that two types of natural disasters such as flood and typhoon at the survey year have a negative effect on rice productivity (the negative current occurrence effect). Taking total loss into consideration, estimation reveals that both drought and land slide with severity serve to deplete rice productivity over time (the negative inter-temporal severity effect).

With regarding to coping strategies, selling productive means such as land, livestock, assets have both the negative inter-temporal coping-occurrence effect and the positive inter-temporal coping-occurrence effect, depending the length of occurrences. With regarding to savings as a source of coping, we find the negative inter-temporal coping-occurrence effect. We did not find significant coping evidence of borrowing money from bank, assistance from relatives, NGOs, and government.

Based on its results and findings, the study recommends the following: (i) Since specific natural disasters may have significantly and differently negative impacts on rice production at the farm level, assistance for rice farmers and the agriculture sector as a whole should be made more site and crops-specific; (ii) the findings provide evidence for the importance of financial resources in support for farms in rice production where natural disaster occur. Savings act as important buffers in the face of natural disaster in the short run but in the long run using savings as coping may lead to lower rice productivity given that it results in a shortage of financial resource at the current time, (iii) Coping with selling productive means has both the negative inter-temporal coping-occurrence effect and the negative inter-temporal coping-severity effect, thus it suggests that farms should rely on other available types of coping rather than deplete rice productivity in the long run.

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Automated Wildlife Recognition

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Abstract

The estimation of wildlife populations is an issue currently being solved at workplaces on many levels. Knowledge of wildlife population and localization is not only very important for reducing damage to agricultural and forest growth, which arises from the local overgrowth of certain animal species, but also for the protection of endangered species of animals and plants.

The article presents the results of a research carried out during 2017 as the first partial objective of a complex automated wildlife estimation project, namely the recognition of game in a free landscape without vegetation cover from an UAV (unmanned aerial vehicle). The paper describes a method of finding game animals in a selected area and identifies problems with the recognition of the animals hiding in the vegetation. These results play an important role in solving the overall complex problem of automated game recognition.

Keywords

Wildlife, automated recognition, picture segmentation, neural networks, mimicry, false positive recognition.

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Introduction

Various efforts to accurately estimate the population of game are centuries old. Nowadays, the census results are the basis for determining the amount of hunting needed to ensure stable game numbers. In most European countries, including the Czech Republic, the population of hooved animals has increased in recent decades, causing more and more damage to forest and field cultures (Bartoš et al., 2010). In order for the population estimates to properly function as a control method, its results should roughly correspond with reality. At present day, most commonly used methods in the Czech Republic account only for 10-33% of the actual population. The accuracy of estimates of game conditions is eloquently evidenced by the comparisons of the spring population with the number of hunted animals (Bartoš et al., 2005). According to statistics from some countries, sometimes more animals were caught than the amount estimated by the census for the whole population, which is also the case in the Czech Republic. That is why new alternative and more efficient methods are being sought.

Better results can be usually achieved using more powerful equipment, but its use alone does not guarantee the quality of outputs. Various methods, such as telemetry monitoring, are used to track game, which are particularly useful for research on game ethology, but are not well suited for population estimation (Jarolímek et al., 2014; Masner et al., 2014). The first findings of aviation census have been published more than forty years ago (Graves et al., 1972). Estimating game population from aircraft or helicopter is practiced, for example, in the Scandinavian countries (Liberg et al., 2010). Thermo-vision is also used frequently (Gill et al., 1997, Focardi et al, 2001 and others), but mostly only for ground imagery. In contrast, mainly in the US and Canada, the use of thermo-vision is expanding not only in land censuses, but also in aerial imaging. The results of monitoring of various animal species in various environments (Wyatt et al., 1980; Bayliss and Yeomans 1989, Wiggers and Beckerman 1993, Focardi et. al. 2001, Garel et. al., 2010, Fuentes et al., 2015) were published.

The current development of the use of autonomous flying devices and Artificial Intelligence tools for image evaluation brings a new dimension for the use of "aerial" censing and game monitoring methods.

Unmanned vehicles are nowadays, mainly due to the massive expansion of the so-called multi-copters (multiple motor helicopters), known mainly by the term "drones". Officially, however, the term UAV (Unmaned Aerial Vehicle) is used. Unmanned vehicles offer a variety of new applications by combining air and ground imagery. At the same time, it brings new methods of retrieving data from selected areas in real time. Some types of UAVs are capable of covering an area of several square kilometres, making them cheaper and more affordable alternative to conventional aircraft. Due to the lower scanning height, one can also get very detailed images from the unmanned vehicle (Eisenbeiss, 2011). In addition to capturing images, monitoring can also be performed „on the fly“, when video is transmitted to the operator screen but not recorded.

Automated image recognition is one of the most important technologies at the moment. It is generally referred to as machine vision. Although machine vision is already very elaborate (Gonzales and Woods, 2002), its practical application provides a number of technical problems. These must always be addressed specifically for a given task. Image processing of a recognized object consists of a series of steps. First, it is needed to capture and digitize the image and then use the image pre-processing method to improve the image, which is especially focused on grayscale, brightness and contrast adjustment, histogram equalization, image sharpening, and various filtration methods. Another important step is to use segmentation methods to distinguish a recognized object from the background. It is primarily segmentation by thresholding, image dyeing algorithms, edge detection and linking methods and various algorithms for object filling. Usually, the gradient change of pixel brightness is used. After the image processing is completed, the next phase, the description of the object, follows. The most well-known methods of object description are the moment method, Fourier descriptors and chain codes, which can also be used for so-called structural description of objects. The final stage of the image processing is the object's classification (recognition). The task of classification is to include objects found in the image in a group of previously known classes (Parker, 2011). The object recognition itself can be realized using artificial intelligence methods or statistical analysis (or by combining them). Typically, the acquired description of the object of a so-called classifier will be presented, which, with a certain degree of accuracy, can determine what the object is. The classifier is familiar with the objects that can be submitted to it. This process is called learning.

A particular example is the SIFT (Scale-Invariant Feature Transform) method, which was first used to detect objects in a picture scene. According to Noviyanto and Arymurthy (2013), the identification of cattle shows that the SIFT method has the best results. From the training set of images, object vectors were calculated, which were subsequently searched in test pictures. If the vectors obtained during training and testing were sufficiently matched, the object was detected and recognized at the same time. However, this principle can be equally well used in classification. From the training sets (one for each class), the flag vectors are obtained by the algorithm and are then compared with the vectors counted for the test set. In the next step, using the selected classification method, it is decided to divide the elements of the test set into individual classes. SIFT consists of four main steps: (1) detection of extremes within scale-space; (2) refining the location of significant points; (3) assigning orientation to significant points; (4) compiling a descriptor of significant points (Lowe 1999 and Lowe 2004).

Yu, Wang and Kays (2013) have published an analysis that shows that the combination of SIFT and cLBP (compound local binary pattern) can serve as a useful technique for recognizing animals in real complex situations. They use sparse coding spatial pyramid matching (ScSPM), which extracts dense SIFT descriptors and mobile-structured LBP (cLBP) as a local function that generates global functions via weighted sparse encoding and max pooling using the multi-scale kernel pyramid and sorts images according to the linear support vector machine algorithm.

The photo (or digital stream) is actually a two dimensional array of points that have a defined light intensity (Gonzales, 2002). These points are called “pixels” and their value is most often given in RGB. The captured object is then recorded as an array of points with a defined intensity due to lighting (Gonzales, 2002). The linking of points then creates the final image in the human brain (Russ, 2008). This image can be a real object display, or non-existing object, meaning the brain is hallucinating. The hallucination state is the state in which the displayed object is interpreted in a human brain differently than the image producer should be. Hallucinatory states are unwanted deviations in the interpretation of the reality model display. However, they are useful tools for people (and probably for living organisms) just to filter the image and perceive reality. Hallucination is the misinterpretation of reality given by the property of the brain to generalize the presented pattern, place it in the context of a known (and logically valid reality) and anchor it. Thanks to this generalization feature, one can drive the car and concentrate on the road but not see its structure (asphalt stones, colour differences, etc.). Unnecessary information is filtered out. In terms of image processing and object recognition the equivalent to such hallucinations is the false positive recognition of an object that actually isn't there.

Therefore, for the purpose of the article, the fundamental differences between the vision of humans and machines must be taken into account. A person is able to generalize and anchor the image in a given reality and link it to the context. This means that human brain not only analyzes the shape, size and colour of an object and compares it to an abstract image of given object type (while taking into accout possible colour variants, usual size ranges and general shape), but also its link to the environment (objects outside / inside, which room is the object in, is it on the ground or on a table and so on). The image is therefore interpreted as a real instance of an abstract object in the context of the environment in which the observer lives. While a machine can be tought what an object looks like by supplying large sample of images, it is extremely difficult for the machine to learn how to use the context portion of vision properly.

According to (Gonzales, 2002), (Russ 2008) the machine does not see the same way humans do. The machine sees a matrix of pixels of varying intensity. For the machine the circle is not "round" but it is a vector of pixel coordinates of similar intensity which are the same distance from the defined centre. The reality the machine sees is diametrically different from humans. It is, in fact, similar to the thinking of an engineer who uses CAD tools to construct devices in "curves". Such a person transforms from a real image into a vector space in order to achieve their goal. In order for the machine to see what needs to be seen by it, it is necessary to teach it and give it the context of the problem. This is the most basic problem of computer vision and is it being tackled with a variety of successes by a number of research teams.

Material a methods

The first partial goal of a complex automated game estimation project is to recognize game in an open area without a vegetation cover from a UAV. To obtain the baseline images, the stag and fallow deer animals were optically scanned in the farm (Figure 1).

To fulfil this objective requires a synchronization

Source: authors´ own processing

Figure 1: Environment and animals used to retrieve the baseline images.

of a whole range of tasks that the machine must perform. The basic steps are shown in the diagram (Figure 2).

Stream cutting

It serves to divide the data stream into the sequentially following images (Figure 3). This division is an easy task for machine image processing. Of course, the image recognition algorithm can also be applied to a data stream (which is a sequence of images). However, due to the algorithm's tuning and other practical reasons, it is better to work with static photos.

Image restoration

At this stage, cleaning the photo from "normal noises", such as changes in brightness, takes place. These are due to light conditions changing during recording (change in light intensity). By balancing the brightness and colour layers, it is ensured that the algorithm processing the photograph has the necessary properties to perform segmentation.

Image segmentation

Image segmentation is a basic task of image processing. It separates unnecessary "noise" objects from a photograph and creates a favourite image to be processed.

Assuming the task is to search for a herd of animals in the open air, the following knowledge base serves as a starting point:

- animals are in a free space, without growing vegetation
- the target are hooved animals (deer)
- the target is a herd - not an individual
- animals are scanned from a flying autonomous machine from a height of about 50 m

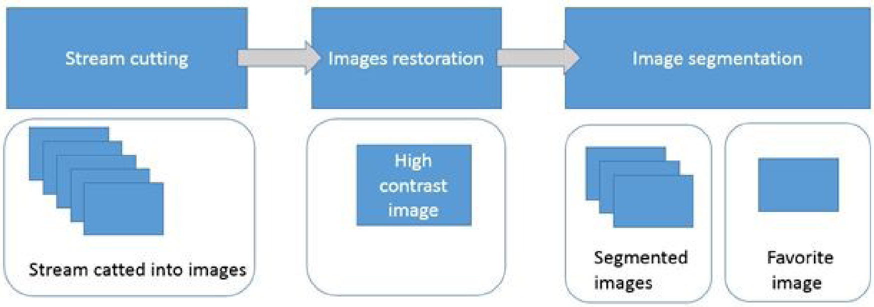
The task is to localize a herd on a pasture based on the data stream of images, see Figure 4.

To be able to locate the object, it was first needed:

- Select a favourite area (based on the knowledge base)
- Search the favourite area to for objects that resemble the animals (or herd)

Selecting the favourite area

Selecting the favourite area will be done by means of thresholding. First, it is necessary to find a suitable threshold (or some threshold function) that will allow to separate (de-segment) "noise objects". Such a noise object is probably a road, a building, or the area with corn and fruit trees. Favorited areas are green surfaces with a smooth terrain, see Figure 5.



Source: authors´ own processing

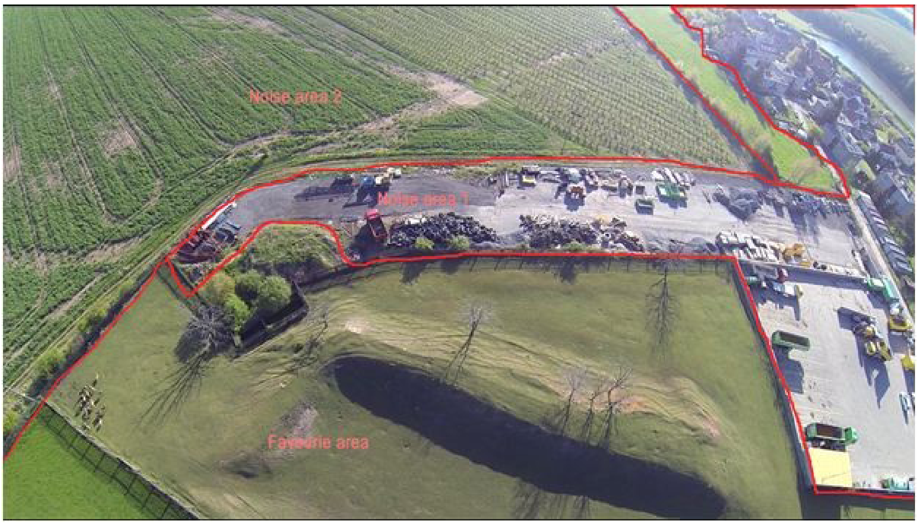
Figure 2: Flow diagram of data stream processing.

Source: authors´ own processing

Figure 3: Video stream split into separate images.

Source: authors´ own processing

Figure 4: An example of target object - herd.



Source: authors´ own processing

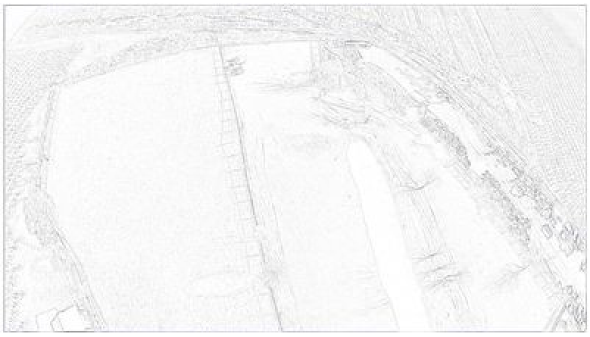
Figure 5: Picture of areas that need to be machine-separated (the areas have been marked manually for the purpose of the article

So how to choose the right method of selecting a given area? In our case, one of the segmentation methods that takes into account the structure of the search area had to be used. This „structural filter“ is then applied to the entire image. The chosen method (for simplicity and applicability) will be:

- Creating mask sized A x B pixels (e.g. A = 10, B = 10, resulting in 10x10 pixels)
- This mask will be moved through the image and its average RGB value will be evaluated. In the case of the model submitted, it will be the average RGB value in the interval:
- R ∈ <100,140>, G ∈ <110,125>, B ∈<80,90>
- The area selected by this method will then be the favourite selected object. Inside this favourite object (pasture) there will be objects of interest (animals, herd). It should be remembered that the size of the mask influences how precisely the machine selects the area. At the same time, the filter must not be too strict. Otherwise, it would discard the area with the animals as well, which would render the whole task pointless.
- For better image processing, the input image is processed by the Difference of Gaussinas edge detector.
- Resulting images are merged.

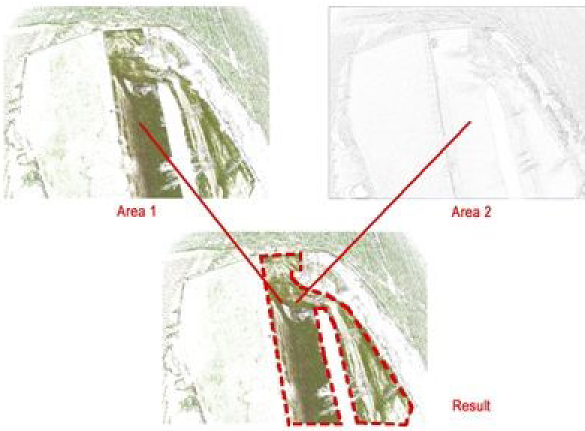
Source: authors´ own processing

Figure 6: Areas selected by the RGB mask.



Source: authors´ own processing

Figure 7: Area processed by an edge detector.



Source: authors´ own processing

Figure 8: Resulting favourite object.

Finding game in the selected area

Finding game in the selected area is a key task. It is important to realize, that the animals try to mask optically and are therefore very difficult to be seen for a number of predators. The human eye is an excellent perceptual organ, but the interpretation of the seen image is performed by the brain. In computer vision, the intelligence of Homo Sapiens and his excellent eyesight (in the case of dog breeds probably an excellent sense of smell) is missing. It is therefore necessary to provide the machine with the necessary context of the problem and to work within the limitations of computer vision (with limited resolution quality).

What is the context:

- a favourite area is where the game should reside (may or may not be there)
- in the favourite area, the game may be split into groups (creating herds, meaning there will be a neighbouring of objects of a similar type)
- the herd will probably move (partially due to the noise and presence of the UAV)

Source: authors´ own processing

Figure 9: Detail of animals in the open.

Locating game can be done in several ways:

- According to shape properties of found objects
- By detecting objects using Artificial Intelligence tools
- According to colour profile

In our case, the simplest option by working with the colour profile of the object was used. Each animal is a light object on a darker surface. If this object moves (if the animal is in motion) then its localization is relatively easy. The goal is to recognize the favourite objects on a video stream and the change of the centre point of favourite objects (possible herd movement). Each favourite object found has its own area, which must be larger than the minimum size (to distinguish, for example, the stones in the pasture that may have a similar colour when viewed from a high angle in direct sunlight) and at the same time smaller than the maximum size. The animals on the pasture will then have a more pronounced colour intensity than the average pasture area (area). Such a moving object is probably a sought-after animal, or an object of similar size and colour (a herding dog for example). This method prevents counting of other objects, such as a maintenance car, wooden shed, etc., resulting in reduced amount of false positive recognitions.

Results and discussion

The problem of game recognition can be divided into two basic types of tasks. Recognizing an object (animal) in an area where it is likely to occur and to distinguish the actual animal species. The first type of task simplifies the problem of just finding an object in a favourite area. This step, however, is necessary prerequisite for the second task, i.e. the recognition of the species. Due to the limits in available technology, it was decided to focus on the first task. Similar problems were also investigated by different teams (Hanzlik et al., 2014), (Pavlickova et al., 2017) who use two different approaches. Algorithmic approach, when machines work virtually based on the brightness of the image and on its threshold. Here, research teams have to successfully solve image segmentation, i.e. separating uninteresting areas from interesting (favourite). Such a task is fairly simple in laboratory conditions when the machine scans an object ideally lit by artificial light in a clean environment. These applications are currently being used in industry and, although not without a complications, their applications in general are more or less successful (e.g. face recognition, smile recognition by Apple, Congitech etc.). Other applications are in the automotive industry and in microelectronics (smart cars track obstacles at different angles around the car - VW, Škoda). Another approach is based on artificial intelligence methods. To a large extent, Google is currently contributing with TensorFlow convolutional neural network technology. It is designed for the task of finding typical images in the data stream, and its application for agriculture has not yet been explored. Hanzlík and Pavlíček research (Hanzlik et al., 2014) is a successful attempt within the area of agriculture. The authors worked with perceptron neural networks and convolutional neural networks. The disadvantage of this approach is the need to carry out a series of learning cycles (not to mention the need for a huge amount of learning data - and these are often absent), which are very slow and good result at the end of the learning cycle is not guaranteed. Currently, there is no satisfactory method to teach the networks to achieve a certain result. Therefore, their use is still experimental and is being developed in areas where these properties do not matter.

Recognizing game is very complicated. Unless one builds on facts such as the animal size and the ideal free space, but rather try to recognize the game through a computer vision in its natural environment, there are a number of struggles. The primary problem is, of course, the mimicry of the animals. They are very successful in hiding from predators by their camouflage, which is of course especially effective in their natural

Source: authors´ own processing

Figure 10: Animal mimicry and its machine recognition.

habitat. Finding such an object with computer vision is possible on experimental images (and with help from humans), but automated search is very complicated. Most machines lack important knowledge of the search context and are producing high amount of false positives. In the case of the presented image, the apparent animal is not revealed at first sight because the machine is unable to distinguish it from the surroundings thanks to the mimicry. Edge or colour-based segmentation methods fail. Although for every image you will eventually find a suitable filter and more or less recognize the animals, in real conditions, the changes in light intensity and therefore the change of colour shade will cause the machine to be very inaccurate and virtually useless. A lying stone may be misinterpreted as the typical white spot on the animals behind thus resulting in false positive identification. This is not unusual in nature itself. Dog-like predators have a solid sight, which makes it possible for them to locate moving objects (and the machine can successfully detect moving objects due to a change in their relative coordinates), but to find lying animals they use smell. Since machine is relying purely on vision, successful recognition is much more complicated.

