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ATTEMPT TO IDENTIFY THE CAUSAL RELATIONSHIPS BETWEEN THE PRICES OF MILK IN SELECTED EU COUNTRIES

POKUS O IDENTIFIKÁCIU KAUZÁLNYCH VZŤAHOV MEDZI CENAMI MLIEKA VO VYBRANÝCH KRAJINÁCH EÚ

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The causality Granger test was used to assess the causal links between the prices of milk in selected European Union countries. The Granger test is based on the vector auto regression models – VAR. The conducted research allowed identifying causal relationships between the prices of milk in the following countries: Poland, Germany, France, the Czech Republic, and Slovakia. The research shows that milk prices in Poland depend on the prices in France, Germany, the Czech Republic and Slovakia, while milk prices in Slovakia are dependent on milk prices in Poland.

Key words: Granger test, VAR model, causal relationship, milk prices

The Polish accession to the European Union has created the opportunity to develop the milk market in the form of access of our products to the markets of the EU countries. The milk market and milk product market in the EU is the most supported and regulated market. Regulation system of the EU milk market has an impact on the price of milk in individual member countries. The relations between the prices of milk in some countries seem to be inevitable.

The aim of this paper is to examine the empirical causal relationships in the milk market. The prices of milk in the selected EU countries (France, Germany, Poland, Slovakia, the Czech Republic) were taken into consideration.

Material and method

In this study, the average monthly prices of milk in €.100 kg^{-1} from May 2004 to October 2010 were used as the empirical material, which is the 78 observations in the following countries: France, Poland, Germany, Slovakia and the Czech Republic. The data were obtained from the Integrated Agricultural Market Information System (http://www.minrol.gov.pl).

In this study, the following symbols were used:

- v_1 – average monthly prices of milk in France in €.100 kg^{-1},
- v_2 – average monthly prices of milk in Germany in €.100 kg^{-1},
- v_3 – average monthly prices of milk in Poland in €.100 kg^{-1},
- v_4 – average monthly prices of milk in the Czech Republic in €.100 kg^{-1},
- v_5 – average monthly prices of milk in Slovakia in €.100 kg^{-1}.

Basic characteristics of the individual time series are presented in Table 1. The lowest average price in the period was recorded in Slovakia – 26.06 €.100 kg^{-1}, while the highest average monthly price was recorded in France – 30.95 €.100 kg^{-1}. The prices of milk in Slovakia show the greatest differentiation – the variation coefficient was 16%. Comparing the prices of milk in all analyzed countries it can be concluded that the milk prices are characterized by variability on a similar average level of about 14 – 15%.

Table 1 The basic characteristics of the individual time series

	v_1	v_2	v_3	v_4	v_5
$\bar{x}$ (mean) (1)	30.95	29.08	26.15	26.06	27.53
s (standard deviation) (2)	3.62	4.32	3.71	4.05	3.75
V (coefficient of variation) (3)	12 %	15%	14 %	16 %	14 %
Min	24.27	22.00	16.90	17.67	21.12
max	40.94	41.00	36.70	35.61	37.65

Source: author's own calculations
Zdroj: vlastné výpočty autora

Tabuľka 1 Základné charakteristiky individuálneho časového radu
(1) stredná hodnota, (2) štandardná odchýlka, (3) variačný koeficient

To verify the hypothesis about the causality between variables, the Granger test was used, constructed on VAR models. Granger Causality: x is simply granger causal to y if and only if the application of an optimal linear function leads to

$$\sigma^2\left(\frac{y_{t+1}}{I_t}\right) < \sigma^2\left(\frac{y_{t+1}}{I_t - \overline{X}_t}\right) \quad (1)$$

i.e. if future values of y can be predicted better, i.e. with a smaller forecast error variance, if current and past values of *x* are used. Compare Charemza and Deadman (1997) and Osińska (2006).

VAR models are presented in econometric literature; therefore in this paper the general characteristics of this model are presented. The VAR models are presented in work of Jusélius (2006) or Cromwel et al. (1994). Multivariate tests for time series models in Lutkepohl (2006).

The variables, which will be used in Granger test, should be stationary; therefore the rank of integration should be known. To test the stationarity of the variables augmented test Dickey-Fuller was used, it is presented in Zivot, Wang (2006) and Sarris, Hallam (2006). Then the two-dimensional VAR model was estimated, which is presented by the formula:

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$$Z_t = \sum_{i=1}^{p} A_i Z_{t-1} + \varepsilon_t \quad (2)$$

where:
Z_t – an observation vector
A_i – matrix of parameters standing for the delayed variable vector Z_{t-l}, ε_t – is a disturbance term

The Schwarz criterion was used to identify the rank of delay. The BIC statistic is presented in work of Ruppert (2010). The use of VAR models requires a normal distribution and the lack of autocorrelation from the disturbance term. The LM tests are presented in works of Baltagi (2002) and Cameron (2005).