Although Artificial Intelligence tools promise to eliminate the context issue and are more or less trying to simulate the functioning of the human brain (similarly to how one actually sees - or interprets the seen objects as a human), this research path is still lengthy. The paper showcases really solid results in game location based on image segmentation and combination of motion (using statistical methods) and the knowledge context which was used to look for the animals. The experiment proved that with an autonomous machine, a herd can be found with a high degree of accuracy. The issue is, that if a herd is in its natural environment, it is complicated to find it, if it is not in motion. This problem is the logical consequence of animal mimicry and without the proper olfactory equipment of the machine, the task of proper recognition using only sight is challenging. It does not mean, however, that the herd cannot be found at all. If it is not physically covered by any object (trees, rocks etc.) it has been proven that the herd location in the open air is possible and relatively successful. However, it is not possible to count the number of individual animals with a high degree of accuracy. Conversely, according to 16 record streams, a relatively accurate approximate count can be established for a herd in motion. Thanks to the movement of the flying machine, it is possible to create a series of pictures of the herd. These images can be grouped together using triangulation methods and be appropriated to measuring points (or surfaces). These points can be, for example, a tree, a corner of fencing, a roof of a building, a road, a river, or a parking area (see Figure 5). A suitable triangulation point is a point that is lonely (its surroundings are visually monotonous) and its appearance is unique enough. For this reason, it is advisable to select three distinct objects (such as tree in a pasture, a pond and a field fence) so that their location is clearly visible in multiple frames. Moving animals are then possible to be recognised based on machine comparison of these pictures. As part of the experiment, a unique identifier was assigned to each discrete cluster of pixels with the appropriate brightness and colour. If this cluster was in motion, it was an animal. If the cluster divided, it was an animal that was covered by another animal. The reverse (animal entering cover) corresponds with two clusters merging. This method proved to be suitable, but only in the experimental conditions, it suffers from quite lengthy data preparation and complicated creation of a suitable cluster recognition algorithm. Now the task of our research team is to convert this method from laboratory models into readily applied solutions.

Conclusion

The described method was tested during the summer of 2017. Based on the calibration of 16 video streams by the operator (finding objects - animals on the pasture), the designed algorithm has proven to be very satisfactory. Machine hallucination occurs approximately on one image in 10 minutes, which is negligible due to the large number of images in the overall video stream. Using a simple statistical method, it is possible to distinguish the deviations in the number of animals found and eliminate those errors. There is, of course, a big problem if the game is hidden by a bush, a tree, or it is hidden behind one another. Another problem are the "long suns" when the shade of the bodies cover other animals and the machine cannot distinguish between them. Either it counts a small amount, or it links them to a single and then discards it, thanks to the maximum object size limit. If the herd is in motion, the ability of the machine to count precisely is almost 100 percent, assuming all animals are moving and their bodies are not overlapping. This problem can be mitigated by the use of statistical method. However, if the animals are stationary or lying, then the recognition becomes very problematic. Tackling this issue is the subject of another planned stage of our research.

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Impact of Subsidies on Technical Efficiency of Meat Processing Companies

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Abstract

The paper deals with the technical efficiency analysis of meat processors in the Czech Republic and evaluates an impact of subsidies on companies' technical efficiency. Albertina database which collects accounting data of the Czech meat processors was used for the empirical analysis for the programming period 2007-2013. Subsidies data was collected from the public register of recipients of the Ministry of Agriculture of the Czech Republic. In total, 207 meat processors were analysed. The methodological approach taken in this study is based on translogarithmic production function and Stochastic Frontier Analysis. True Random Effects model, and Battese and Coelli model were used to evaluate the impact of subsidies on technical efficiency. The results of both used methods indicate positive impact of subsidies on meat processors technical efficiency. Material input displays the highest elasticity; the lowest elasticity belongs to production factor Capital. Technical change has a positive impact on production.

Keywords

Stochastic Frontier Analysis, technical efficiency, meat processors, subsidies, investments.

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Introduction

The meat industry is one of the main branches of the Czech food industry together with the bakery and milk industry. Meat industry significantly contributes to the total food industry sales (i.e. 23.2% in 2016), to the number of employees (24.4%), and to the number of enterprises (25.1%). From the long-term perspective, low wages in the branch are observed. Workers are remunerated below the average wages that are common for CZ-NACE 10 (Food processing industry). There is also a long-time decline in the number of employees (Ministry of Agriculture, 2017). With regard to this unfavorable branch situation, the meat industry was chosen to analyse whether the subsidies contribute to technical efficiency growth. The subsidies in food processing (especially Rural Development Program (RDP)) are expected to contribute to the higher business performance, as stated in the definition of the measure.

Several studies have empirically investigated the effect of subsidies on technical efficiency in agriculture. Piesse and Thirtle (2000) showed that inefficiency, among other factors, can be explained by subsidies. Other negative effects of subsidies on technical efficiency were found for example by Karagiannis and Sarris (2005), Hadley (2006), Zhu and Oude Lansink (2008).

Čechura (2009) and Trnková et al. (2012) dealt with the relationship between subsidies and their impact on farms' efficiency in the Czech Republic. These authors found out rather their negative impact. On the other hand, Pechrová and Vlašicová (2013) proved positive impact of subsidies on technical efficiency.

There are numerous studies analysing the impact of subsidies in the agricultural sector, some of them are listed above. Despite this, little research has been done about the food processing industry (Beckeman and Skjolkebrand, 2007). Innovations and investments are an important instrument of the food industry competitiveness and they are the main instrument of industrial policy (Menrad, 2004; Skuras et al., 2006). Subsidies, being a source of innovation, influence the growth of a firm, and some studies say that no firm can survive without at least some innovation (Geroski et al., 1997; Coad and Rao, 2008). According to Bernini and Pellegrini (2011) subsidies are targeted at influencing the allocation of investments to increase competitiveness, sustainable growth and create new workplaces.

According to Mroczek (2013), the last decade has been the period of intense development of the Polish food industry. There has been a significant recovery in investments and an increase in the value of fixed assets of food business enterprises (generally evaluated on the level of whole food processing industry). Investments are active elements of businesses (machinery and equipment), that have significantly improved the performance of food industry.

Skuras et al. (2006) dealt with the effect of subsidies on technical efficiency in Greek food and beverage industry. Subsidies are the main instrument of the industrial and regional policy of developed countries around the world. The results of their research question the positive effect of subsidies on productivity. Bernstein and Mamuneas (2008) investigated the impact of investment in food processing and found, that these investments positively contributed to total factor productivity (TFP) growth. Some other studies indicated also a positive impact on firms' performance, for example Cerqua and Pellegrini (2014), and Geroski (2005). The negative impact was proved by Wynarczyk and Thwaites (1997), Harris and Trainor (2005). Minviel and Latruffe (2017) used meta-analysis approach and found that farm's technical efficiency is commonly negatively influenced by subsidies.

In the Czech environment, the RDP (Rural Development Program) analysis has been provided. Impacts of the measure I. 1. 3. 1 "Adding value to agricultural and food industries to the food business economy" by Mezera et al. (2014) were evaluated. Their results suggest that the aid has a positive impact on financial stability and labor productivity.

The methods used to analyze the impact of subsidies on the food industry business economy is usually based on the contrafactual analysis (Mezera and Špička, 2013). Mezera et al. (2014) in their research used online surveys and interviews. For the analysis of subsidies impact on meat industry economy, fixed effect model was applied (Špička et al., 2017). Evaluation of the technical efficiency of processing companies in the Czech Republic and the Slovak Republic was conducted by Čechura and Malá (2014), Čechura and Hockmann (2010), Čechura and Hockmann (2011), Daňková and Bosáková (2005). However, these studies do not investigate the impact of subsidies on firm's technical efficiency.

Other methods, including production function approach and TFP (Total Factor Productivity) growth calculation, were used by Bergström (2000) to evaluate the impact of subsidies on the productivity of manufacturing industry in Sweden, and by Skuras (2006) for Greek food and beverage manufacturing industry. Bernini and Pellegrini (2011) applied Difference-In-Difference Matching (MDID) estimator to evaluate the impact of aids.

The studies, dealing with the analysis of subsidies effect on firm efficiency, are mostly based on two approaches. The first approach considers the subsidy as a conventional input along with labor, land, and capital, and assumes that subsidies directly affect the productivity of firms. This approach has some drawbacks: while traditional inputs are necessary for the production, subsidies are not a necessary production factor and by themselves cannot generate any output, while traditional inputs can (Kumbhakar and Lien, 2010). Hence, this approach is inconsistent with the economic theory.

The second approach uses SFA and assumes that subsidies affect productivity through the mean of technical inefficiency. This approach does not treat subsidies as a traditional input, and therefore escapes criticism of the previous approach. The common argument proposed for the effect of subsidies on technical efficiency is that subsidies discourage farmer from applying more effort into their production activities than in the absence of subsidies, and hence reduce productivity (Kumbhakar and Lien, 2010).

The aim of this article is to evaluate the impact of subsidies of food processing firms on their technical efficiency using Stochastic Frontier Analysis (SFA), True Random Effects model (TRE) (Greene 2005), and Battese and Coelli model (1995). The period 2007-2013 was used to evaluate the total effects of subsidies on technical efficiency in the last programming period. The research questions to be addressed are:

(1) What is the average level of technical efficiency of Czech meat processing companies?

(2) Do subsidies have a positive impact on technical efficiency?

(3) Are there any differences between the results of used methods?

(4) How the technical efficiency of Czech meat processor develops in time?

The paper is structured as follows: the Materials and methods section represent the estimation strategy and describes the data set; the Results and discussion section presents the results of production function estimation and compares the obtained results with previous studies, the Conclusion section contains concluding remarks.

Materials and methods

This chapter specifies the data and used methods, and shortly introduces the data characteristics (Table 1 and Table 2). In this paper, two approaches are used. First, the "True" random effects model, and second, the Battese and Coelli model.

Data input

The panel data set was collected from the Albertina database. The analysis uses information from the final accounts of companies whose main activity is meat processing (divided according to CZ-NACE, it means branch CZ-NACE 10.1 Processing and preserving of meat and production of meat products) in the period from 2007 till 2013. The time period was used with respect to programming period of Rural Development Programme (RDP). After the cleaning process (checking the correctness of branch of enterprises, removing companies with missing observations and negative values of the variables), the unbalanced panel data set contains 1418 observations of 207 meat processing companies of the Czech Republic. These businesses were divided into size groups according to a number of employees. Three groups were defined (small, medium and large). Small enterprises employ 0-49 employees, medium 49-249 employees and large more than 250. Total 128 small businesses, 61 medium-sized and 18 large companies were analysed.

Food industry businesses have a possibility to draw the finance from RDP. For the previous programming period 2007-2013, it was the measure I. 1. 3 Adding value to agricultural and food products. The aid is aimed at firms' investment and innovation activity. Information about subsidies drawing was obtained from the Ministry of Agriculture of the Czech Republic, Register of subsidies recipients, which is commonly available. The division of subsidies recipients is shown in table 1.

The following variables were used in the analysis: Output, Labour, Capital, Material input (Material and Energy), and Subsidies. The output is represented by the total sales of goods, products, and services of the food processing company. To avoid price changes, Output was deflated by the price index of food processing companies according to the branch. The Labour input is used in the form of total personnel costs per company, divided by the average annual wage. The Capital variable is represented by the value of tangible assets. Material input is total costs of material and energy consumption per company. Capital and Material were deflated by the price index of the industrial sector. Output, Capital, and Material input variables are measured in thousand CZK, Labour variable is a coefficient.

Stochastic Frontier Analysis (SFA)

Following Farrell (1957), many different methods have been considered for the estimation of efficiency. Two widely used approaches are the Data Envelopment Analysis (DEA), which is nonparametric and deterministic, and the Stochastic

Farm size	Number of firms	Mean (thous. CZK)	Std.dev (thous. CZK)	Total sum of subsidies (thous. CZK)
Small (<50 workers)	32	272.03	1 922.82	235 307
Medium (50-250)	37	724.69	3 634.12	309 444
Large (>250)	11	1 869.99	6 983.45	235 619

Source: own processing

Table 1: Division of subsidies recipients depending on farm size.

Variable	Mean (thous. CZK)	Std. deviation (thous. CZK)	Min (thous. CZK)	Max (thous. CZK)
Output	222 483	510 863.3	525.8	5 060 008
Capital	84 427.34	254 630.1	123.5	3 731 411
Labour	21 024.62	44 717.43	42.1	480 140
Material	205 519.6	448 403.7	87.2	4 922 032

Source: own processing

Table 2: Characteristics of data set (average per enterprise).

Frontier Analysis (SFA), which is, on the contrary, parametric.

Differences between these approaches can be considered according to the assumptions and techniques used to construct an efficient frontier. On the one hand, parametric methods estimate the frontier using statistical methods. On the other hand, nonparametric methods rely on linear programming to calculate the values of the efficient frontier.

Parametric methods impose an explicit functional form for the frontier and require the distributional assumption of the inefficiency term. Nonparametric methods, in contrast, impose neither assumptions about the functional form of the frontier nor any distributional assumptions about inefficiency. Estimation of the frontier, in turn, allows for random noise in the analysis. Moreover, it allows hypotheses testing. Therefore, many authors have concluded that parametric methods, such as SFA, is more suitable for efficiency analysis in agriculture, where measurement errors and differences in climate conditions take place.

To study the determinants of technical efficiency we used the SFA methodology developed by Aigner et al. (1977). Stochastic frontier models allow analysing technical inefficiency in the framework of production functions. The SFA method is based on an econometric (i.e., parametric) specification of a production frontier. Using a generalized production function and cross-sectional data, this method can be depicted as follows:

$$\boldsymbol{y_i = f(x_{ij};\beta)\cdot exp(\varepsilon_i)} \qquad (1)$$

where y represents output, x is a vector of inputs, β is a vector of unknown parameters, and ε is the error term. The subscripts i and j denote the firm and inputs, respectively.

In this specific formulation, the error term is farm specific and is composed of two independent components, $\varepsilon_i = v_i - u_i$. The first element, v_i is a random variable reflecting noise and other stochastic shocks entering the definition of the frontier, such as weather, luck, strikes, and so on. This term is assumed to be an independent and identically distributed normal random variable with zero mean and constant variance $\boldsymbol{iid}\ [\boldsymbol{N \sim (0, \sigma_v^2)}]$.

The second component, u_i, captures technical inefficiency relative to the stochastic frontier. The inefficiency term u_i is nonnegative and it is assumed to follow a half-normal distribution (Kumbhakar and Lovell 2000).

An index for TE can be defined as the ratio of the observed output (y) and maximum feasible output (y*):

$$\boldsymbol{TE_i = \frac{y_i}{y_i^*} = \frac{f(x_{ij};\beta)\cdot exp(v_i - u_i)}{f(x_{ij};\beta)\cdot exp(v_i)} = exp(-u_i)} \qquad (2)$$

Because $y \le y^*$, the TE index is bounded between 0 and 1; *TE* (technical efficiency) achieves its upper bound when a firm is producing the maximum output feasible level (i.e., $y = y^*$), given the input quantities. Jondrow et al. (1982) demonstrated that farm-level TE for half-normal distribution of inefficiency term can be calculated from the error term εi as the expected value of $-u_i$ conditional on ε_i, which is given by

$$\boldsymbol{E[u_i|\varepsilon_i] = \frac{\sigma_u\sigma_v}{\sigma}\left[\frac{\phi(\varepsilon_i\lambda/\sigma)}{1-\Phi(\varepsilon_i\lambda/\sigma)} - \frac{\varepsilon_i\lambda}{\sigma}\right]} \qquad (3a)$$

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\lambda = \sigma_u/\sigma_v$, $\phi(\cdot)$ represent the standard normal density and $\Phi(\cdot)$ the standard normal cumulative density functions.

In the case of exponential distribution of inefficiency farm-level TE is calculated in the form

$$\boldsymbol{E[u_i|\varepsilon_i] = \tilde{\mu}_i + \sigma_v\left[\frac{\phi(-\tilde{\mu}_i/\sigma_v)}{1-\Phi(\tilde{\mu}_i/\sigma_v)}\right]} \qquad (3b)$$

where $\tilde{u} = -\varepsilon - \sigma_v^2/\sigma_u$

Thus, the TE measure for each firm is equal to $\boldsymbol{TE_i = exp(-E[u_i|\varepsilon_i])}$ (4)

"True" random effects model (TRE)

In the fixed-effects model, it is assumed that the inefficiency term is fixed and the correlation with regressors is allowed. Unlike fixed effects model the opposite situation is considered, in which the u_i are randomly distributed with constant mean and variance, but are assumed to be uncorrelated with the regressors and the v_{it}. The random effects specification assumes that the firm specific inefficiency is the same every year, i.e. the inefficiency term is time invariant. In these propositions, the model absorbs all unmeasured heterogeneity in u_i.

Greene (2005) argued that the random effects model with the proposed extensions has three significant weaknesses. The first is its implicit assumption that the effects are not correlated with the included variables. The second problem with the random effects is its hypothesis that the inefficiency is the same in every period. For a long time series data, this is likely to be an undesirable assumption. The third shortcoming of this model is that in this model u_i carries both the inefficiency and, in addition, any time invariant firm specific heterogeneity. To avoid the former limitations Greene (2005) proposed "True" random effects model that is as follows:

$$y_{it} = \alpha + \beta' x_{it} + w_i + v_{it} - u_{it} \qquad (5)$$

where w_i is the random firm specific effect and v_{it} and u_{it} are the symmetric and one sided components.

Since heterogeneity between food processing firms was proved by many studies (see Čechura and Hockmann, 2017; Rudinskaya, 2017) TRE model was chosen as an appropriate tool.

Battese and Coelli model (1995)

Beside the TRE model, the empirical part of the paper is based on Battese and Coelli (1995) model (technical inefficiency effects model). Battese a Coelli (1995) incorporate vector of explanatory variables z_{it}', which influence technical efficiency of firm *i* at time *t*

$$u_{it} = z_{it}' \delta + w_{it} \qquad (6)$$

where δ is a vector of unknown parameters, wit is a random term defined by truncated-normal distribution.

According to this model $TEit = exp(-u_{it}) = exp\{-z_{it} \delta - w_{it}\}$.

Battese and Coelli (1995) model was chosen to analyse the effect of subsidies on technical inefficiency mean.

Results and discussion

The empirical analysis is based on the estimation of translogarithmic production function in which both the output and inputs are expressed in logarithmic form and normalised by their arithmetic means. The inefficiency term is assumed to have an exponential distribution.

The three factor translogarithmic production function was estimated in the form:

$$\ln y_{it} = \beta_0 + \sum_{j=1}^{J} \beta_j ln x_{jit} + \beta_t t + \frac{1}{2}\sum_{j=1}^{J}\sum_{k=1}^{K} \beta_{jk} ln x_{jit} ln x_{kit} + \frac{1}{2}\beta_{tt} t^2 + \sum_{j=1}^{J} \beta_{jt} ln x_{jit} t + \varepsilon_{it}$$

where *y* is output, *x* with subscript *j* refers to a certain production factor, subscripts *i*, with *i* = 1,2,…, *N*, and *t*, with *t* = 1,…, *T*, refer to a certain producer and time (year), respectively.

The first-order estimated parameters *Capital (C), Labour (L), Material input (M)* are significant under z-test at 1% level of significance (Table 3). It means, that these variables have a significant impact on total production. Signs of the coefficients are positive that is consistent with economic theory (the assumption of monotonicity is fulfilled). The curvature condition of quasi-concavity in inputs (diminishing marginal productivity for each input) is achieved in the case of all production factors. Since the values of production factors were normalised by their arithmetic means after logarithmic transformation, in translogarithmic model these coefficients represent elasticities, that is possible percentage change in aggregate output because of one percent change in input. All production elasticities are positive; the highest elasticity displays Material input (0.82783). If the *Material input* change by one percent, the production will change by 0.82783 %. The lowest elasticity belongs to production factor *Capital* (0.02234). If Capital change by one percent, the production will change by 0.02234 %. Technical change has a positive

Variable	Coefficient	p-value	Variable	Coefficient	p-value
Const.	0.43889	0.000	CL	-0.00219	0.000
C	0.02234	0.000	CM	0.01741	0.000
L	0.12658	0.000	LM	-0.00809	0.000
M	0.82783	0.000	CT	0.00084	0.000
T	0.00416	0.000	LT	0.00019	0.000
CC	0.00337	0.000	MT	-0.00721	0.000
LL	0.01445	0.000	Usigma Subsidies	-0.00006	0.002
MM	0.00049	0.002	Const.	-1.82686	0.000
TT	0.00863	0.000	Vsigma Const.	-21.38963	0.001

Source: own processing

Table 3: The estimation results of TRE model with subsidies variable.

impact on production (the variable *Time (T)* is positive and significant at 1% level of significance). Moreover, the impact of technical change accelerated over time (βTT > 0). It is characterised by Labour- and Capital intensive, and Material-saving behaviour. The sector is characterised by slightly diminishing returns to scale. Subsidies variable has impact on the variance of technical inefficiency.

Nivievskyi and von Cramon-Taubadel (2008) in their research found that labour intensity has a negative impact on farm competitiveness.

The parameters of the Battese and Coelli model are statistically significant at 1% level of significance (Table 4). The slopes of the coefficients are positive, that is consistent with economic theory. The highest elasticity belongs to the production factor Material (0.82233). The other factors have a lower impact on production (0.14016 for Labour and 0.04457 for Capital). Estimated parameters of production factors satisfy the curvature assumption of quasi-concavity in inputs. The parameter λ is more than one indicates that the variation in efficiency component is more significant than the variation in statistical noise. Technical change is characterised by Labour- intensive, and Capital- and Material-saving behaviour. The sector is characterised by constant returns to scale. The previous model (TRE) estimated diminishing returns to scale, but the difference between two estimated values is rather insignificant. Subsidies variable positively influence the technical efficiency mean. Both of used methods indicated a significant impact of subsidies on technical efficiency. Moreover, Battese a Coelli model proved that the impact is positive.

Bernini and Pellegrini (2011) show higher growth in output, employment, and fixed assets in subsidized firms, but a lower increase in total factor productivity than in unsubsidized manufacturing firms in Sweden. The negative effect of subsidies on efficiency and productivity in food industry sector was found by Harris and Trainor (2005), Harris and Trainor (2005), and Skuras (2006). In this paper, as well as in research of Cerqua and Pellegrini (2014), and Bernstein and Mamuneas (2008), a positive effect was estimated.

By empirical analysis was proved, that subsidies have a positive impact on technical efficiency. Moreover, the development of technical efficiency has increasing trend from 2007 to 2010 (Graph 1). We can say, that inputs were used very efficiently and the average technical efficiency has increased. However, since 2010 the technical efficiency has decreased. The explanation of the reasons is questionable. It can be caused, on the one hand, by changing the structure of the database itself. On the other hand, analysed subsidies (considering their investment and innovation behaviour) are the part of the inputs, i.e. the Capital variable. By the certain point of the subsidies reception, the efficiency of subsidies applying can decrease, that could result in lower technical efficiency.

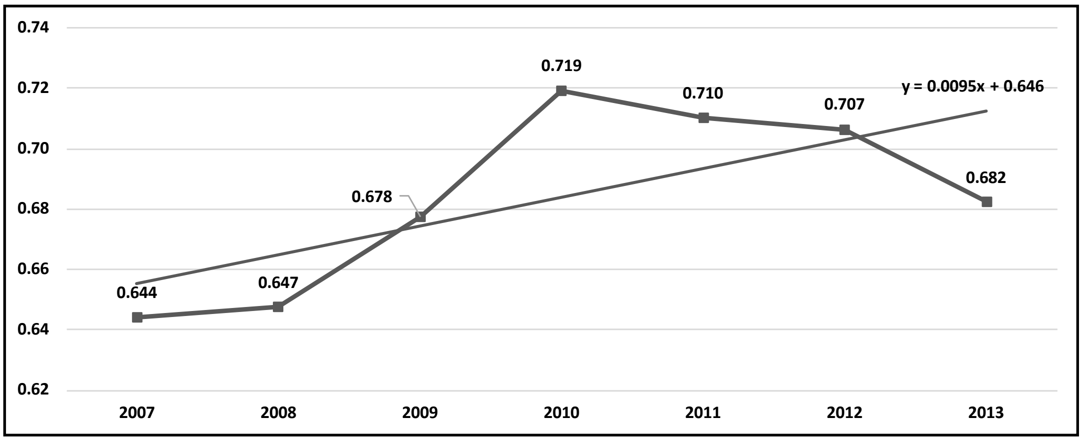
These results are consistent with Bergström (2000) who found that subsidisation is positively correlated with the growth of value added, and productivity of the subsidised firms appears to increase in the first year. After the first year, however, the more subsidies a firm has received, the worse productivity growths development was observed. Subsidies can lead to lower firms' productivity because they give firms an incentive to change the mix of capital and labour and it can lead to inefficiencies. Moreover, the subsidised firms might be over-invested in the capital.

Other cause can be repeated aids received by the same firm. There were some firms, that received subsidies repeatedly, so the application of new investment did not reach adequate outputs.

Variable	Coefficient	p-value	Variable	Coefficient	p-value
Const.	0.90462	0.000	CL	-0.00366	0.006
C	0.04457	0.000	CM	0.04082	0.000
L	0.14016	0.000	LM	-0.01814	0.000
M	0.82233	0.000	CT	-0.00919	0.061
T	0.02703	0.001	LT	0.00360	0.003
CC	0.00241	0.063	MT	-0.01593	0.005
LL	0.01708	0.000	Mu		
MM	0.01643	0.031	Subsidies	-155.752	0.000
TT	0.00374	0.537	lambda	80.01371	0.000

Source: own processing

Table 4: The estimation results of Battese and Coelli model (1995) with subsidies.



Source: own processing

Graph 1: TE development.

Farm size	Number of firms	Mean	Std. dev	Max value	Coef. of variation
Small (<50 workers)	128	0.6707	0.2701	0.9882	40.3%
Medium (50-250)	61	0.7021	0.2307	0.9379	32.9%
Large (>250)	18	0.7333	0.2313	0.9526	31.5%

Source: own processing

Table 5: Estimated TE depending on farm size.

Table 5 shows estimated technical efficiency depending on farm size. The most efficient are large meat processors with more than 250 employees. Their operation expects a high degree of investments and innovations with automated processes that can help them to reach higher labour productivity and effective use of inputs. Least efficient are small processors. Small firms usually do not invest in new technologies (as shown in table 1, the average subsidy was 272 thousand CZK). They focus on manual manufacture and production of a specialized range of good, where is not possible to use machines and other equipment to such an extent. The coefficient of variation indicates relatively high variation of technical efficiency level in the group of small farms. As the size of firms grows, their estimated technical efficiency level approaches to average.

Conclusion

Production elasticities estimated for Capital, Labour, and Variable input are 0.02234, 0.12658 and 0.82783 in case of TRE model and 0.04457, 0.14016 and 0.82233 in case of Battese and Coelli model, that is consistent with the results of previous studies (Čechura and Hockmann, 2010; Rudinskaya, 2017). Both models estimated almost similar production elasticity. The higher elasticity of variable input can be explained by the fact that meat processing industry is a sector in which agricultural raw material plays the central role in the production processes. For the average firm in the full sample, there is a constant or slightly diminishing economies of scale. It suggests that the impact of production expansion on a production level will be rather small. Technical progress is characterized by Labour- and Capital intensive, and Material-saving behaviour, that is partially in context with the expectation of Čechura and Hockmann (2010) for this period. Authors expected Capital-using and Labour-saving technical change.

Subsidies on investments, that anticipate the modernization of food industry production, positively contribute to the growth of technical efficiency. According to recent surveys (see Boudný and Janotová 2015), higher labour productivity in Western EU countries is due to a higher level of organization, modernization, and automation which is associated with a relatively high investment intensity. In the Czech Republic, labour productivity is relatively low compared to the other Member States. In this context, subsidies on the modernization of food industry production are an important source of growth in technical efficiency.

Development of technical efficiency had increasing trend until the year 2010, after that period, however, technical efficiency in meat processing sector decreased. The recipients of the highest amount of subsidies are mostly large food processing companies, which represent a lower number of firms and higher technical efficiency.

These findings are the important message for policy makers with respect to the setting of CAP subsidies for the next programming period. Many studies evidenced that subsidies supporting investment and innovation activity, positively influence overall competitiveness in food processing sector by increasing their technical efficiency. However, more attention must be paid to small entities and efficient subsidies facilities utilization.

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Polish Sugar Industry Development

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Abstract

Poland, and its sugar market, represents very specific phenomenon among countries producing primarily sugar from sugar beet. Polish sugar production is relatively high in comparison to other European countries and have not negligible export potential. Main aim of presented contribution is to identify main trends and important specifics connected to sugar industry development between years 2000 and 2017. From the analyses of Polish sugar industry and sugar market following findings could be concluded. Production of sugar beet is constantly developing toward more intensive production; mainly yield, sugar content and average cultivated area per one grower increased significantly, but still Polish producers belongs among the smallest in the whole EU. Production is also subsidised by coupled national payment of 380 EUR/ha. Polish market underwent significant restructuring that on one side resulted in significant reduction of amount of sugar refineries and sugar beet producers. On the other hand, it resulted in considerable concentration of production capacities among subjects that successfully passed the transformation phase. Despite reduction of sugar refineries from original 76 to 18, sugar beet production remained almost unchanged at the level of 12 million tonnes. Also raw sugar production remained almost unchanged and during the period oscillated around the level of 2 million tonnes. On contrary production of white sugar increased significantly from 1.54 million tonnes in 2001 to 2.1 million tonnes in 2016. Reduction of sugar refineries was in this perspective compensated by the modernisation of production facilities and increase of their processing capacities. Between 2001 and 2016 length of sugar campaign increased from average 51 days to about 112 days. The average processing capacity of one sugar refinery grew by tens of percent. At present all production capacities are controlled by only four actors (Krajowa Spolka Cukrowa S.A., Nordzucker Polska S.A., Pfeifer&Langen, Südzucker Polska S.A.). The market evince strong characteristics of oligopoly with domination of 3 subjects, state-owned Krajowa Spolka Cukrowa S.A.; Südzucker Polska S.A and Pfeifer&Langen, both owned by German capital. Polish sugar export was not harmed significantly during transformation period. Recently it oscillates around 0.5 million tonnes annually. Increasing unit price per kilogram of exported sugar is considered as positive and important factor that pushed total value of exports to approximately 240 million EUR. Extreme territorial concentration is seen as a weak point of Polish sugar foreign trade. Top 10 countries participate on Polish exports and imports with sugar approximately by 72.56% and 92.94% respectively (2016).

Keywords

Poland, sugar, production, trade, sugar beet, price, export, import, production capacities, producers, competitiveness, concertation.

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Introduction

Poland and its sugar market represents very specific phenomenon among countries producing beet sugar. Polish sugar industry, as one of the few in the former Eastern bloc, survived very critical period. Despite significant reduction in the number of sugar factories from 76 (2001) to only 18 (2017), Polish sugar industry kept considerable production capacity. Current installed capacity of all sugar refineries can process approximately 114 thousand tonnes of sugar beet per one day. Refineries employ about 3,300 people. Annual sugar beet production reaches about 12.3 million tonnes and annual sugar production approaches 2.3 million tonnes. Polish sugar industry produces about 1.3% of world sugar production and 12% of EU sugar. Polish share on global production of sugar from sugar beet oscillates around 5.6%. Local production exceeds local consumption of sugar by almost 600 thousand tonnes annually. Surplus in production creates appreciable export potential. Annually about 500 thousand tonnes of sugar is being exported, it represents a considerable share particularly on the European market or in the perspective of global trade with beet sugar. Polish market underwent significant restructuring that on one side resulted in significant reduction of number of sugar refineries and sugar beet producers. On the other hand, it resulted in considerable concentration of production capacities among subjects that successfully passed the transformation phase. Observed concentration is a general characteristic of the whole EU sugar industry (Benešová et al., 2015). Although many improvements were implemented by Polish sugar industry, still there are problems to be solved – for example logistics (Polowczyk and Baum, 2016) or observed slowdown in investments (Szajner, 2016).

In addition, it is important to mention, that during the transformation significant production capacities were acquired by foreign, predominantly German, capital. Foreign capital is represented by following companies: Südzucker; Nordzucker; Pfeifer&Langen. Position of the Polish state is also a specific feature of local sugar industry. The state still controls one of the largest sugar production corporations operating on Polish territory - Krajowa Spółka Cukrowa S.A.. Through this entity, state operates seven sugar refineries that produce about one-third of Polish sugar. Despite the general trends in Europe, the Polish market still has a relatively high degree of decentralization. Several large companies are operating on the market. They compete for market share, not only in relation to Poland's internal market but also in relation to the EU market. From this perspective, the Polish market is very different from the markets of most other EU countries. In this respect, a number of studies focusing on the issue of Polish sugar industry are worth noting (Artyszak, 2009; Bücherl 2004; 2005; 2006; 2008; Dobrowolski and Bücherl, 2007; 2009; Iwan 2005a; 2005b; Jagiełło, 2009; Molas et al., 2017; Trajer, 2013; Walkenhorst, 2001; Wawro, 2006; 2007; 2008; Wawro and Kuster 2004). These studies show a difficult process of transformation of Polish sugar industry, which had to respond not only to changes in the internal environment (transition from the centrally planned economy to the market economy; restructuring of the economy in relation to the changing conditions in Poland's internal market) but also to changes of external conditions (restructuring of the global economy; accession to the European Union; adaptation to the conditions of the common Agricultural Policy; ongoing reforms of the sugar market in the EU single market). Abovementioned studies also concludes that Poland was able to transform this sector and adapt to new conditions. During transformation, Polish sugar industry became competitive and gained strong position within internal market of the EU, and it also strengthen in third countries like Israel, Georgia, Russia, Kazakhstan, etc. While Polish sugar is being exported in amount of about 280 thousand tones to EU countries (mainly Germany, Lithuania, Italy, Latvia, Greece and Hungary), still 220 thousand tons of sugar is mainly directed to abovementioned third countries.

Materials and methods

Main aim of presented contribution is to identify main trends and important specifics connected to Polish sugar industry development between 2000 and 2017. Own analyses is based on comparison of secondary data sourced from Polish national sources (National Research Institute, Agricultural Market Agency, Ministry of Agriculture and Rural Development, Central Statistical Office of Poland), Eurostat and F.O.Licht database.

For the purpose of own analyses, the following categories of data are observed: sugar beet yields, harvested area and total production; sugar production and trade (H4-1701); number and specifics of farms linked to beet production; number and specifics of sugar refineries; sugar consumption and its structure; sugar prices. Also, selected economic and financial indicators of individual actors are specified.

Individual data are analysed in usual metric units; prices are expressed in euros in nominal expression. The development over time is analysed by using simple statistical indicators such as average, median, geometric mean and base index (2017/2000).

The concentration of production capacities is analysed from the point of view of the most important Polish sugar industry players. This analysis is based on application of Herfindahl-Hirschmanov index (further referred as HHI) and “Four-firm concentration ratio” (further referred as CR4). HHI is able to measure the market concentration of the industry; therefore, it is used by competition authorities to secure antitrust policy. HHI is characterized as the sum of the market shares of each trader in the sector and it is calculated as a sum of squared market share values of investigated entities in the industry:

$$HHI = \sum_{i=1}^{N} s_i^2 = s_1^2 + s_2^2 + s_3^2 + \dots + s_n^2 \quad (1)$$

where si stands for market share of corporation "*i*" in the sugar production, *N* denotes total amount of corporations operating on the relevant market in the given country. According to Hirschman (1964), HHI ranges between 0 and 10 000, while 0 indicates no concentration and high competitiveness of the market and 10 000 indicates low level of competition and signalise monopoly. In this contribution classification of concentration is based on methodology used by U. S. Department of Justice and Federal Trade Commission (2010). Their methodology indicates highly competitive environment for values below 100. Values below 1,500 indicates non-concentrated environment where operates number of important sugar companies. Values above 2,500 usually indicates market with monopolistic competition where exists significant concentration. The more HHI approaches 10,000, the more monopoly characteristics are evinced by the market.

The "Four-firm concentration ratio" (CR4) indicator is used to identify the main actors in the sugar market within the monitored group of countries. It assesses the share of the four largest companies operating in the sugar industry. This indicator is calculated as:

$$CR_n = \sum_{i=1}^{n} s_i = s_1 + s_2 + s_3 + \dots + s_n \quad (2)$$

For the CR4 evaluation, interpretation of DG Compete was used (London Economics, 2007). The values between 0 and 50% indicate perfect competition directing towards oligopoly. The range from 50 to 80% is a clear oligopoly and the results above 80% express the direction of the oligopoly towards the monopoly.

Attention is also paid to the competitiveness of Polish sugar industry and its ability to gain comparative advantage (measured by RCA, LFI and TBI index).

The Balassa index (or Revealed Comparative Advantage, RCA) tries to identify whether a country has a "revealed" comparative advantage rather than to determine the underlying sources of comparative advantage (Balassa, 1965; 1977; 1991). The index is calculated as follows:

$$RCA = (X_{ij} / X_{it}) / (X_{nj} / X_{nt}) = (X_{ij} / X_{nj}) / (X_{it} / X_{nt}) \quad (3)$$

where *x* represents exports, *i* is a country, *j* is a commodity and *n* is a set of countries, *t* is a set of commodities.

The next index used in this paper is the Lafay index (Lafay, 1992). Using this index (LFI) we consider the difference between each item's normalized trade balance and the overall normalized trade balance. Using the LFI index we can focus on the bilateral trade relations between the countries and regions. For a given country(*i*) and for any given product (*j*), the Lafay index is defined as:

$$LFI_j^i = 100\left(\frac{x_j^i - m_j^i}{x_j^i + m_j^i} - \frac{\sum_{j=1}^{N}(x_j^i - m_j^i)}{\sum_{j=1}^{N} x_j^i + m_j^i}\right)\frac{x_j^i + m_j^i}{\sum_{l=1}^{N} x_j^i + m_j^i} \quad (4)$$

where xij and mij are exports and imports of product *j* of country *i*, towards and from the particular region or the rest of the world, respectively, and *N* is the number of items. Positive values of the Lafay index indicate the existence of comparative advantages in each item; the larger the value the higher the degree of specialisation. (Zaghini, 2003)

Finally, Trade Balance Index (TBI) is employed to analyse whether a country has specialization in export (as net-exporter) or in import (as net-importer) for a specific group of products. TBI is simply formulated as follows:

$$TBI_{ij} = (x_{ij} - m_{ij})/(x_{ij} + m_{ij}) \quad (5)$$

where TBI_{ij} denotes trade balance index of country *i* for product *j*; x_{ij} and m_{ij} represent exports and imports of group of products *j* by country *i*, respectively (Lafay, 1992). A country is referred to as a "net-importer" in a specific group of products if the value of TBI is negative, and as a "net-exporter" if the value of TBI is positive (Widodo, 2009).

Results and discussion

Polish sugar market developed in a very specific way during last 17 years. Significant changes influenced not only sugar-producing entities, but also agricultural producers who supply a key input for sugar production in Poland – sugar beet. Between 2000 and 2017, the situation in the sugar beet production sector changed significantly. While in 2000 sugar beet was harvested from 318 ths. hectares, between 2015 and 2017 beet was harvested only from 202 ths. hectares. Although the area shrank by about 34%, total sugar beet production was not limited. Annual production oscillated around 10 and 12 million tonnes. Decrease of harvested area was compensated by improving situation in yield (as also described by Řezbová et al., 2013); between 2000 and 2017 yield increased by 60% from 40 t/ha up to more than 60t/ha. Also, number of farmers changed. While in 2000 about 112 ths. farms were producing sugar beet, in 2017 only 34 ths. farms continued with sugar beet production.

There was observed increase in the average number of farms supplying one refinery. In 2000, about 1,500 sugar beet producers supplied one refinery, while in 2017 this value already exceeded 1,900 farms. Also, average harvested area per one farm increased. While in 2000 average farm harvested beet from 3ha, in 2017 average area approached 6.5 ha. Significance of this change was also confirmed by research conducted on the level of the EU (Eurostat, 2017) as it concluded that share of small scale farers (up to 5 hectares) on sugar beet production was reduced from 90 to 7.3%. As small farms produced almost 50% of total sugar beet in 2000, in 2013 their share was only 1.2%. At present, nearly 50% of beet growing areas are under the control of farms with a size exceeding 50 hectares, growing sugar beet on more than fifty hectares. As a result, significant restructuring of sugar beet production was observed, this resulted in a reduction in the number of growers and greater concentration of production capacities. Undoubtedly, this trend has also been accompanied by a significantly higher efficiency of beet production, which subsequently allowed a significant increase in yield. Over the period, sugar beet price oscillated between 25 and 40 EUR per tonne, however in terms of the long-term average, price ranged between 25 and 30 EUR/tonne.

Also from the European point of view, it needs to be mentioned, that some national coupled payments are still provided for sensitive commodities. Based on information from Table 2 it needs to be stressed out, that in comparison with for example the Czech Republic and Italy, the support in Poland is higher by more than 100 EUR per hectare. Also, when other aspects of Polish sugar beet production are compared to other EU

Sugar beet production	2000-2002	2003-2005	2006-2008	2009-2011	2012-2014	2015-2017	GEOMEAN	Basic index 2017/2000
Area (thous. ha)	318	290	232	203	201	202	0.97	0.661
Yield (t/ha)	39.8	41.8	47.2	53.3	61.5	60.2	1.032	1.599
Production (thous. tonnes)	12 643	12 127	10 957	10 832	12 358	12 255	1.002	1.058

Source: Sugar market - the state and prospects, No. 20-44, Institute of Agricultural and Food Economics - National Research Institute, Agricultural Market Agency, Ministry of Agriculture and Rural Development, Warsaw 2001-2017

Table 1: Sugar beet production development.

EUR	Finland	Croatia	CZ	Italy	Greece	Poland	Slovakia	Hungary	Rumania
	67	121	267	276	311	384	390	396	600

Source: Ministry of Agriculture of the Czech Republic (2017)

Table 2: National additional coupled payments – calculated per hectare.

Average[1,2]	Area (thous. Ha)[1]	Yield (100 kg)[1]	Production (thous. tonnes)[1]	Cultivated area per one grower[2]
France	421.06	874.98	36 901.89	13.86
Germany	351.33	741.93	24 034.60	10.70
Poland	**202.16**	**604.83**	**12 309.43**	**5.30**
United Kingdom	95.67	720.99	6 968.33	28.22
Netherlands	71.50	832.62	5 979.35	4.51
Belgium	56.77	787.60	4 238.61	7.69
Czech Republic	61.48	630.50	3 878.40	77.40
Spain	35.66	932.88	3 329.82	5.43
Italy	36.18	603.21	2 115.09	5.09
Austria	43.91	707.99	3 104.19	6.84

Note: [1] 2015-2017 average; [2] 2014-2016 average
Source: Eurostat, 2017, CEFS Sugar Statistics 2016

Table 3: Production in selected EU countries.

countries (Table 3), it can be understood, that although Poland evince third largest sugar beer production in the whole EU and cultivate third largest area, Polish producers belongs among the smallest suppliers of sugar beet. Average cultivated area of one Polish sugar beet grower is equal to 5.3 ha in 3 year average. In comparison to largest producers (France and Germany), the average area is less than half. On contrary, among the top 10 EU producers, the largest average area is reached by the by Czech (77.4 ha) and UK (28.2) farmers.

Stable production of sugar beet logically resulted also in relatively stable production of sugar (table 7). Between 2000 and 2017, total sugar production oscillated close to 2 million tonnes of raw sugar equivalent. Sugar production was also significantly increased in relation to one harvested hectare. Original value of year 2000 (production of 6.56 tonnes of sugar per one hectare) almost doubled (to 11.2 tonnes per hectare). Observing values in table 7 it can be concluded, that production of raw sugar equivalent grew year-on-year by approximately 1% and sugar production per hectare has been increasing on average by 3.4% per year.

Years	Number of farms		Cultivated area	
	In total	Per 1 operating sugar enterprise	In total	Per 1 farm
	thous.		thous. ha	ha
2000	111.9	1.5	333	2.98
2002	91.5	1.4	303	3.31
2004	77.9	1.8	297	3.81
2006	63.2	2.0	262	4.15
2008	40.9	2.2	187	4.57
2010	38.2	2.1	206	5.39
2012	35.8	2.0	212	5.92
2014	35.0	1.9	198	5.66
2016	34.0	1.9	206	6.06
2017	34.0	1.9	220	6.47
Growth rate /GEOMEAN	0.932	1.014	0.976	1.047
BASIC INDEX 2017/2000	0.304	1.267	0.661	2.171

Source: Sugar market - the state and prospects. No. 20-44. Institute of Agricultural and Food Economics - National Research Institute. Agricultural Market Agency. Ministry of Agriculture and Rural Development. Warsaw 2001-2017.

Table 3: Production in selected EU countries.

Countries	Number of farms							Cultivated area						
	Total no.	0-5 ha		5-50 ha		over 50 ha		In total	0-5 ha		5-50 ha		over 50 ha	
	(thous.)	thous.	%	thous.	%	thous.	%	thous. ha	thous. ha	%	thous. ha	%	thous. ha	%
2003														
Poland	101.3	91.1	89.9	9.6	9.5	0.6	0.6	303	150.7	49.7	86.1	28.4	66.2	21.8
2013														
Poland	41.1	3	7.3	33.2	80.8	4.9	11.9	193.7	2.4	1.2	100	51.6	91.3	47.1

Source: Eurostat database.

Table 5: Structure of sugar beet producers.

EUR/tonne	2000	2002	2004	2006	2008	2010	2012	2014	2015	2016	GEO-MEAN	Basic 2000/2017
Poland	25.41	29.05	41.31	33.05	29.51	28.31	32.78	30.1	28.56	26.72	1.003	1.052

Source: Eurostat database.

Table 6: Sugar beet prices.

Sugar production (raw sugar equivalent)	Poland	
	thous. tonnes	tonnes per ha
2000/2001	2.013	6.56
2002/2003	2.193	7.24
2004/2005	2.176	7.45
2006/2007	1.873	7.94
2008/2009	1.411	8.02
2010/2011	1.556	7.33
2012/2013	2.025	9.82
2014/2015	2.156	11.2
2016/2017	2.283	11.2
Growth rate /GEOMEAN	1.008	1.034
BASIC INDEX 2017/2000	1.134	1.707

Source: Sugar market - the state and prospects. No. 20-44. Institute of Agricultural and Food Economics - National Research Institute. Agricultural Market Agency. Ministry of Agriculture and Rural Development. Warsaw 2001-2017.

Table 7: Development of raw sugar production.

A number of companies operating on the market (see Table 8 and 9) and the development of the number of sugar refineries are another specific feature of the Polish sugar industry. Between 2001 and 2017, the number of sugar refineries was reduced by more than 70%. Most of the sugar refineries was closed by Krajowa Spółka Cukrowa S.A (20 refineries); Śląska Spółka Cukrowa (16 refineries); Sűdzucker S.A. (12 refineries) and British Sugar Overseas - Poland (10 refineries). Śląska Spółka Cukrowa and British Sugar Overseas closed all their sugar production activities and since then they are not active on the market. Pfeiffer&Langen closed 7 and Nordzucker S.A. closed 6 sugar refineries. It is important to mention that the reduction in the number of sugar refineries has not been reflected significantly in sugar production. Despite the decreasing number of sugar refineries (-58), the volume of sugar production has not been significantly affected. Even the production loss caused by closure of two groups was completely compensated. Producers who remained on the market increased production. In particular, Südzucker S.A. increased sugar production capacity from 105 ths. to 523 ths. tonnes; Pfeiffer&Langen increased production from 273 ths. to 550 ths. tonnes. Also, campaign length was extended, and it resulted in improved efficiency. In average, Polish sugar campaign prolonged from 51 (2001) to 112 days (2016); Krajowa Spółka Cukrowa S.A increased the average number of campaign days from 51 to 102; Sűdzucker S.A. from 40 to 127 days; Pfeiffer&Langen from 51 to 120 days and Nordzucker S.A. from 55 to 103 days.

Speaking about sugar-producing groups, it is worth mentioning, that mainly Sűdzucker and Pfeiffer&Langen required more sugar beet due to longer campaign increased production. Therefore, they increased their share on purchased beet measured by share on contracted beet production area. Their share rose from 8.3 to 22.4% and 15.6 to 26.3% respectively (table 8). In the case of other producers, their shares on the contracted production areas remained preserved. On the other hand, all companies evince significant reduction in the number of contracted farms. But this reduction was fully compensated by the fact, that an average contracted farm intensified its production.

Specification	Cultivated area		Number of farms (thousands)	Average area of 1 farm (ha)	Yield (t/ha)
	thous. ha	%			
2001/2002					
Krajowa Spółka Cukrowa S.A.	122.3	40.7	46.5	2.6	na
Śląska Spółka Cukrowa	46.6	15.5	10	4.6	na
Sűdzucker S.A.	25	8.3	11.8	2.1	na
Pfeiffer&Langen	46.9	15.6	12.2	3.9	na
British Sugar Overseas - Polska	34.8	11.6	12.4	2.8	na
Nordzucker S.A.	25.2	8.4	6.5	3.9	na
Poland	**300.8**	**100**	**99.4**	**3**	**na**
2003/2004					
Krajowa Spółka Cukrowa S.A.	130.1	42.6	42.5	3.1	na
Sűdzucker S.A.	72.7	23.8	17.8	4.1	na
Pfeiffer&Langen	45.5	14.9	10.8	4.2	na
British Sugar Overseas - Polska	33.4	10.9	8.9	3.8	na
Nordzucker S.A.	23.7	7.8	5.9	4	na
Poland	**305.4**	**100**	**85.9**	**3.6**	**na**

Source: Sugar market - the state and prospects. No. 20-44. Institute of Agricultural and Food Economics - National Research Institute. Agricultural Market Agency. Ministry of Agriculture and Rural Development. Warsaw 2001-2017; Świetlicki (2015, 2016, 2017)

Table 8: The most important sugar producers in Poland and their sugar beet capacity (to be continued).

Specification	Cultivated area		Number of farms	Average area of 1 farm (ha)	Yield (t/ha)
	thous. ha	%	(thousands)		
2005/2006					
Krajowa Spółka Cukrowa S.A.	110.9	40.5	33.4	3.3	na
Sűdzucker S.A.	67.3	24.6	14.8	4.6	na
Pfeiffer&Langen	43.2	15.8	9.9	4.4	na
British Sugar Overseas - Polska	29.9	10.9	7.1	4.2	na
Nordzucker S.A.	22.6	8.3	5.5	4.1	na
Poland	**273.9**	**100**	**70.7**	**3.9**	**na**
2009/2010					
Krajowa Spółka Cukrowa S.A.	75.2	39.4	18.2	4.1	54.9
Sűdzucker S.A.	43.8	22.9	8.1	5.4	59.4
Pfeiffer&Langen	32.2	16.9	6.1	5.3	58.9
British Sugar Overseas	21.8	11.4	4.3	5	51.7
Nordzucker S.A.	18	9.4	3.3	5.5	60.4
Poland	**191**	**100**	**40**	**4.8**	**56.7**
2011/2012					
Krajowa Spółka Cukrowa S.A.	77	40.5	16.3	4.9	57.9
Sűdzucker S.A.	43	22.6	6.8	6.6	69.1
Pfeiffer&Langen	51	26.8	9.6	5.5	58.4
Nordzucker S.A.	19	10	3.2	6.1	66.4
Poland	**190**	**100**	**35.9**	**5.3**	**61.1**
2013/2014					
Krajowa Spółka Cukrowa S.A.	76	41.2	16.2	4.7	59.7
Sűdzucker S.A.	51.4	27.8	9.6	5.3	57.1
Pfeiffer&Langen	38.7	21	6.8	5.7	64.5
Nordzucker S.A.	18.5	10	3.1	6	66.8
Poland	**184.6**	**100**	**35.7**	**5.2**	**60.8**
2016/2017					
Krajowa Spółka Cukrowa S.A.	83.6	41.2	15.2	5.5	65.8
Sűdzucker S.A.	45.4	22.4	6.4	7.1	68.6
Pfeiffer&Langen	53.4	26.3	9.4	5.7	63.5
Nordzucker S.A.	20.7	10.2	3.1	6.7	72.5
Poland	**203.1**	**100**	**34.1**	**6**	**66.5**

Source: Sugar market - the state and prospects. No. 20-44. Institute of Agricultural and Food Economics - National Research Institute. Agricultural Market Agency. Ministry of Agriculture and Rural Development. Warsaw 2001-2017; Świetlicki (2015, 2016, 2017)

Table 8: The most important sugar producers in Poland and their sugar beet capacit (continuation).

Specification	2001	2003	2005	2007	2009	2011	2013	2015	2016
Number of enterprises									
Krajowa Spółka Cukrowa S.A.	27	24	18	11	7	7	7	7	7
Śląska Spółka Cukrowa	16	x	x	x	x	x	x	x	x
Sűdzucker S.A.	6	17	11	10	5	5	5	5	5
Pfeiffer&Langen	11	5	4	4	4	4	4	4	4
British Sugar Overseas	10	3	2	2	x	x	x	x	x
Nordzucker S.A.	6	8	5	2	2	2	2	2	2
Total	76	57	40	29	18	18	18	18	18

Source: Sugar market - the state and prospects. No. 20-44. Institute of Agricultural and Food Economics - National Research Institute. Agricultural Market Agency. Ministry of Agriculture and Rural Development. Warsaw 2001-2017; Świetlicki (2015, 2016, 2017).

Table 9: The most important sugar producers - selected characteristics (to be continued).

Specification	2001	2003	2005	2007	2009	2011	2013	2015	2016
Number of enterprises									
Production of white sugar (thous. tonnes)									
Krajowa Spółka Cukrowa S.A.	629	797	795	722	608	694	na	na	815
Śląska Spółka Cukrowa	244	x	x	x	x	x	x	x	x
Sűdzucker S.A.	105	488	537	462	375	468	na	na	523
Pfeiffer&Langen	273	220	208	337	286	500	na	na	550
British Sugar Overseas	153	280	177	227	x	x	x	x	x
Nordzucker S.A.	137	161	351	185	169	197	na	na	196
Total	1 540	1 946	2 068	1 934	1 437	1 859	1 713	1 464	2 084
Time of sugar beet processing (days)									
Krajowa Spółka Cukrowa S.A.	51	60	65	83	103	97	91	71	102
Śląska Spółka Cukrowa	48	x	x	x	x	x	x	x	x
Sűdzucker S.A.	40	66	96	92	114	126	101	130	127
Pfeiffer&Langen	51	87	92	124	140	114	107	95	120
British Sugar Overseas	66	57	90	99	x	x	x	x	x
Nordzucker S.A.	55	72	101	94	88	97	99	82	103
Total	51	62	84	93	107	107	98	81	112

Source: Sugar market - the state and prospects. No. 20-44. Institute of Agricultural and Food Economics - National Research Institute. Agricultural Market Agency. Ministry of Agriculture and Rural Development. Warsaw 2001-2017; Świetlicki (2015, 2016, 2017).

Table 9: The most important sugar producers - selected characteristics (continuation).

Installed daily capacity for sugar beet processing among individual refineries is another characteristic feature of Polish sugar industry. An overview of these capacities, together with a detailed list of active sugar refineries, can be found in table 10. Based on the available data it can be concluded that Polish sugar refineries can be considered relatively large. Their daily beet processing capacity ranges from 3,500 to 12,200 tonnes, average capacity per one sugar refinery reaches about 6,351 tonnes per day. With only two exceptions, all refineries produce sugar from sugar beet; only refineries in Glinojeck and Chelmza have limited capacity (1,200 t/day and 800 t/day respectively) to process also imported raw sugar. During the transformation period, average annual sugar production capacity was increased significantly. Between 2001 and 2006, average production of each refinery increased from 20 ths. to 116 ths. tonnes per annum. An important indicator is also the increase of annual average sales per one sugar refinery. In 2016, average refinery evinced sales of about 70 million EUR. Total turnover of all Polish refineries was about 1.153 billion EUR. Labour productivity development was also observed; in 2016 sugar production per one employee reached approximately 630 tonnes. Turnover per employed person was about 380 ths. EUR per person employed (see table 11). Also, economic indicators of the whole sugar industry improved (table 12). Indicators changed as follow between 2000 and 2016: total revenues (+17%), net income (+198%), return on sales (from 6.7 to 17%), liquidity (from 1.1 to 4.0). Also a continuous transfer of investments was reflected in the Polish sugar industry, as cumulated investments reached a total of 4.115 billion PLN (1.016 billion EUR) between 2000 and 2016. Similarly to Szajner (2016), it can be concluded that investments are being slowed down. Investment peak is observed in 2006 (93.6 million EUR), since than investments have been falling to 49.4 million EUR in 2016.

The economic performance of the sector was largely reflected in relatively stable sugar market. The average price, with some exceptions, fluctuated between 0.5 and 0.6 EUR/kg. Polish market was also stabilised by slowly increasing consumption as it rose from 1.6 to 1.72 million tonnes. Increase in consumption was not pushed by change in consumption among Polish households, but it was pushed by food industry. While consumption of households decreased from 780 to 550 ths. tonnes between 2000 and 2017 (-30%), consumption of food industry increased from 770 ths. to 1.1 million tonnes (+42%). Decreasing consumption of Polish households was fully compensated by the growing consumption of food industry, which increased consumption by more than 300,000 tons a year. Per capita sugar consumption remained relatively stable throughout the monitored period. It remained at a level exceeding 40 kg per year (Table 14).

It is necessary to mention, considering sugar production and installed production capacities, that Polish market evince relatively high concentration rate. According to the HH index (2,944 points), Polish sugar market operates under monopolistic competition with significant concentration. CR4 index (100%) indicates that market directs from oligopoly towards the monopoly. Polish sugar market evinces oligopolistic character. The distribution of installed production capacities also shows the high degree of market concentration (HH Index even reaches 3,070).

Owner/Operator	Location	Region	Production Capacity	Feedstocks
Krajowa Spolka Cukrowa S.A.	Dobrzelin	Lodz	2012:4,290 t/day	Sugar beet
Krajowa Spolka Cukrowa S.A.	Kluczewo	Greater Poland	2012:7,989 t/day	Sugar beet
Krajowa Spolka Cukrowa S.A.	Krasnystaw	Lublin	2012:9,457 t/day	Sugar beet
Krajowa Spolka Cukrowa S.A.	Kruszwica	Kuyavian-Pomeranian	2012:8,644 t/day	Sugar beet
Krajowa Spolka Cukrowa S.A.	Malbork	Pomeranian	2012:5,754 t/day	Sugar beet
Krajowa Spolka Cukrowa S.A.	Naklo	Kuyavian-Pomeranian	2012:4,809 t/day	Sugar beet
Krajowa Spolka Cukrowa S.A.	Werbkowice	Lublin	2012:7,516 t/day	Sugar beet
Nordzucker Polska S.A.	Chelmza	Kuyavian-Pomeranian	2012:6,511 t/day DRC:2008:800 t/day	Sugar beet. raw sugar
Nordzucker Polska S.A.	Opalenica	Kuyavian-Pomeranian	2012:6,116 t/day	Sugar beet
Pfeifer&Langen	Glinojeck	Mazovia	2014:12,200 t/day DRC: 2009:1,200 t/day	Sugar beet. raw sugar
Pfeifer&Langen	Gosty	Greater Poland	2012:5,274 t/day	Sugar beet
Pfeifer&Langen	Miejska Górka	Greater Poland	2012:4,251 t/day	Sugar beet
Pfeifer&Langen	?roda	Greater Poland	2012:5,808 t/day	Sugar beet
Südzucker Polska S.A.	Cerekiew	Opole	2016:5,600 t/day	Sugar beet
Südzucker Polska S.A.	Ropczyce	Subcarpathia	2016:6,100 t/day	Sugar beet
Südzucker Polska S.A.	Strzelin	Lower Silesia	2016:5,900 t/day	Sugar beet
Südzucker Polska S.A.	Strzyzow	Subcarpathia	2012:3,500 t/day	Sugar beet
Südzucker Polska S.A.	Swidnica	Silesia	2016:4,600 t/day	Sugar beet

Source: F.O.Licht. 2017

Table 10: Sugar refineries and their processing capacities (tonnes per day).

Specification	2001	2003	2005	2007	2009	2011	2013	2015	2016
Sales. in total (million EUR)	na	na	na	1 155	1 039	1 540	1 477	1 031	1 253
Sales. per 1 enterprise (million EUR)	na	na	na	40	58	86	82	57	70
Labour productivity (tonnes per emplyee)	na	na	na	263	342	531	518	444	630
Labour productivity (thous. EUR per employee)	na	na	na	157	221	440	434	312	380

Source: Sugar market - the state and prospects. No. 20-44. Institute of Agricultural and Food Economics - National Research Institute. Agricultural Market Agency. Ministry of Agriculture and Rural Development. Warsaw 2001-2017.

Table 11: Selected Economic Characteristics of Polish Sugar Industry - Part I.

Specification	2000	2002	2004	2006	2008	2010	2012	2014	2016	BASIC
Net revenue. current prices (million EUR)	1 101.40	1 217.60	1 396.30	1 356.10	1 175.10	1 148.20	1 820.20	1 255.00	1 290.30	1.17
Net profit (million EUR)	73.4	-5.2	149.3	108.8	-88.1	164.2	398.3	134.3	218.9	2.98
Return on sales (%)	6.7	-0.4	10.7	8	-7.5	14.3	21.9	10.7	17	2.55
Current liquidity ratio	1.1	1.1	1.4	1.7	2.6	3.3	3.4	3.3	4	3.77
Investment. current prices (million EUR)	23.5	34	55.4	93.6	87.5	72.4	69.4	52.5	49.4	2.11

Source: Sugar market - the state and prospects. No. 20-44. Institute of Agricultural and Food Economics - National Research Institute. Agricultural Market Agency. Ministry of Agriculture and Rural Development. Warsaw 2001-2017.

Table 12: Selected Economic Characteristics of Polish Sugar Industry - Part II.

Year	PLN per 1 kg	EUR per 1 kg
2000	2.36	0.59
2002	2.10	0.54
2004	2.62	0.58
2006	2.64	0.68
2008	2.19	0.62
2010	2.15	0.54
2012	3.25	0.78
2014	2.08	0.50
2016	2.37	0.54
Growth rate /GEOMEAN	1.0003	0.9950
BASIC INDEX 2017/2000	1.0042	0.9225

Source: Central Statictical Office of Poland. Local Data Bank. https://bdl.stat.gov.pl/BDL/start#. 21.08.2017

Table 13: Development of white beet sugar price in Poland (in sacks).

Year	Sugar consumption (thous. tonnes)				Sugar consumption per capita (kg)
	households	food industry	other uses	in total	
2000	780	770	45	1 595	41.6
2002	755	790	45	1 590	43.6
2004	740	830	45	1 615	37.6
2006	730	845	45	1 620	35.2
2008	715	855	50	1 620	38.4
2010	660	850	60	1 570	39.9
2012	600	950	60	1 610	42.5
2014	610	1 025	65	1 700	44.3
2016	545	1 075	70	1 690	41.5
2017	550	1 095	75	1 720	42.5
Growth rate / GEOMEAN	0.9797	1.0209	1.0305	1.0044	1.0013
BASIC INDEX 2017/2000	0.7051	1.4221	1.6667	1.0784	1.0216

Source: Sugar market - the state and prospects. No. 44. Institute of Agricultural and Food Economics - National Research Institute. Agricultural Market Agency. Ministry of Agriculture and Rural Development

Table 14: Development and structure of Polish sugar consumption.

Polish sugar industry is strongly influenced by international trade. Between 2000 and 2017, the volume of sugar exports oscillated between 350 and 700 thousand tonnes. The peak (702 ths. tonnes) was reached in 2006, the minimum (335 ths. tonnes) was realized in 2011. In average, total annual exports amounted to 430 ths. tonnes and increased in average by 0.9% per annum. Polish exports can be characterized by relatively significant year-on-year fluctuations. Its standard deviation from the average was about 30%. On contrary to volumes, value of exports evinced annual growth of about 5.3% as the value increased from approx. 100 million to 240 million EUR. Lowest value of exports is observed in 2002 (51 million EUR), while maximum (377 mil. EUR) occurred in 2012. Also export values were highly volatile. This statement is supported by the standard deviation of mean that reached 45%. The value and volume of exports was influenced by the development of unit prices as they increased from 0.23 in 2002 to 0.48 EUR/Kg in 2017, instability of export price is supported by standard deviation of mean at the level of 33%.

Value and volume of imports rose more dynamically compared to exports. Between 2000 and 2017, volume of imports increased from 55 to 210 ths. tonnes; value of imports rose from 16 to 90 million EUR. While value and volume of exports gained in average 5.3%, respectively 0.9% per annum, import values and volumes gained in average 8.2% and 10.8% (table 15). However, it must be noted, that import was even more unstable than exports; standard deviation from mean are 59% (for volumes) and 69% (for values). Although the growth rate of imports outperformed the of exports (with only exception of kilogram price: 4.3% per annum for export vs. 2.4% for import), Poland managed to maintain a positive trade balance in the analysed period, both in value and volume terms. At present (2016/2017), the surplus of the trade balance is estimated to be about 150 million EUR and 290 ths. tonnes of sugar.

A particular feature of the Polish sugar market is its trade orientation primarily to the EU countries. Poland export significant share of its production in the EU. However, the EU market has not always been a key sugar destination. In the pre-accession period, particularly in year 2000, Poland only exported 1.85% of its exported volumes (i.e. around 2.51% of exported value) to the EU. Subsequently, as the accession was approaching, share of Polish exports to the EU increased. In 2003, EU received about 24.98% and 26.09% of exported volume and value respectively. Entry into the EU was a turning point from the perspectives of Polish agrarian foreign trade. In 2004, as much as 48.56% and 73.53% of Polish export directed to the EU countries measured in volume and value. This situation was affected by change in export price, related to higher price of sugar in the EU. The export price, after Poland became EU member and accessed the single market, grew from an average 0.21 to 0.57 EUR/kg between 2003 and 2004. Exports to the EU single market grew from 100 ths. tonnes (23 million EUR) in the period immediately before the accession

Total trade	Export			Import			Trade balance	
	ths. tonnes	million EUR	EUR/kg	ths. tonnes	million EUR	EUR/kg	ths. tonnes	million EUR
2000	427.9	99.7	0.23	55.2	15.7	0.28	372.7	84.0
2001	295.1	91.1	0.31	64.0	20.4	0.32	231.1	70.7
2002	207.8	51.0	0.25	86.1	28.1	0.33	121.8	22.9
2003	425.6	87.0	0.20	75.1	19.1	0.25	350.5	67.9
2004	428.3	161.3	0.38	44.2	20.3	0.46	384.1	141.0
2005	657.7	184.4	0.28	48.0	26.2	0.55	609.7	158.2
2006	702.6	225.6	0.32	70.6	45.9	0.65	632.0	179.7
2007	348.4	139.5	0.40	49.5	30.4	0.61	298.9	109.1
2008	403.7	164.2	0.41	125.3	68.1	0.54	278.4	96.1
2009	188.2	101.8	0.54	244.8	126.3	0.52	-56.6	-24.5
2010	380.8	186.4	0.49	200.9	93.4	0.46	179.9	93.0
2011	335.3	230.4	0.69	288.0	163.8	0.57	47.3	66.6
2012	576.1	377.2	0.65	252.1	154.4	0.61	324.0	222.8
2013	507.9	307.2	0.60	197.0	117.5	0.60	310.9	189.7
2014	467.8	219.3	0.47	209.4	112.2	0.54	258.4	107.1
2015	432.0	186.9	0.43	118.5	54.6	0.46	313.5	132.3
2016	464.9	225.7	0.49	229.7	106.3	0.46	235.2	119.4
2017	500.0	240.0	0.48	210.0	90.0	0.43	290.0	150.0
Growth rate / GEOMEAN	1.009	1.053	1.043	1.082	1.108	1.024	N/A	N/A
BASIC INDEX 2017/2000	1.168	2.407	2.060	3.804	5.733	1.507	0.778	1.785

Source: Sugar market - the state and prospects. No. 20-44. Institute of Agricultural and Food Economics - National Research Institute. Agricultural Market Agency. Ministry of Agriculture and Rural Development. Warsaw 2001-2017

Table 15: Development of foreign trade in sugar.

to less than 300 ths. tonnes (150 million EUR) in 2016. The export maximum was reached in 2013, when the total volume of exports amounted to approximately 365 ths. tonnes (about 250 million EUR). The share of EU countries in sugar exports reached its peak in 2009, when about 88.52% (in volume terms) and 91.94% (in value terms) of exports directed to single market. After 2013, export to EU evinced further decrease. In 2016, 61.37 percent of trade volume finished in EU (66.37 of trade value). Above stated information indicates, that between 2004 and 2016 the exports to the EU underwent turbulent changes and fluctuations, as volume and kilogram export prices strongly oscillated. The average year-on-year change can serve as an evidence of this turbulent development, it achieved in value and volume terms 30.8 and 27.6 percent respectively. High fluctuation can be also indicated by a high percentage rate of standard deviation from the mean reaching 57.52% and 65.92% percent in volume and value respectively. Unit export price showed in average standard deviation from the mean of about 28.13 percent.

Among relatively volatile exports, similar market behaviour can be observed in relation to imports. Import volumes and values evince relatively high average annual rate of change. Through the observed period, annual average rate of change reached in value and volume 9.4 and 12.3 percent respectively. Observed export growth rate outperformed import growth rate (see Table 15). On the other hand, import deviations were much more intensive than export annual deviations as it could be observed in the values of average standard deviation from mean of sugar import volumes (64.13%) and values (78.16%). Even growth rate of kilogram import prices (2.6% per annum) grew little bit faster than export prices (2.5% per annum). Import prices has higher standard deviation from the mean (37.70%), comparing to export price (28.13%). Generally, volumes of imports from EU countries fluctuated over time. At the beginning of the analysed period, the share of imports from the EU countries was very significant, both in the case of import volumes (about 45 ths. tonnes, share 82.7%) as well as in the case of import values (12.5 million EUR, share 79.6%). Prior to the EU accession (2003), imports amounted to 74 ths. tonnes, respectively it amounted to less than 20 million EUR and the share of imports from EU countries accounted for 96.86% and 98.93% respectively. In the period after the accession, share of EU countries on Polish sugar

Total trade	Export			Import			Trade balance	
	ths. tonnes	million EUR	EUR/kg	ths. tonnes	million EUR	EUR/kg	ths. tonnes	million EUR
2000	7.9	2.5	0.32	45.3	12.5	0.27	-37.4	-10.0
2001	4.5	2.0	0.45	41.4	13.6	0.33	-36.9	-11.6
2002	45.5	12.3	0.27	75.9	24.7	0.33	-30.4	-12.4
2003	106.3	22.7	0.21	74.3	18.5	0.25	32.0	4.2
2004	208.0	118.6	0.57	41.1	19.3	0.47	166.9	99.3
2005	112.0	69.1	0.62	33.2	19.7	0.59	78.8	49.4
2006	79.5	50.8	0.64	53.0	35.5	0.67	26.5	15.3
2007	182.9	99.0	0.54	34.9	22.5	0.64	148.0	76.5
2008	248.3	124.6	0.50	82.1	46.5	0.57	166.2	78.1
2009	166.6	93.6	0.56	223.4	115.8	0.52	-56.8	-22.2
2010	231.5	118.6	0.51	182.9	72.3	0.40	48.6	46.3
2011	258.7	185.7	0.72	124.0	136.9	1.10	134.7	48.8
2012	209.2	160.5	0.77	45.7	36.4	0.80	163.5	124.1
2013	365.1	250.5	0.69	59.6	39.9	0.67	305.5	210.6
2014	318.7	169.0	0.53	92.1	49.3	0.54	226.6	119.7
2015	277.5	129.0	0.46	60.6	29.7	0.49	216.9	99.3
2016	285.3	149.8	0.53	86.0	44.8	0.52	199.3	105.0
2017	1.276	1.308	1.025	1.094	1.123	1.026	N/A	N/A
Growth rate / GEOMEAN	63.291	96.376	1.523	4.636	7.228	1.559	-7.754	-15.059
BASIC INDEX 2017/2000	1.168	2.407	2.060	3.804	5.733	1.507	0.778	1.785

Source: Sugar market - the state and prospects. No. 20-44. Institute of Agricultural and Food Economics - National Research Institute. Agricultural Market Agency. Ministry of Agriculture and Rural Development. Warsaw 2001-2017.

Table 16: Polish foreign trade in sugar within the EU internal market.

imports was gradually reduced. A minimum was reached in 2012, when EU accounted only for 18.13% of imported volume and 23.58% of imported value. Imports from the EU reached its maximum in terms of volumes in 2009 (223 ths. tonnes) and in terms of value in 2011 (137 million EUR) (Table 16). EU sugar market regulations supported import fluctuations, as they significantly affected Polish production capacities as well as capacities in other countries. In addition, the Common Commercial Policy and Common Agriculture Policy influenced performance of agrarian foreign trade, as both policies isolated the EU internal sugar market from the rest of the world. The sugar price and supplied quantity were not determined by demand, but their development was largely determined by subsidies, production and import regulations. Present Polish sugar market is characterised by positive trade balance expressed both in trade volume and value. Negative trade balance was only observed prior to Polish EU accession and in year 2009. Internationalization of its production capacities was very important aspect that has significantly influenced the character of Polish foreign trade. Majority of production is no longer under the control of primarily Polish capital, but they are under the control of international capital. A significant part of Polish production and export capacities are controlled mainly by German companies such as Nordzucker, Südzucker and Pffeifer&Langen. Polish sugar industry was significantly affected by applied sugar production quotas (Table 17). For a long time, they limited production at the level of 1.4 million tonnes of sugar a year. On one hand, quotas greatly reduced the export ambitions of Polish sugar industry; however, on the other hand quota system generally protected the Polish market from competition from other EU countries.

2004/2005	1,580.0 (A); 91.9 (B)
	91.9 (B)
2005/2006	1,495.3 (A)
	87.0 (B)
2006/2007	1,671.9
2007/2008	1,772.5
2008/2009 – 2015/2016	1,405.6

Source: Sugar market - the state and prospects. No. 20-44. Institute of Agricultural and Food Economics - National Research Institute, Agricultural Market Agency, Ministry of Agriculture and Rural Development. Warsaw 2001-2017.

Table 17: Development of sugar production quotas (in ths. tonnes).

The territorial structure of the Polish sugar trade is very concentrated. The top five export destinations (Germany, Israel, Lithuania, Italy and Latvia) accounted for approximately 52.6 percent of Polish sugar exports in value. Russian Federation, Czechia, Georgia, Greece and Hungary belong together with above mentioned countries, to the TOP10 export partners. The share of TOP10 trading partners in total sugar exports reached approximately 72.56% in 2016. An even higher degree of concentration is observed by the territorial structure of Polish imports. TOP5 (Sudan, Zimbabwe, Mozambique, Germany, Lithuania) and TOP10 (TOP5+Sweden, Mauritius, Czechia, Denmark, Ukraine) import destinations accounted for 71.4 and 92.94 percent of sugar imports to Poland. More details about the territorial concentration of the Polish sugar trade are shown in tables 18 and 19. The HH Index analysis shows the high level of concentration of the territorial structure of the sugar foreign trade, both from the export and import perspective. The HHI value for the export reaches 965 points and the HHI value of imports reaches about 1228 points. Also, CR4 confirms high level of territorial concentration, as CR4 export and import analyses evince value of 47.2 and 62.5 percent respectively.

Existing comparative advantage in relation to partner countries is another specific feature of Polish sugar industry. Table 20 provides an overview of the comparative advantage at the level of individual trading partners/countries. These data show that Poland has carried foreign trade transaction with about ninety countries in 2016. It can be concluded, based on the results of the LFI analyses, that Poland achieved bilateral comparative advantage of its exports with about 50 countries. From more general perspective (RCA analyses), Polish exports were able to achieve trade advantage with about 30 countries. Poland also achieved positive trade balance

Period	Trade Flow	Reporter	Partner	Commodity Code	Trade Value	Share
2016	Export	Poland	World	H4-1701	247 348 280	100.00%
2016	Export	Poland	Germany	H4-1701	63 492 160	25.67%
2016	Export	Poland	Israel	H4-1701	22 031 586	8.91%
2016	Export	Poland	Lithuania	H4-1701	16 744 527	6.77%
2016	Export	Poland	Italy	H4-1701	14 510 120	5.87%
2016	Export	Poland	Latvia	H4-1701	13 329 238	5.39%
TOP5					130 107 631	52.60%
2016	Export	Poland	Russian Federation	H4-1701	10 109 310	4.09%
2016	Export	Poland	Czechia	H4-1701	11 152 137	4.51%
2016	Export	Poland	Georgia	H4-1701	8 269 608	3.34%
2016	Export	Poland	Greece	H4-1701	8 659 708	3.50%
2016	Export	Poland	Hungary	H4-1701	11 178 580	4.52%
TOP10					179 476 974	72.56%
2016	Export	Poland	Kazakhstan	H4-1701	5 698 003	2.30%
2016	Export	Poland	Sri Lanka	H4-1701	5 471 887	2.21%
2016	Export	Poland	Sudan	H4-1701	4 847 230	1.96%
2016	Export	Poland	Belgium	H4-1701	5 327 845	2.15%
2016	Export	Poland	Lebanon	H4-1701	4 347 579	1.76%
TOP15					205 169 518	82.95%
2016	Export	Poland	United Arab Emirates	H4-1701	3 649 026	1.48%
2016	Export	Poland	Rep. of Moldova	H4-1701	2 953 972	1.19%
2016	Export	Poland	Slovakia	H4-1701	3 442 443	1.39%
2016	Export	Poland	Algeria	H4-1701	2 619 704	1.06%
2016	Export	Poland	Egypt	H4-1701	2 310 116	0.93%
2016	Export	Poland	Sweden	H4-1701	2 790 227	1.13%
2016	Export	Poland	Mongolia	H4-1701	2 369 033	0.96%
2016	Export	Poland	Denmark	H4-1701	2 532 022	1.02%
Suma					227 836 061	100%

Source: UN Comtrade, own processing, 2017

Table 18: The most important export destination of Polish sugar industry.

Period	Trade Flow	Reporter	Partner	Commodity Code	Trade Value	Share
2016	Import	Poland	World	H4-1701	114,124,905	100.00%
2016	Import	Poland	Sudan	H4-1701	24,739,488	21.68%
2016	Import	Poland	Zimbabwe	H4-1701	17,542,325	15.37%
2016	Import	Poland	Mozambique	H4-1701	14,883,948	13.04%
2016	Import	Poland	Germany	H4-1701	14,200,067	12.44%
2016	Import	Poland	Lithuania	H4-1701	10,119,752	8.87%
TOP5					81485580	71.40%
2016	Import	Poland	Sweden	H4-1701	8,736,605	7.66%
2016	Import	Poland	Mauritius	H4-1701	5,624,101	4.93%
2016	Import	Poland	Czechia	H4-1701	4,919,229	4.31%
2016	Import	Poland	Denmark	H4-1701	3,420,576	3.00%
2016	Import	Poland	Ukraine	H4-1701	1,879,914	1.65%
TOP10					106,066,005	92.94%
2016	Import	Poland	France	H4-1701	1,390,992	1.22%
2016	Import	Poland	Netherlands	H4-1701	1,121,101	0.98%
2016	Import	Poland	Brazil	H4-1701	950,492	0.83%
2016	Import	Poland	Colombia	H4-1701	749,977	0.66%
2016	Import	Poland	Austria	H4-1701	736,365	0.65%
TOP15					111,014,932	97.27%
2016	Import	Poland	United Kingdom	H4-1701	642,017	0.56%
2016	Import	Poland	Cambodia	H4-1701	535,896	0.47%
2016	Import	Poland	Slovakia	H4-1701	395,269	0.35%
2016	Import	Poland	Argentina	H4-1701	326,897	0.29%
2016	Import	Poland	Belgium	H4-1701	242,498	0.21%
2016	Import	Poland	Rep. of Moldova	H4-1701	164,171	0.14%
2016	Import	Poland	Italy	H4-1701	144,014	0.13%
2016	Import	Poland	United Arab Emirates	H4-1701	141,240	0.12%
Suma					113,606,934	99.55%

Source: UN Comtrade, own processing, 2017

Table 19: The most important import destination of Polish sugar industry.

Country	LFI	Country	TBI	Country	RCA
Austria	-0.123	Austria	-0.48	Austria	0.111
Belgium	0.487	Belgium	0.913	Belgium	1.154
Bulgaria	0.18	Bulgaria	1	Bulgaria	0.487
Croatia	0.001	Croatia	1	Croatia	0.01
Cyprus	0.169	Cyprus	1	Cyprus	0.762
Czechia	-0.085	Czechia	0.388	Czechia	0.694
Denmark	0.027	Denmark	-0.149	Denmark	0.539
Estonia	0.175	Estonia	0.987	Estonia	1.28
Finland	0.007	Finland	1	Finland	0.033
France	-0.083	France	-0.438	France	0.056
Germany	0.343	Germany	0.634	Germany	0
Greece	2.12	Greece	0.997	Greece	4.477
Hungary	0.793	Hungary	0.992	Hungary	1.77
Ireland	0.054	Ireland	0.993	Ireland	0.204
Italy	0.449	Italy	0.98	Italy	1.052
Latvia	1.456	Latvia	1	Latvia	4.926
Lithuania	-0.415	Lithuania	0.247	Lithuania	3.107

Source: UN Comtrade, own processing, 2017

Table 20: Comparative advantages of Polish sugar exports toward EU countries (2016) (to be continued).

Country	LFI	Country	TBI	Country	RCA
Luxembourg	0.703	Luxembourg	1	Luxembourg	2.605
Malta	0	Malta	1	Malta	0.003
Netherlands	0.039	Netherlands	0.326	Netherlands	0
Portugal	0	Portugal	1	Portugal	0.001
Romania	0.055	Romania	1	Romania	0.303
Slovakia	0.145	Slovakia	0.794	Slovakia	0.487
Slovenia	-0.005	Slovenia	-0.515	Slovenia	0.002
Spain	0.026	Spain	0.98	Spain	0.1
Sweden	-1.374	Sweden	-0.516	Sweden	0.711
United Kingdom	-0.023	United Kingdom	0.242	United Kingdom	0.058

Source: UN Comtrade, own processing, 2017

Table 20: Comparative advantages of Polish sugar exports toward EU countries (2016) (continuation).

Country	LFI	Country	TBI	Country	RCA
Algeria	0.002	Algeria	1	Algeria	1.674
Argentina	0	Argentina	-0.998	Argentina	0.033
Armenia	0	Armenia	1	Armenia	0.001
Australia	0.007	Australia	1	Australia	0
Azerbaijan	0.003	Azerbaijan	1	Azerbaijan	0.016
Bahrain	0.002	Bahrain	1	Bahrain	4.901
Barbados	-0.02	Barbados	-1	Barbados	0.001
Belarus	-0.031	Belarus	-0.169	Belarus	0.02
Belize	-11.836	Belize	-1	Belize	0
Bosnia Herzegovina	-0.252	Bosnia Herzegovina	-1	Bosnia Herzegovina	0
Brazil	-0.039	Brazil	-1	Brazil	0
Bunkers	0	Bunkers	1	Bunkers	0.351
Cambodia	-0.817	Cambodia	-1	Cambodia	0
Cameroon	8.41	Cameroon	1	Cameroon	19.357
Canada	0.015	Canada	1	Canada	0.043
Colombia	-0.151	Colombia	-1	Colombia	0
Cook Isds	0	Cook Isds	1	Cook Isds	2.528
Cuba	-0.027	Cuba	-1	Cuba	0
Egypt	0.48	Egypt	1	Egypt	1.911
Georgia	9.382	Georgia	1	Georgia	29.776
Ghana	0.234	Ghana	1	Ghana	0.625
China	0.074	China	0.984	China	0.214
Iceland	0.012	Iceland	1	Iceland	0.048
India	0.002	India	1	India	0.04
Indonesia	-0.036	Indonesia	-1	Indonesia	0
Israel	2.961	Israel	1	Israel	11.779
Jordan	0	Jordan	1	Jordan	0.006
Kazakhstan	5.228	Kazakhstan	1	Kazakhstan	11.216
Kuwait	0	Kuwait	1	Kuwait	2.754
Kyrgyzstan	0.062	Kyrgyzstan	1	Kyrgyzstan	0.302
Lebanon	5.845	Lebanon	1	Lebanon	16.165
Libya	0	Libya	1	Libya	0.031
Malawi	-0.011	Malawi	-1	Malawi	0
Malaysia	0.002	Malaysia	1	Malaysia	0.013
Mauritius	-20.721	Mauritius	-1	Mauritius	0
Mongolia	0.05	Mongolia	1	Mongolia	11.248

Source: UN Comtrade, own processing, 2017

Table 21: Comparative advantages of Polish sugar exports toward non-EU countries (2016) (to be continued).

Country	LFI	Country	TBI	Country	RCA
Mozambique	-11.495	Mozambique	-1	Mozambique	0
Myanmar	9.452	Myanmar	1	Myanmar	26.348
Norway	0	Norway	1	Norway	0.003
Oman	0.005	Oman	1	Oman	8.775
Pakistan	0.001	Pakistan	1	Pakistan	0.005
Paraguay	0	Paraguay	-1	Paraguay	0
Qatar	0.026	Qatar	1	Qatar	1.859
Rep. of Korea	0.033	Rep. of Korea	1	Rep. of Korea	0.162
Rep. of Moldova	5.298	Rep. of Moldova	0.895	Rep. of Moldova	11.753
Russian Federation	0.982	Russian Federation	1	Russian Federation	2.504
Saudi Arabia	0.001	Saudi Arabia	1	Saudi Arabia	0.476
Senegal	0	Senegal	1	Senegal	0.013
Singapore	1.558	Singapore	1	Singapore	13.958
South Africa	0.474	South Africa	1	South Africa	1.051
Sri Lanka	29.112	Sri Lanka	1	Sri Lanka	81.557
Sudan	-7.441	Sudan	-0.672	Sudan	74.32
Swaziland	-0.002	Swaziland	-1	Swaziland	0
Sweden	-1.374	Sweden	-0.516	Sweden	0.711
Switzerland	-0.006	Switzerland	-0.809	Switzerland	0.001
Syria	4.065	Syria	1	Syria	19.464
Thailand	0	Thailand	-1	Thailand	0
Turkey	0.347	Turkey	1	Turkey	1
Turkmenistan	0	Turkmenistan	1	Turkmenistan	3.571
Ukraine	-0.188	Ukraine	-0.987	Ukraine	0
United Arab Emirates	0.046	United Arab Emirates	0.925	United Arab Emirates	4.462
USA	-0.001	USA	0.118	USA	0.036
World	0.157	World	0.369	World	1.031
Zimbabwe	-18.116	Zimbabwe	-1	Zimbabwe	0

Source: UN Comtrade, own processing, 2017

Table 21: Comparative advantages of Polish sugar exports toward non-EU countries (2016) (continuation).

to most of its trade partners. From the perspective of comparative advantages, it is crucial that Poland achieved comparative advantages over most of the EU member states (18 EU countries: Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, Germany, Greece, Hungary, Latvia, Luxembourg, the Netherlands, Romania, Slovakia, Spain). Poland also reached positive trade balance in relation to 22 EU member countries (Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Finland, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Romania, Slovakia, Spain, United Kingdom). In addition, Poland exhibit revealed comparative advantage toward eight EU member states (Belgium, Estonia, Greece, Hungary, Italy, Lithuania, Latvia, Luxembourg).

As far as third countries are concerned, Poland exhibit revealed comparative advantage toward 24 non-EU countries (Algeria, Bahrain, Cameroon, Cook Islands, Egypt, Georgia, Israel, Kazakhstan, Kuwait, Lebanon, Mongolia, Myanmar, Oman, Qatar, Moldova, Russian Federation, Singapore, South Africa, Sri Lanka, Sudan, Syria, Turkmenistan, United Arab Emirates) (Table 21). In bilateral relations, comparative advantage (LFI) was proved over 32 non-EU countries (Azerbaijan, Bahrain, Cameroon, Canada, Egypt, Georgia, Ghana, China, Iceland, India, Israel, Kazakhstan, Kyrgyzstan, Lebanon, Malaysia, Mongolia, Myanmar, Saudi Arabia, Singapore, South Africa, Sri Lanka, Syria, Turkey, United Arab Emirates). In 2016, Poland's positive sugar trade balance was reported for 40 non-EU trading partners (Algeria, Armenia, Australia, Azerbaijan, Bahrain, Cameroon, Bunkers, Canada, Egypt, Georgia, Ghana, Kazakhstan, Kuwait, Kyrgyzstan, Lebanon, Libya, Malaysia, Mongolia, Myanmar, Norway, Oman, Pakistan, Qatar, Korea, Moldova, Russia, Saudi Arabia, Senegal, Singapore, South Africa, Sri Lanka, Syria, Turkmenistan, United Arab Emirates, USA). Generally, Poland was able to exhibit bilateral and well as absolute comparative advantages in relation to the third countries.

Conclusion

The analysis shows the following findings in relation to Polish sugar production and sugar markets. Polish market underwent significant restructuring that on one side resulted in significant reduction of amount of sugar refineries and sugar beet producers. On the other hand, it resulted in considerable concentration of production capacities among subjects that successfully passed the transformation phase. Total amount of farmers producing sugar beet decreased from about 112 thousand in 2000 to just 34 thousand in 2017. At the same time, the number of sugar refineries decreased from 76 to 18. Although this reduction seems to be very drastic, in reality, sugar sector was able to absorb successfully this change and finally the sector became much stronger. Between 2000 and 2017, total sugar beet production is almost unchanged at the level of 12 million tonnes. The decline in sugar beet harvested area was substituted by a significant increase in yields and by an increase in average sugar content. Average harvested area per one farm increased, but still, Polish producers belongs among the smallest in the whole EU. In comparison to German or French producers their average harvested area is less than half. Relatively small farms are getting additional national coupled support for sensitive sugar beet production. It equalled to about 380 EUR per hectare. In comparison to for example Czech Republic or Italy, this value was by more than 100 EUR higher.

Also, raw sugar production remained almost unchanged and during the period oscillated around the level of 2 million tonnes. On contrary, production of white sugar increased significantly from 1.54 in 2001 to almost 2.1 million tonnes in 2016. Reduction of sugar refineries was in this perspective compensated by the modernisation of those production facilities that were able to survive. Investments totalled about 1 billion EUR. At the same time, refineries increased their processing capacities. Between 2001 and 2016 length of sugar campaign increased from average 51 days to about 112 days. The average processing capacity of one sugar refinery grew by tens of percent and reached 6,351 tonnes a day (installed processing capacity of the smallest refinery is 3,500 and the capacity of the biggest refinery is 12,200 tonnes per day). The general stability of the Polish market has one forfeit – extreme concentration. Only four players (Krajowa Spolka Cukrowa S.A., Nordzucker Polska S.A., Pfeifer&Langen, Südzucker Polska S.A.) control all production capacities. The market is highly oligopolistic, dominated by three subjects: state-owned Krajowa Spolka Cukrowa, Südzucker and Pfeifer&Langen (both owned by German capital). Polish market is highly dominated by German influence, since companies controlled by German capital control approximately 56 percent of installed production capacities and produce more than 60 percent of white sugar.

The transformation process of Polish sugar industry did not significantly damaged sugar exports. Although volume of export significantly fluctuated, from the long-term perspective it oscillates around 0.5 million tonnes annually. Increasing unit price per kilogram of exported sugar is considered as a positive and important factor that pushed total value of exports to approximately 240 million EUR in 2017. Opposite to exports, volume of imports rose dynamically from 55 ths. tonnes in 2000 to more than 200 ths. tonnes in 2017. The total value of imports grew much slower than value of exports. Imports oscillates around 100 million EUR and makes sugar trade balance positive in the long-run. Polish sugar export is strongly oriented toward EU countries, while significant portion of imports originate in non-EU countries, in particular in countries with preferential access to EU markets under General System of Preferences. It is also important to mention that Poland has a considerable export potential and its exports are very competitive especially in comparison to other EU countries. However, more dynamic production development was disabled by system of production quotas (valid until 10/2017) that limited production of Polish sugar at the level of 1.4 million tonnes a year.

Results of the competitiveness analysis of sugar foreign trade concluded, that Polish sugar exports have a considerable potential. But extreme territorial concentration is seen as weak point. Top 10 countries participate on Polish exports and imports with sugar approximately by 72.56% and 92.94% respectively (2016). The main partners of Polish exports are Germany, Israel, Lithuania, Italy and Latvia, while main importers are Sudan, Zimbabwe, Mozambique, Germany and Lithuania. At present, significant restructuring in the Polish sugar industry can be observed because of changes in EU's sugar policy (abolition of sugar quotas). General changes in EU legislative environment raise a question, whether Poland will further strengthen its position on the European sugar market or whether the sugar market will suffer as a result of the restructuring of the sugar market, which is expected to be run by multinational actors in the European sugar market. Further possible export development might be oriented toward Asian markets, as Asian countries are the largest importers of Sugar (Svatoš et al., 2013), but China as one of the largest importer still maintains tariff quotas (Pawlak et al., 2016).

To conclude, what are the specifics of Polish sugar industry? Definitely Poland is third largest sugar producer in the whole EU, but to sustain its sugar market the whole industry needed to overcome difficult times after EU accession. Production of beet is secured by very small farms. Production of sugar is not only in hand of private companies, but large portion of production is still controlled by the state. Sugar-refineries not controlled by the state are controlled by only foreign capital (German). Limited number of surag producers creates a situation which leads toward monopolistic competition with significant concentration. Polish sugar export has considerable potential, but its limited export territorial concentration is seen as a weak point.

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Dynamic Effects of Public Investment Support in the Food and Beverage Industries

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Abstract

Impact evaluation of public investment is essential for policy makers to evaluate the effectiveness of public resource allocation and for company management from various industries to determine whether to participate in grant programmes. This article aims to use statistical and econometrical methods (such as propensity score matching, average treatment effect on treated, difference-in-difference approach and pooled regression with time lags) to evaluate the impacts of investment support from the Rural Development Programme, national sources and the Operational Programme Enterprise and Innovation on selected key economic indicators. This representative case study of 412 companies from the Czech food and beverage industry during the period from 2007-2015 noted some interesting findings, many of which go against previous findings. The food and beverage industry is an important beneficiary of public investment subsidies. Investment support increases investment activity and the size of supported companies. This investment support could lead to a crowding-out effect, which has been revealed in recent studies. Simultaneously, investment support changes the capital structure of participants towards higher use of bank loans and positively affects long-term profitability. However, there were not any significant, positive effects on the intensity of the use of fixed assets and labour productivity, which has been a key impact indicator for programme evaluations. However, research revealed positive dynamic effects of investment support on improving resource efficiency.

Keywords

Treatment effects, impact evaluation, lagged effects, food and beverage industry.

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Introduction

Many companies in various industries use investment subsidies from national and international public sources. In the European Union, there are structural funds and development programmes to increase the competitiveness of companies. Each country adds its own national sources to co-finance investment projects or provides full national investment support for enterprises that are not eligible for support from European funds.

There are many stakeholders interested in how such programmes work, including beneficiaries, governmental payment agency, ministry, banks, and the European Commission. Impact evaluation is particularly interesting for public money providers (such as the ministry and European Commission). Public investment support principles are closely linked to concepts of economy, efficiency and effectiveness. Each programme document contains a set of objectives that must be accomplished (effectiveness). Once the goals are attained, it is fundamental to see how they can be met with the least amount of effort (efficiency). Unlike efficiency, which examines the volume of resources and their utilization, economy looks more in terms of their costs. Impact evaluation of public investment support is in the spotlight of researchers and analysts working for the public sector.

Most published studies have been empirical studies regarding the impact evaluation of public investment support. Impact evaluation spans qualitative and quantitative methods, as well as ex ante and ex post methods. (Khandker et al., 2010) provided a good overview of econometric quantitative methods. Variants of impact evaluation include randomized evaluations (Duflo et al., 2008), the propensity score matching (PSM) approach (Caliendo and Kopeinig, 2008), double-difference (DID) methods (Abadie, 2005; Bertrand et al., 2004; Heckman et al., 1998), the use of instrumental variables (Angrist et al., 1996), regression discontinuity (Cerqua and Pellegrini, 2014; Decramer and Vanormelingen, 2016; Hahn et al., 2001; Lee and Lemieux, 2010; van der Klaauw, 2002) and pipeline comparisons (Ravallion, 2005). The main challenge across different types of quantitative evaluation methods is to find a good comparison point, such as a beneficiary's outcome in the absence of the intervention. However, some authors do not prefer matching before impact evaluation (Petrick and Zier, 2011). The (European Commission - Directorate-General for Agriculture and Rural Development, 2014) presented a broader set of quantitative and qualitative evaluation methods (Table 1).

A comprehensive discussion about the advantages and disadvantages of methods is beyond the scope of this article. This article is about the application of selected statistical and econometric methods to the food processing industry. Thus, an overview of econometric methods is presented in the introduction. The theoretical part of this article compares investigated indicators, methods, regions and results from relevant, recently-published articles. Table 2 summarizes key information, and results are discussed later. It is evident that there is not a consensus about methods and indicators. The choice of indicators depends on data availability and the purpose of evaluation.

There have been only a few published studies focused on the food industry, although it is an important beneficiary of European and national funds. In the Czech Republic, companies in the food and beverage industry received 8 billion CZK (i.e., more than 300 million EUR) from 2008-2015. Therefore, it is highly important to evaluate the effects of investment subsidies on key economic indicators.

The selection of key indicators depends on the purpose of the grant programmes. There were three main development programmes for food and beverage industries in the Czech Republic during the previous programming period. First, the Rural Development Programme (RDP) provided investment subsidies for small and medium enterprises within the following two sub-measures: I.1.3.1 Adding value to agricultural and food products, and I.1.3.2 Cooperation for development of new products, processes and technologies (or innovations) in food industry. The measures were granted for tangible and intangible investments concerning processing, marketing and/or development of new products, processes and technologies linked to products, covered by Annex I of the EC Treaty (except for fishery products), and respecting the EC standards applicable to the investment concerned (MoA, 2008). The investments should improve the overall performance of the small and medium enterprises and increase competitiveness

Method	Input	Output	Examples of methods
Qualitative methods	Mainly text (spoken or written) and/or theory	Substance of text analysed, effects, impacts (ordinal)	Intervention logic, interviews, MAPP, Delphi method
Theory-based evaluation	Programme theory or any other social/ economic theory	Estimate on effectiveness of the intervention logic	Realist Evaluation Theory-based evaluation
Econometric methods	Economic theory and data at unit level	Estimates of (net) effects (cardinal), hypothesis tests	PSM, regression analysis, DiD
Experimental methods	Designed experiment observations	Estimates of (net) effects (cardinal) hypothesis tests	RCT: Phase in design, pilot project design, encouragement design
Computational economic models	Economic theory and parameters	Estimates of impacts (cardinal)	Regional and national input-output, general and partial equilibrium models, farm models, CBA, CEA
Environmental approaches	Scientific theory, figures on unit level, coefficient or parameter	Effects, impacts, text on environment	LCA, integrated modelling approaches, SEA
Combinations of approaches	All of the above	All of the above	GRIT, theory of driving forces, pressures, states, impacts, responses

Note: CBA = Cost-benefit analysis, CEA = Cost-effectiveness analysis, LCA = Life-cycle analyses, GRIT = Generation of Regional Input-Output Tables, MAPP = Method for Impact Assessment of Programmes and Projects, RCT = Randomized controlled trial, SEA = Strategic Environmental Assessment
Source: (European Commission - Directorate-General for Agriculture and Rural Development, 2014)

Table 1: Overview of evaluation approaches.

Methods	Source	Region (Time)	Industry	Key Indicators
General method of moments (GMM) by (Arellano and Bond, 1998)	Harris and Trainor (2005)	Northern Ireland (1983–1997)	Manufacturing	Total factor productivity (TFP)
Propensity score matching (PSM) DID estimator (DID)	Bernini and Pellegrini (2011)	Southern Italy (1996–2004)	Manufacturing	Output Employees Fixed assets Gross Margin/Output Profitability (ROI, ROE) Fin. charges/output Output/employees Fin. charges/debt Value added
No matching "Naïve" regression model using pooled data (panel data regression) Static and dynamic (lagged) version of DID	Petrick and Zier (2011)	Eastern Germany (1999-2006)	Agriculture, forestry, fishery	Number of employees Regional population density Average yearly wages per employee
Generalized propensity score (GPS)	Bia and Mattei (2012)	Northern Italy (2000–2003)	Manufacturing	Employment
Average treatment on treated (ATT) and DID Modified conditional DID estimator (PSM-DID)	Michalek (2012)	Slovakia (2002-2005) Germany (2000-2006)	Agriculture	Profit / corrected / extended profit per farm, per family labour, per fully employed person Addition to economic assets Milk production per farm Labour productivity Transfers from farm to household for living, for building of private assets, total Farm total employment
Average treatment effect on treated (ATT) and DID (Abadie and Imbens, 2006) Nearest neighbour matching	Ratinger et al. (2013)	Czech Republic (2007-2010)	Agriculture	Total sample: Gross value added (GVA) Productivity (GVA/Labour cost)Profit Bank indebtedness Investment in fixed assets
The PSM estimator of net effects (Smith and Todd, 2005) Average treatment effect on treated (ATT) Conditional difference in differences (CDID) method	Bartova and Hornakova (2016)	Slovakia (2007-2013)	Agriculture	Total factor productivity (TFP) Gross value added (GVA) Profit Assets Utilized Agricultural Area (UAA) GVA/UAA, GVA/AWU Profit/UAA, Profit/AWU Assets/UAA, Assets/AWU
Direct covariate matching (Ho et al., 2007) Propensity score matching (Rosenbaum and Rubin, 1985) Greedy pair matching without replacement (no matches outside calipers) Average treatment effect on treated (ATT) and DID (Heckman et al., 1998)	Kirchweger et al. (2015)	Austria (2003-2010)	Agriculture	Total livestock units (LU) Stocking density (LU/ha) Total output Farm income Share of net worth on total assets (%)
Regression discontinuity design (RDD) by (Lee and Lemieux, 2010)	Decramer and Vanormelingen (2016)	Belgium (2001-2012)	Multiple sectors (12)	Fixed assets Sales Value added Employment
No matching Fixed-effect model (panel data regression)	Naglova et al. (2016); Spicka et al. (2017)	Czech Republic (2008–2013)	Dairy industry Meat processing industry	Labour productivity Profitability (ROA) Capital structure (Credit Debt Ratio) Production consumption Sales

Source: own processing

Table 2: Different econometric approaches that impact evaluation of public investment support.

of the agri-food industry. The key economic indicator for impact evaluation was labour productivity (gross value added per worker). In the RDP, sub-measure I.1.3.2 Cooperation for development of new products, processes and technologies (or innovations) in the food industry was also available to large companies. Second, the national support programme of the Ministry of Agriculture No. 13 was complementary to RDP, and it was available to large companies but was not aimed at cooperation projects supported by the RDP (I.1.3.2). Finally, companies making products not covered by Annex I to the EC Treaty were supported by the Ministry of Industry and Trade under the Operational Programme Enterprise and Innovation (MoIT, 2007). Value added was a key performance indicator.

Following the literature review and impact indicators of development and operational programmes, we identified key economic variables that could be affected by investment support. The aim of this article is to ex-post evaluate effects of investment support on the fixed assets, capital structure, labour productivity, profitability and direct cost efficiency of Czech companies producing food and beverages from 2007-2015. Although the impact evaluation that is presented is a case study of the Czech Republic, the methodical framework could be used by other evaluators in different industries and countries.

Labour productivity is an important indicator focused on by the European Commission (European Commission - Directorate-General for Agriculture and Rural Development, 2016), since it is the key economic indicator of a company's productivity (Rezbova and Skubna, 2013). Investment support should increase labour productivity because of the investment in more modern and efficient technology. Moreover, investment support should also focus on creating new jobs and improving the quality of life. However, output should increase more than labour costs (Decramer and Vanormelingen, 2016). The hypothesis is that there is a positive dynamic effect of investment support on labour productivity. Otherwise, the strategic goals of development and operating programmes will not be accomplished. Lagged effects are possible since investments are gradually introduced after completion.

As a consequence of higher investment activity, supported companies should increase fixed assets more dynamically than nonparticipants (Medonos et al., 2012). This hypothesis could be supported by the fact that most investment subsidies should be aimed at improving the value of capital for supported companies. Simultaneously, fixed assets should be used more efficiently, as measured by Fixed Assets Turnover[1].

The capital structure of supported companies should change as companies use bank loans for financial modernization. If we assume that supported companies have higher investment activity than non-supported companies, there should be significant differences in the credit debt ratio[2] for participants and nonparticipants (Ratinger et al., 2013). Nevertheless, measuring this dynamic effect could be problematic since taking a bank loan precedes receiving support.

Profitability is an essential indicator of a company's financial performance. There should be a positive effect of investment support on a company's profitability since profitability has been a strategic interest of shareholders (Naglova et al., 2016). Long-term profitability[3] is a better measure than current profitability, since long-term profitability takes account of retained earnings and is one of the selection criteria for the Czech RDP (MoA, 2008).

Finally, direct cost efficiency[4] measures a company's operating efficiency. Investment support aims increasing output and decreasing average costs (e.g. energy-saving technologies, lower material losses). There should be positive effects for investment support on direct cost efficiency (European Commission - Directorate-General for Agriculture and Rural Development, 2016).

Materials and methods

This research is based on the individual data from companies that received investment support from the Ministry of Agriculture and Ministry of Industry and Trade of the Czech Republic in the previous programming period (from 2007 to 2015 when the last applications were completed). The database of supported companies was connected to the financial statement database MagnusWeb, which contains individual data on assets, liabilities, revenues and costs for the companies listed in the Czech Business Register.

[1] Fixed Assets Turnover (x) = Sales / Fixed Assets

[2] Credit Debt Ratio (%) = (Bank Loans / Total Assets) x 100

[3] Long-term Profitability (%) = (Retained Profit + Current Profit) / Total Assets x 100

[4] Direct Cost Efficiency = Cost of Material, Energy and Services / Sales

Ex post impact evaluation of public investment support often follows a DID framework. Compared with PSM, DID assumes that unobserved heterogeneity in participation is present but such factors are time invariant. The literature recommends combining the PSM and DID to resolve the problem of selection bias by matching units (Khandker et al., 2010). It is necessary to process the PSM followed by the DID estimate. This approach is called conditional DID and it has been used for impact evaluation (Bartova and Hornakova, 2016; Bergemann et al., 2009; Gilligan and Hoddinott, 2007; Kirchweger and Kantelhardt, 2015; Pufahl and Weiss, 2009).

Propensity score matching is the most common matching technique used in the evaluation of grant programmes. PSM constructs a statistical comparison group that is based on a model of the probability of treatment participation by using observed characteristics. Participants are then matched on the basis of this probability, called a propensity score, to nonparticipants (Khandker et al., 2010). There are two assumptions for PSM validity as follows: i) conditional independence (namely, that unobserved factors do not affect participation), and ii) sizable, common support or overlap in propensity scores across the participant and nonparticipant samples. In this article, the PSM process follows four main steps (European Commission - Directorate-General for Agriculture and Rural Development, 2014; Khandker et al., 2010).

1. Build a dataset that includes participants and nonparticipants from the time periods prior to and following investment support. This dataset is characterized in a separate chapter. Ideally, the sample should respect the population structure. The sample size was calculated through the same method as (Krejcie and Morgan, 1970).

$$s = \frac{X^2 NP(1-P)}{d^2(N-1)} + X^2 P(1-P), \quad (1)$$

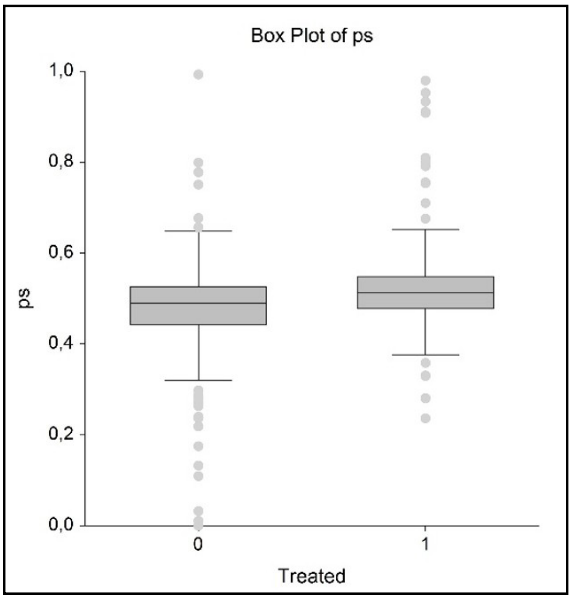
where s denotes the required sample size, X^2 indicates the Chi-squared table value for 1 degree of freedom at the desired confidence level (3.841), P represents the population proportion (assumed to be 0.5 since this would provide the maximum sample size) and d denotes the statistical significance expressed as a proportion (0.05).

There were 6 560 Czech companies producing food and beverages (NACE 10 and 11) at the beginning of the programming period in 2007. Equation (1) resulted in a required sample size of 363 companies. We gathered 620 randomly selected companies, which is higher than expected. A Chi-squared test was performed to guarantee that the actual set of companies does not significantly differ from the structure of NACE 10 and 11 (4-digit codes).

2. Select performance and structural variables (covariates) to find similar groups of participants and nonparticipants. Generally, covariates entering the logit function are expected to determine both programme participation and outcomes. The selection of covariates was processed through principal component analysis (PCA).

The PCA identified 13 variables, representing 80.69 % of the variability of the original 63 variables. However, in the logit regression, we did not directly use the factors, but we used the indicators that had a high correlation with the factors, since they were most suitable for analysis. Annex table A1 shows the set of selected indicators and the factors' focus. It is obvious that factors cover the most important structural and economic features of companies.

3. Calculate propensity scores for each individual unit based on the likely determinants of a company's participation in the modernization programme. The logit model estimates participation probabilities for companies that received an investment subsidy ("participants", T = 1) and those without any investment support in the reference period ("nonparticipants", T = 0). In this case, causality is not as interesting as the correlation of covariates with T. There are three significant determinants of a company's participation, including the amount of bank loans, liquidity (Acid Test Ratio) and capital structure (Debt Ratio), which were used as covariates for propensity score matching. Other variables did not significantly determine participation in the modernization programme. The distribution of estimated propensity scores is illustrated in Figure 1, where a good overlap is evident. Annex table A2 provides the results of logit analysis.



Source: own calculation

Figure 1. Distribution of propensity scores of participation (logit model).

4. Matching algorithms are used to match participants to nonparticipants. Approaches used for matching include nearest-neighbour matching, caliper and radius matching, stratification and interval matching, and kernel and local linear matching. Nearest-neighbour matching was selected since it has been the most commonly used matching framework in empirical studies of the agri-food sector. The nearest-neighbour was matched to the estimated propensity score *p(X)* as an aggregate measurement. Probability *p(X)* was estimated on the fitted values with a parametric logit model, using the observed treatment assignment (yes/no) as the explained and *X* as the explanatory variables. When performing an impact evaluation on a group of companies with different branches, it was necessary to acknowledge that participants and nonparticipants have similar branch structures classified by NACE (4-digit) codes since the food and beverage industry has very high heterogeneity.

Two distinct matching procedures can be applied – optimal data matching (ODM) and greedy data matching (GDM). The linear greedy data matching algorithm was applied in the article, such as in previous studies of the agri-food sector by other authors (Bozik, 2011; Kirchweger et al., 2015). There are several ways to measure distance. The best distance measure depends on the number of covariate variables, the variability within the covariate variables, and other factors. Based on empirical studies that compared various distance metrics (Gu and Rosenbaum, 1993; Rosenbaum, 1989; Rosenbaum and Rubin, 1985), authors decided to use the Mahalanobis Distance within Propensity Score Calipers (no matches outside calipers) as this paper's distance calculation method since it is best when there are fewer covariates (3) to match.

The performance of distance metrics involving calipers is somewhat dependent on the caliper radius used. The level of caliper radius depends on how much tight or loose matching is preferred. The caliper radius is calculated using sample variances of the treatment and control groups. Because of the limited available data, "loose matching" with 1σ was applied. The Mahalanobis distance within propensity score calipers (no matches outside calipers) can be formulated as

$$d(i,j) = \begin{cases} (\mathbf{u}_i - \mathbf{u}_j)^T C^{-1} (\mathbf{u}_i - \mathbf{u}_j) \Big| if \left| q(\mathbf{x}_i) - q(\mathbf{x}_j) \right| \le c \text{ and } FM_{i,l} = FM_{j,l} \text{ for all } l \\ \infty \quad \text{otherwise} \end{cases}, \qquad (2)$$

where *i* refers to the i^{th} treatment subject, *j* refers to the j^{th} control subject, *d(i,j)* is the estimated distance between subjects *i* and *j*, **x** is the vector of observed covariates used to estimate the propensity score, and $q(\mathbf{x})$ is the propensity score based on the covariates **x**. Vector $\mathbf{u} = (\mathbf{y}, q(\mathbf{x}))$ is the vector of observed covariates **y** and the propensity score, C is the sample covariance matrix of the matching variables (including the propensity score) from the full set of control subjects, and c is the caliper radius. $FM_{i,l} = FM_{j,l}$ are the values of the l^{th} forced match variable for subjects *i* and *j*, respectively. If no forced match variables are specified, then $FM_{i,l} = FM_{j,l}$ for all *l*. However, we used one forced match variable 4-digit NACE code to have the same branch structure in groups of participants and nonparticipants. The number of matches per treatment was 1 (i.e., 1:1 matching), as there were not enough nonparticipants for 1:N matching.

Finally, we selected the matching order to be sorted by distance. This option caused the programme to sort the matrix of all pair-wise treatment-control distances. It then assigned matches in ascending order starting with the smallest distance until all treatments have been matched with the specified number of controls. Annex table A3 shows the results of matching.

The final sample includes 206 participants and 206 nonparticipants from the same branch of the food and beverages industry. Some participants (23.99 %) and nonparticipants (40.97 %) were not matched because of the specified forced match variable's 4-digit NACE and caliper radius.

5. Calculate average treatment effects. The European Commission (European Commission - Directorate-General for Agriculture and Rural Development, 2016) recommends using the average treatment effects on treated (ATT) for evaluating the effects of investment support. ATT is defined as

$$\tau ATT = E[\tau \mid D = 1] = E[Y(1) \mid D = 1] - E[Y(0)|D = 1] \quad (3)$$

where τ = Y(1) - Y(0). Y(D) is a result variable where D equals 1 if the unit received investment support (participant) and 0 otherwise (nonparticipant).The theoretical principle of ATT can be described through the Roy-Rubin-model (Caliendo and Kopeinig, 2008). A positive (negative) ATT indicates a better (worse) development of outcome variables for treated companies when compared to control companies.

We calculated the difference-in-difference effects (DID) of indicators from 2007–2015. We estimated DID cumulatively in each year between participants and nonparticipants. The starting point was 2007 at the beginning of the programming period. Then, differences between 2007 and subsequent years were tested.

To measure the dynamic effects of investment subsidies, robust linear dynamic panel-data estimation was applied based on OLS (Allison, 2009; Wooldridge, 2016). The evaluation of the model included a Wald test of simple and composite linear hypotheses about the parameters of the fit model (Greene, 2012). Since the panel data have both a time-series and cross-sectional dimension, we used robust estimation assuming there are heteroscedastic and autocorrelated errors. The fixed-effects were estimated as a panel regression between the economic indicator (y) and investment subsidies (x).

$$y_{it} = \alpha + x_{it}\beta + v_i + \epsilon_{it} \qquad i = 1, \dots, N; t = 1, \dots, T, \quad (4)$$

where y_{it} is an observation of a dependent variable (labour productivity[5], fixed assets, fixed assets turnover[6], credit debt ratio[7], long-term profitability[8], direct cost efficiency[9]) for i-th unit in time t. α is a scalar common to all entities. x_{it} is it-th row of NT × K matrix X, which contains the observed values of K. It denotes whether the company was supported (0 if company was not supported, 1 if company received support). Therefore, the model with binary regressors estimates the average impact of the investment subsidy on the selected economic indicator. v_i is the unit-specific error term. It differs between units, but for any particular unit its value is constant. ϵ_{it} is the "usual" error term with the typical properties (mean 0, uncorrelated with itself, uncorrelated with x, uncorrelated with v, and homoskedastic), although with more research we could decompose $\epsilon_{it} = u_t + \omega_{it}$, assume that ω_{it} is a conventional error term, and better describe u_t.

We tested one-year and two-year[10] lags of independent variables, since we aimed to reveal some effects of an investment subsidy one year after project was finished and launched. The dynamic panel-data estimation was applied in the sample of 412 companies (206 participants and 206 nonparticipants) to respect matching results and the counterfactual approach. Linear panel-data estimation and diagnostic tests were processed by the STATA software package.

Results and discussion

Heterogeneity among firms and sectors is an important feature of the Czech food processing industry (Rudinskaya, 2017). Drawing investment subsidies from the RDP is the domain of small and medium enterprises. In the sample of 206 participants, 215 projects were supported from the RDP, 124 projects from national subsidy programme and 137 projects from the Operation Programme of the Ministry of Industry and Trade from 2008-2015. Table 3 shows that this sample amply represents the total number of supported projects.

Before we start to describe the results of evaluation, it would be interesting to look at the significance of investment support on the supported companies. Figure 2 presents the share of investment support

[5] Labour Productivity = Value Added / Total Personnel Expenses

[6] Fixed Assets Turnover (x) = Sales / Fixed Assets

[7] Credit Debt Ratio (%) = (Bank Loans / Total Assets) x 100

[8] Long-term Profitability (%) = (Retained Profit + Current Profit)/ Total Assets x 100

[9] Direct Cost Efficiency = Cost of Material, Energy and Services / Sales

[10] Two-year lag was processed when we supposed delayed effect as a consequence of running up the investment (fixed assets turnover, long-term profitability, labour productivity, direct cost efficiency).

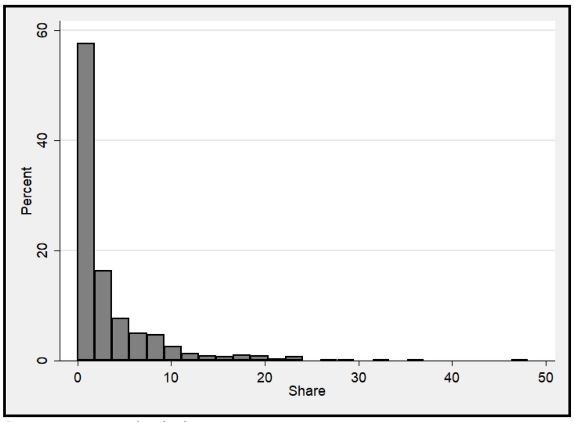
Size	RDP	National subsidy from Ministry of Agriculture	Ministry of Industry and Trade
Small	86 (265 913 942)	0	41 (114 543 000)
Medium	113 (493 782 253)	0	96 (554 470 600)
Large	16 (109 794 481)	124 (393 116 401)	0
Total sample	215 (869 490 676)	124 (393 116 401)	137 (744 765 600)
% of population	18.84 (21.72)	40.52 (30.35)	32.08 (27.13)

Note: number of projects (investment subsidy in CZK)
Source: own calculation

Table 3: Distribution of participants in the sample (2008-2015).

in total assets of the supported companies (in the year of receiving the subsidy).

We found that 80 % of projects had less than a 5 % share of investment subsidies in the total assets. However, the project might be relatively large if we consider that approximately 10 % is the depreciation rate under the assumption of a 10-year average economic life of the projects.



Source: own calculation

Figure 2. Share of investment subsidies in total assets of participants.

Average treatment effect, DID and lagged effects

Change in the fixed assets was evaluated as first (Table 4).

It is evident that ATT was increasing as average fixed assets of participants increased from 72.65 m CZK to 113.25 m CZK from 2007-15. Simultaneously, average fixed assets of nonparticipants were relatively stagnant. ATT became statistically significant in 2012 at a 0.05 significance level. This finding is in compliance with other authors (Decramer and Vanormelingen, 2016; Kirchweger and Kantelhardt, 2015). While participants invested in upgrading and expanding production capacities (Spicka et al., 2016), the non-participants invested enough to cover the depreciation of fixed assets.

The DID showed clearly positive cumulative effects of investment support on fixed assets when compared to the base year 2007. However, linear panel-data estimation showed significant effects without any lags, but there were not any significant lagged effects. This can be explained by the fact that companies book new fixed assets just after they complete projects. Investment subsidies increased the value of fixed assets by an average of 10.51 million CZK (p-value = 0.034). Overall, it can be concluded that investment support positively affects investment in fixed assets. Alternatively, nonparticipants could be crowded out because they did not expand. A recent study showed that the crowding-out effect of the RDP is close to 100 %, implying that firms use public support to substitute for private investments (Ciaian et al., 2015).

Fixed assets turnover measures whether there were any positive effects of investment subsidy on fixed assets efficiency (Table 5) to improve competitiveness and profitability.

Lower participants' turnover of fixed assets since 2010 could be caused by an increase in their profit margins after support when companies started to produce food and beverages with a higher value added. There were not any significant difference-in-difference (DID) effects when compared to 2007. However, linear panel-data regression revealed a significant effect without any lags. Coefficients show that investment support decreased fixed asset turnover by an average of 5.322. This is quite logical since investors increased fixed assets, but investment increased without a corresponding increase in sales. After one year of operation, a negative (but not significant) effect on fixed assets turnover continued. When considering a two-year lag, there is a positive but not significant effect of investment support on fixed assets turnover. Thus, an increase in fixed assets turnover is delayed when compared to an increase in fixed assets. However, the positive effect was not significant. It is an important finding for policy makers and management that investment support both increases the value of fixed assets and improves efficiency, but not before two years after launching the finished project on average. Unfortunately, other

Year	Participants	Control	ATT	SE	t	p-value
2007	72 653	59 137	13 516	17 964	0.7524	0.4522
2008	78 699	59 503	19 196	18 258	1.0514	0.2937
2009	84 898	59 080	25 818	19 900	1.2974	0.1952
2010	90 869	58 314	32 555	20 009	1.6270	0.1045
2011	95 041	58 110	36 931	20 239	1.8248	0.0688
2012	100 174	58 899	41 274	20 796	1.9847	0.0478
2013	103 236	59 405	43 831	20 858	2.1014	0.0362
2014	106 187	60 096	46 091	20 712	2.2253	0.0266
2015	113 250	59 996	53 254	21 365	2.4925	0.0131
DID	Participants	Control	ATT	SE	t	p-value
2008-07	6 046	366	5 680	1 861	3.0524	0.0024
2009-07	12 245	-57	12 302	4 550	2.7036	0.0071
2010-07	18 216	-823	19 039	5 588	3.4073	0.0007
2011-07	22 387	-1 027	23 414	6 196	3.7790	0.0002
2012-07	27 520	-238	27 758	7 304	3.8005	0.0002
2013-07	30 582	268	30 315	8 208	3.6934	0.0003
2014-07	33 533	959	32 574	9 651	3.3754	0.0008
2015-07	40 597	860	39 737	11 538	3.4442	0.0006
OLS	Coef.	Robust SE	t	p-value	95% Conf. Interval	
Const.	75 209.7	620.5	121.21	0.000	73 989.9	76 429.5
Lag0	10 508.8	4 937.4	2.13	0.034	803.1	20 214.6
Const.	77 886.4	392.8	198.28	0.000	77 114.3	78 658.6
Lag1	-235.2	3 471.0	-0.07	0.946	-7 058.4	6 587.9
Wald test	F	p-value	corr(ui, Xb)	sigma_u	sigma_e	rho
Lag0	4.53	0.034	0.099	198 836.5	46 994.6	0.947
Lag1	0.00	0.946	-0.116	202 354.0	44 675.5	0.954

Source: own calculation

Table 4: ATT, DID and OLS of fixed assets (´000 CZK).

Year	Participants	Control	ATT	SE	t	p-value
2007	17.584	18.066	-0.482	5.172	-0.0933	0.9257
2008	13.295	16.553	-3.258	3.947	-0.8255	0.4096
2009	21.920	14.787	7.133	13.852	0.5149	0.6069
2010	7.803	15.213	-7.410	2.766	-2.6786	0.0077
2011	8.967	14.997	-6.030	3.064	-1.9679	0.0498
2012	8.932	14.593	-5.661	2.939	-1.9260	0.0548
2013	8.562	14.363	-5.800	3.067	-1.8915	0.0593
2014	7.604	13.146	-5.542	2.358	-2.3505	0.0192
2015	9.184	13.454	-4.270	3.181	-1.3424	0.1802
DID	Participants	Control	ATT	SE	t	p-value
2008-07	-4.204	-1.425	-2.778	4.161	-0.6678	0.5047
2009-07	4.422	-3.191	7.613	13.384	0.5688	0.5698
2010-07	-9.695	-2.765	-6.930	5.134	-1.3498	0.1778
2011-07	-8.531	-3.054	-5.477	5.025	-1.0899	0.2764
2012-07	-8.566	-3.456	-5.110	4.838	-1.0561	0.2916
2013-07	-8.936	-3.616	-5.320	5.304	-1.0032	0.3164
2014-07	-9.895	-4.833	-5.062	5.220	-0.9698	0.3327
2015-07	-8.314	-4.524	-3.790	5.630	-0.6733	0.5012

Source: own calculation

Table 5: ATT, DID and OLS of fixed assets turnover (x) (to be continued).

OLS	Coef.	Robust SE	t	p-value	95% Conf. Interval	
Const.	13.945	0.225	61.910	0.000	13.502	14.388
Lag0	-5.322	1.790	-2.970	0.003	-8.841	-1.803
Const.	12.810	0.063	203.800	0.000	12.687	12.934
Lag1	-0.891	0.555	-1.600	0.109	-1.982	0.201
Const.	12.297	0.200	61.410	0.000	11.903	12.691
Lag2	0.846	1.765	0.480	0.632	-2.623	4.316
Wald test	F	p-value	corr(ui, Xb)	sigma_u	sigma_e	rho
Lag0	8.840	0.003	0.030	29.803	51.641	0.250
Lag1	2.570	0.109	0.058	30.013	52.644	0.245
Lag2	0.230	0.632	-0.061	30.331	55.642	0.229

Source: own calculation

Table 5: ATT, DID and OLS of fixed assets turnover (x) (continuation).

authors have not yet used fixed assets turnover. However, we found that fixed assets turnover is an important indicator for the impact evaluation of investment support.

Credit debt ratio measures whether there are any differences in the use of bank loans for investment activity between participants and nonparticipants (table 6).

Participants had higher credit debt ratios from 2007–2015. Differences between participants and the control group were statistically significant at the 0.05 significance level since 2009. This indicates that participants used more bank loans for co-financing investment projects. However, there were not any difference-in-difference effects. Companies in the control group slightly decreased their credit debt ratio, while indicators in the participant group fluctuated. A higher credit debt ratio for participants corresponds to findings of other authors (Ratinger et al., 2013) but DID effects go against them. However, linear panel-data analysis established a significant impact for investment support on changing credit debt ratios. This finding indicates that supported companies used bank loans for co-financing fixed asset increases. However, recent empirical research showed a negative impact for long- and short-term debt on the technical efficiency of the Czech food processing industry (Rudinskaya, 2017). Investment support increased credit debt ratio by 2.554 p.p. in the year of support. Measuring dynamic effects could be slightly biased for large projects when taking a bank loan precedes getting support by one or more years. Usually, companies take bank loans before starting their investment projects. After the project is completed, companies get the investment subsidy. Nevertheless, there is no bias in the case of smaller projects (which prevail) when getting support often quickly follows taking a bank loan.

Table 7 presents the effects of investment support on long-term profitability including linear panel-data estimates.

Long-term profitability follows both current and retained earnings. It is one of the key selection criteria for the evaluation of applicants when projects are submitted in the Czech Republic. Therefore, it is evident that participants had higher long-term profitability for 2007–2015, and that it was significantly different at the 0.05 level in most years. However, positive DID effects of investment support on long-term profitability were not significant for the whole period. There were two years (2009 and 2010) with significant dynamic effects at the 0.05 significance level when long-term profitability of participants sharply increased, unlike the control group where the indicator dropped against 2007. There was the deep economic crisis in 2009 and 2010. The long-term profitability of the nonparticipant group decreased, while the profitability of participants increased. However, participants reinvested earnings and thus increased retained earnings. There were also positive significant effects of investment support on long-term profitability at the 0.1 level for the years 2012, 2014, and 2015 when compared to 2007.

Concerning dynamic effects, there were not any significant effects for investment support on long-term profitability at the 0.05 significance level. However, there were significant positive effects at the 0.1 significance level in the year of support (b = 1.690, p-value = 0.084) and two years after support (b = 1.540, p-value = 0.053). The p-value of effects two years after support is very close to 0.05. Other authors did not use long-term profitability but instead used current profitability

Year	Participants	Control	ATT	SE	t	p-value
2007	14.580	12.531	2.049	1.615	1.2686	0.2053
2008	15.577	13.194	2.383	1.621	1.4704	0.1422
2009	14.570	11.341	3.228	1.490	2.1673	0.0308
2010	13.867	10.599	3.268	1.430	2.2858	0.0228
2011	14.686	10.830	3.856	1.420	2.7149	0.0069
2012	14.900	10.313	4.587	1.400	3.2761	0.0011
2013	13.847	10.212	3.635	1.343	2.7062	0.0071
2014	14.029	9.875	4.153	1.382	3.0059	0.0028
2015	14.817	10.059	4.758	1.424	3.3416	0.0009
DID	Participants	Control	ATT	SE	t	p-value
2008-07	0.997	0.663	0.334	0.928	0.3597	0.7193
2009-07	-0.010	-1.190	1.179	1.090	1.0824	0.2797
2010-07	-0.713	-1.932	1.219	1.180	1.0335	0.3020
2011-07	0.106	-1.701	1.807	1.305	1.3847	0.1669
2012-07	0.320	-2.218	2.538	1.369	1.8537	0.0645
2013-07	-0.733	-2.319	1.586	1.357	1.1687	0.2432
2014-07	-0.551	-2.655	2.104	1.483	1.4191	0.1566
2015-07	0.237	-2.472	2.709	1.479	1.8317	0.0677
OLS	Coef.	Robust SE	t	p-value	95% Conf. Interval	
Const.	12.447	0.073	169.960	0.000	12.303	12.591
Lag0	2.554	0.583	4.380	0.000	1.409	3.700
Const.	12.542	0.058	217.850	0.000	12.428	12.655
Lag1	1.131	0.509	2.220	0.027	0.131	2.131
Wald test	F	p-value	corr(ui, Xb)	sigma_u	sigma_e	rho
Lag0	19.210	0.000	0.035	12.787	8.090	0.714
Lag1	4.950	0.027	0.041	12.812	7.760	0.732

Source: own calculation

Table 6: ATT, DID and OLS of credit debt ratio (%).

Year	Participants	Control	ATT	SE	t	p-value
2007	18.799	15.272	3.528	3.545	0.9950	0.3203
2008	19.884	14.341	5.544	3.854	1.4383	0.1511
2009	22.643	13.203	9.440	4.530	2.0837	0.0378
2010	23.141	13.963	9.178	4.550	2.0172	0.0443
2011	22.702	14.075	8.628	5.079	1.6985	0.0902
2012	22.492	10.606	11.886	5.699	2.0856	0.0376
2013	23.125	11.142	11.983	6.179	1.9393	0.0532
2014	25.637	10.008	15.629	7.454	2.0967	0.0366
2015	26.610	11.933	14.677	7.242	2.0267	0.0433
DID	Participants	Control	ATT	SE	t	p-value
2008-07	1.085	-0.931	2.016	1.452	1.3878	0.1659
2009-07	3.843	-2.068	5.912	2.317	2.5512	0.0111
2010-07	4.342	-1.308	5.650	2.687	2.1023	0.0361
2011-07	3.903	-1.197	5.100	3.706	1.3759	0.1696
2012-07	3.693	-4.665	8.358	4.507	1.8545	0.0644
2013-07	4.326	-4.129	8.455	5.180	1.6324	0.1034
2014-07	6.838	-5.264	12.101	6.653	1.8189	0.0697
2015-07	7.811	-3.339	11.150	6.523	1.7091	0.0882

Source: own calculation

Table 7: ATT, DID and OLS of long-term profitability (%) (to be continued).

OLS	Coef.	Robust SE	t	p-value	95% Conf. Interval	
Const.	17.542	0.123	142.860	0.000	17.301	17.783
Lag0	1.690	0.977	1.730	0.084	-0.231	3.611
Const.	17.734	0.101	174.860	0.000	17.535	17.934
Lag1	0.972	0.896	1.080	0.279	-0.790	2.734
Const.	17.774	0.090	197.750	0.000	17.597	17.951
Lag2	1.540	0.793	1.940	0.053	-0.018	3.099
Wald test	F	p-value	corr(ui, Xb)	sigma_u	sigma_e	rho
Lag0	2.990	0.085	0.075	49.328	28.228	0.753
Lag1	1.180	0.279	0.074	52.354	26.925	0.791
Lag2	3.780	0.053	0.074	55.699	24.979	0.833

Source: own calculation

Table 7: ATT, DID and OLS of long-term profitability (%) (continuation).

in the form of ROA, ROE or ROI. They revealed significant positive effects of investment support on profitability (Bernini and Pellegrini, 2011; Spicka et al., 2017).

Table 8 describes the development of labour productivity as measured by value added to labour cost.

From 2007–15, there were not any significant differences for average labour costs between participants and the control group in absolute values or in difference-in-difference approach. Thus, there is no effect of investment subsidies on labour productivity, which is a strategic goal of development programmes aimed at innovation and the modernization of manufacturing facilities. When considering time lag, there were not any significant lagged effects of investment support on labour productivity. This is a particularly important finding for policy makers. Despite the finding that innovator's size and employment grow faster than the companies with a low innovation, which is in line with previous findings (Freel, 2000), there was not any significant change in labour productivity for the treated companies. Our finding is in contrast with previous findings from the agricultural sector (Ratinger et al., 2013), but it supports findings from the meat processing industry (Spicka et al., 2017). Decramer and Vanormelingen (2016) found that the effect of the subsidies on the growth of the receiving firms was rather limited. Only for the very small firms was there a positive effect on investment, employment, sales, value added and productivity. For larger firms, they did not find any effect. In our sample, there were not any very small firms. Therefore, our results confirm previous findings.

On the one hand, modernization and innovation should improve labour productivity due to the implementation of more efficient technologies (Harrison et al., 2014). In the Czech Republic, empirical research indicated labour-saving for the capital- and material-intensive behaviours of the food processing companies (Rudinskaya, 2017). It is particularly important since there has been a lack of blue-collar workers in Central European countries (Svejnar, 1995). However, there is pressure on keeping employment in the countryside, which is a strategic focus of the Rural Development Programme. No significant effects of investment support on labour productivity in the Czech Food industry could be caused by poor selection criteria of project applications from 2007–2013. Evaluation put little stress on the efficiency and productivity of investment projects. In the new programming period since 2014, a new evaluation system has been implemented that is based on cost-effectiveness analysis and financial planning.

Direct cost efficiency is another key indicator for impact assessment. It describes the relationship between sales of products and intermediate consumption (cost of material, energy, services). Table 9 provides information regarding ATT, DID and lagged effects. A lower indicator denotes improved direct cost efficiency.

Participating companies had improved average direct cost efficiency more than nonparticipants from 2007–2015. However, there was a significant difference for only a few years. This indicates that participants were more efficient concerning relationships between direct cost and sales than nonparticipants. A pooled regression revealed positive effects for investment support on direct cost efficiency in the year of subsidy and one year after launching the investment project. Nevertheless, the effects are significant only at $\alpha = 0.1$.

Year	Participants	Control	ATT	SE	t	p-value
2007	1.732	1.583	0.149	0.170	0.8767	0.3811
2008	1.568	1.401	0.166	0.123	1.3549	0.1762
2009	1.678	1.542	0.137	0.128	1.0683	0.2860
2010	1.461	1.563	-0.103	0.213	-0.4829	0.6295
2011	1.576	1.561	0.015	0.122	0.1216	0.9033
2012	1.469	1.463	0.006	0.093	0.0609	0.9515
2013	1.598	1.532	0.066	0.096	0.6793	0.4973
2014	1.676	1.600	0.076	0.093	0.8168	0.4145
2015	1.567	1.615	-0.048	0.160	-0.2999	0.7644
DID	Participants	Control	ATT	SE	t	p-value
2008-07	-0.164	-0.181	0.017	0.138	0.1230	0.9022
2009-07	-0.053	-0.041	-0.012	0.169	-0.0738	0.9412
2010-07	-0.271	-0.019	-0.252	0.215	-1.1707	0.2424
2011-07	-0.156	-0.022	-0.135	0.172	-0.7827	0.4342
2012-07	-0.263	-0.120	-0.144	0.158	-0.9098	0.3635
2013-07	-0.134	-0.050	-0.084	0.161	-0.5215	0.6023
2014-07	-0.056	0.017	-0.073	0.160	-0.4560	0.6487
2015-07	-0.164	0.033	-0.197	0.210	-0.9382	0.3487
OLS	Coef.	Robust SE	t	p-value	95% Conf. Interval	
Const.	1.560	0.006	243.650	0.000	1.547	1.572
Lag0	0.049	0.051	0.960	0.338	-0.051	0.149
Const.	1.558	0.006	272.140	0.000	1.546	1.569
Lag1	-0.028	0.051	-0.550	0.579	-0.127	0.071
Const.	1.560	0.007	239.530	0.000	1.547	1.573
Lag2	0.040	0.057	0.700	0.485	-0.073	0.153
Wald test	F	p-value	corr(ui, Xb)	sigma_u	sigma_e	rho
Lag0	0.920	0.338	0.065	1.023	1.023	0.500
Lag1	0.310	0.579	-0.083	1.034	0.946	0.544
Lag2	0.490	0.485	0.067	1.057	0.951	0.552

Source: own calculation

Table 8: ATT, DID and OLS of labour productivity (x).

Year	Participants	Control	ATT	SE	t	p-value
2007	1.622	7.264	-5.642	2.550	-2.2123	0.0275
2008	1.702	49.315	-47.613	35.717	-1.3331	0.1833
2009	1.058	14.317	-13.258	9.777	-1.3561	0.1758
2010	1.098	2.792	-1.693	0.841	-2.0141	0.0446
2011	0.880	2.084	-1.204	0.486	-2.4751	0.0137
2012	0.909	3.004	-2.095	0.837	-2.5036	0.0127
2013	0.901	2.664	-1.764	0.958	-1.8421	0.0662
2014	0.869	4.989	-4.120	1.736	-2.3732	0.0181
2015	1.016	5.598	-4.582	2.443	-1.8757	0.0614
DID	Participants	Control	ATT	SE	t	p-value
2008-07	0.080	42.051	-41.971	34.365	-1.2213	0.2227
2009-07	-0.563	7.052	-7.616	9.176	-0.8300	0.4070
2010-07	-0.524	-4.472	3.949	2.348	1.6820	0.0933
2011-07	-0.742	-5.180	4.438	2.326	1.9083	0.0570
2012-07	-0.713	-4.260	3.547	2.374	1.4942	0.1359
2013-07	-0.721	-4.600	3.878	2.006	1.9333	0.0539
2014-07	-0.753	-2.275	1.522	2.088	0.7289	0.4665
2015-07	-0.606	-1.667	1.061	2.150	0.4934	0.6220

Source: own calculation

Table 9: ATT, DID and OLS of direct cost efficiency (x) (to be continued).

OLS	Coef.	Robust SE	t	p-value	95% Conf. Interval	
Const.	5.719	0.025	226.340	0.000	5.669	5.769
Lag0	-0.380	0.201	-1.890	0.059	-0.775	0.015
Const.	5.841	0.010	598.110	0.000	5.822	5.861
Lag1	-0.147	0.086	-1.700	0.090	-0.316	0.023
Const.	3.015	0.005	612.420	0.000	3.005	3.025
Lag2	-0.020	0.043	-0.460	0.644	-0.105	0.065
Wald test	F	p-value	corr(ui, Xb)	sigma_u	sigma_e	rho
Lag0	3.570	0.060	0.037	45.839	124.841	0.119
Lag1	2.890	0.090	0.035	49.201	132.858	0.121
Lag2	0.210	0.644	0.038	20.195	37.016	0.229

Source: own calculation

Table 9: ATT, DID and OLS of direct cost efficiency (continuation).

These results correspond with previous findings from the agricultural sector (Medonos et al., 2012; Ratinger et al., 2013; Spicka et al., 2017). Uncovering positive effects for investment support on direct cost efficiency confirms the purpose of investment support as an important measurement for improving material and energy efficiency of participants.

Conclusion

The article focused on impact evaluation of investment support on selected important economic indicators using statistical and econometric methods. The case study of the Czech food industry from 2007-2015 noted some interesting findings that are important for policy makers and other stakeholders (managers, investors).

According to the policy guidelines, investment support should enhance viability and competitiveness and promote resource efficiency for supported enterprises. The food industry is a suitable branch for the case study because it has been heavily supported by European and national funds for a long time. The article partially confirmed previous studies but revealed new dynamic effects of investment support from three complementary grant programmes (the Rural Development Programme, a national subsidy programme and the Operational Programme Enterprise and Innovation). Supported companies were compared with similar non-treated companies from the same branches of the food and beverage industry.

If we generalize our findings, supported companies (participants) have higher investment activity than nonparticipants. Investment support increases the amount of fixed assets and size of participants. Alternatively, nonparticipants invest enough to cover the depreciation of fixed assets and do not develop themselves. However, the turnover of fixed assets did not significantly improve after completion and launching the investment. This means that participants are not able to generate additional sales from new fixed assets to improve productivity. Finally, there could be another negative effect. It was revealed that nonparticipants that do not develop their business and investment support could have a crowding out effect for companies that have not received investment support, which corresponds to recent studies.

Second, investment support changes the capital structure of participants towards increased usage of bank loans and a growing credit debt ratio. This is particularly important for the next programming period of 2021+ that will be more focused on financial instruments, which will play an important role in the achievement of Cohesion Policy objectives. Such instruments may take the form of equity or quasi-equity investments, loans or guarantees, or other risk sharing instruments. Where appropriate, they may be combined with grants.

Concerning the impact of investment support on profitability and productivity, empirical research showed only positive effects on long-term profitability at the 0.1 significance level for the year of support and two years after support. A positive effect for investment support on long-term profitability is good news for management of supported companies and policy makers. Long-term profitability has been one of the key selection criteria in the Czech RDP. However, no effect of investment support on labour productivity is a very unfavourable finding since increasing labour productivity is key goal of all investigated development programmes.

In the previous programming period from 2007-2013, the Ministry of Agriculture did not require proper ex-ante evaluation of project applications. Neither financial plans nor cost benefit analyses were included in project applications. Project selection was based on a verbal description of project, features of the applicant and the rate of investment subsidy (from 40 % to 50 %). In the current programming period, selection criteria have been improved to include cost-efficiency analysis and financial planning.

Finally, this research revealed positive dynamic effects for investment support on direct cost efficiency, which supports ongoing efforts to improve resource efficiency. The current RDP puts more emphasis on material and energy efficiency and related environmental effects.

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Appendix

Factors	Indicators	Unit	Cumulative Percent
F1: Company's size	Total Assets	´000 CZK	35.54
F2: Financial stability	Debt Coverage = Cash Flow / Debt	times	43.61
F3: Trading goods	Cost of Goods Sold	´000 CZK	49.16
F4: Intensity	Asset Turnover = Sales of Goods and Products / Total Assets	times	53.82
F5: Liquidity	Acid Test Ratio = (Current Assets – Inventory) / Current Liabilities	times	57.66
F6: Retained earnings	Retained earnings	´000 CZK	61.29
F7: Use of bank loans	Bank loans	´000 CZK	64.73
F8: Financial leverage	Debt Equity Ratio = (Debt / Equity) x 100	%	67.95
F9: Sales of long-term assets	Revenues from disposals of fixed assets and materials	´000 CZK	71.04
F10: Capital structure	Debt Ratio = (Debt / Total Assets) x 100	%	73.99
F11: Working capital management	Working Capital Ratio (WCR) = Net Working Capital / Sales of Goods and Products x 100	%	76.62
F12: Financial earnings	Profit / loss from financial operations (transactions)	´000 CZK	78.73
F13: Production margin	Relative Gross Profit Margin = ((Sales of Products – Cost of Products Sold) / Sales of Products) x 100	%	80.69

Source: own calculation

Table A1: Results of the PCA.

Variable	Coef.	Std. Err.	z	p-value	Odds Ratio	[95% Conf. Interval]	
Const.	0.566	0.219	2.586	0.010	1.761	0.137	0.994
Bank loans	0.000	0.000	2.955	0.003	1.000	0	0
Debt Ratio	-0.008	0.003	-2.828	0.005	0.992	-0.014	-0.003
Liquidity	-0.095	0.045	-2.138	0.033	0.909	-0.183	-0.008
Log Likelihood	-411.886	N = 620					
Model R^2	0.0305						

Source: own calculation

Table A2: Results of logit regression – selection of significant variables (N = 620).

Group Comparison Report for Variable = Logit(ps)						
Group Type	**Treated**	**N**	**Mean**	**SD**	**Mean Difference**	**Standardized Difference (%)**
Before Matching	1	271	-0.1076	0.49		
	0	349	0.1167	0.78	-0.2243	-34.39%
After Matching	1	206	-0.0406	0.36		
	0	206	0.0352	0.3	-0.0758	-22.93%
Group Comparison Report for Variable = Bank loans						
Group Type	**Treated**	**N**	**Mean**	**SD**	**Mean Difference**	**Standardized**
Difference (%)						
Before Matching	1	271	49 774.41	129 402.5		
	0	349	19 823.43	88 391.27	29 950.98	27.03%
After Matching	1	206	32 889.38	79 004.24		
	0	206	15 123.61	44 212.91	17 765.77	27.75%
Group Comparison Report for Variable = Liquidity (Acid Test Ratio)						
Group Type	**Treated**	**N**	**Mean**	**SD**	**Mean Difference**	**Standardized Difference (%)**
Before Matching	1	271	1.6603	1.74		
	0	349	2.2452	6.78	-0.5849	-11.81%
After Matching	1	206	1.6393	1.79		
	0	206	1.5791	1.74	0.0603	3.41%
Group Comparison Report for Variable = Debt Ratio (%)						
Group Type	**Treated**	**N**	**Mean**	**SD**	**Mean Difference**	**Standardized Difference (%)**
Before Matching	1	271	59.6552	27.32		
	0	349	67.3433	53.41	-7.6881	-18.12%
After Matching	1	206	60.7391	27.92		
	0	206	62.9961	35.71	-2.257	-7.04%

Source: own calculation

Table A3: Results of PSM.

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