The procedure of the Granger causality test begins with the estimation of model parameters:

$$y_t = \alpha_0 + \alpha_1 y_{y-1} + \ldots \alpha_p y_{t-p} + \varepsilon_t \quad (3)$$

$$y_t = \alpha_0 + \alpha_1 y_{y-1} + \ldots \alpha_p y_{t-p} + \beta_1 x_{t-1} + \beta_2 x_{t-2} + \ldots + \beta_q x_{t-p} + \eta_t \quad (4)$$

where:
x_t – empirical value of the variable X
y_t – empirical value of the variable Y
p – rank of delay of the variable
ε_t, η_t – disturbance term of the models

The Granger test verifies the hypotheses:

$$H_0: \sigma^2(\varepsilon_t) = \sigma^2(\eta_t)$$
$$H_0: \sigma^2(\varepsilon_t) \neq \sigma^2(\eta_t) \quad (5)$$

and the test statistic is presented by the formula:

$$F = \frac{n \cdot \left(s^2(\varepsilon_t) - s^2(\eta_t)\right)}{s^2(\varepsilon_t)} \quad (6)$$

The F statistic has chi-square distribution – $\chi^2(q)$.

Results and research

Examination of causal relationships between variables started from testing stationarity. The hypotheses of stationarity of variables were rejected on the basis of the ADF test. The correct specification of the VAR model requires stationarity of the variables. Therefore the first differences of the variables were taken under consideration Δv_i, $i = 1,\ldots,5$. The decision was made that the first differences are stationary (Table 2 and Table 3).

Table 2 The results of ADF test for variables v_i, $i = 1,\ldots5$

Variable (1)	ADF	p-value (2)
v_1	-3.23822	0.01791
v_2	-2.59625	0.09369
v_3	-2.03587	0.2715
v_4	-2.48926	0.1181
v_5	-2.36391	0.1522

Source: author's own calculations
Zdroj: vlastné výpočty autora

Tabuľka 2 Výsledky ADF testu pre premenné v_i, $i = 1,\ldots5$
(1) premenná, (2) p-hodnota

Table 3 The results of ADF test for variables Δv_i, $i = 1,\ldots5$

Variable (1)	ADF	p-value (2)
Δv_1	-6.05444	8.851e-008
Δv_2	-3.37572	0.01185
Δv_3	-4.12558	0.000876
Δv_4	-2.68761	0.007613
Δv_5	-3.37897	0.01173

Source: author's own calculations
Zdroj: vlastné výpočty autora

Tabuľka 3 Výsledky ADF testu pre premenné Δv_i, $i = 1,\ldots5$
(1) premenná, (2) p-hodnota

The next step was to estimate the ranks of delays for the VAR models which were made by means of estimating eight models:

- Model 1 describes the relationship between first differences in milk prices in France and the first differences in milk prices in Poland.
- Model 2 describes the relationship between first differences in milk prices in Poland and the first differences in milk prices in France.
- Model 3 describes the relationship between first differences in milk prices in Germany and the first differences in milk prices in Poland.
- Model 4 describes the relationship between first differences in milk prices in Poland and the first differences in milk prices in Germany.
- Model 5 describes the relationship between first differences in milk prices in Slovakia and the first differences in milk prices in Poland.
- Model 6 describes the relationship between first differences in milk prices in Poland and the first differences in milk prices in Slovakia.
- Model 7 describes the relationship between first differences in milk prices in the Czech Republic and the first differences in milk prices in Poland.
- Model 8 describes the relationship between first differences in milk prices in Poland and the first differences in milk prices in the Czech Republic.

The ranks of delays were chosen on the basis of the Shwarz criterion. Optimal rank of delay was chosen when the BIC statistic was the lowest (Table 4).

Table 4 The values of BIC statistic for chosen rank of delay models

Model	Rank of delay (q) (1)	BIC
1	1	4.411673
2	1	2.754384
3	1	2.840738
4	1	2.358229
5	1	2.434605
6	1	2.671697
7	1	2.612094
8	1	2.379952

Source: author's own calculations
Zdroj: vlastné výpočty autora

Tabuľka 4 Hodnoty štatistiky BIC pre vybranú úroveň modelov oneskorenia
(1) stupeň oneskorenia

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To estimate model parameters, GRETL programme was used, giving the following results:

- Model 1: $\Delta v_{1t} = 0.162090\ \Delta v_{1t-1} + 0.295224\ \Delta v_{3t-1}$
- Model 2: $\Delta v_{3t} = 0.507051\ \Delta v_{3t-1} + 0.109462\ \Delta v_{3t-1}$
- Model 3: $\Delta v_{2t} = 0.635159\ \Delta v_{2t-1} + 0.034376\ \Delta v_{3t-1}$
- Model 4: $\Delta v_{3t} = 0.358474\ \Delta v_{3t-1} + 0.320626\ \Delta v_{2t-1}$
- Model 5: $\Delta v_{4t} = 0.505272\ \Delta v_{4t-1} + 0.335870\ \Delta v_{3t-1}$
- Model 6: $\Delta v_{3t} = 0.459952\ \Delta v_{3t-1} + 0.165223\ \Delta v_{4t-1}$
- Model 7: $\Delta v_{5t} = 0.39199\ \Delta v_{5t-1} + 0.259312\ \Delta v_{3t-1}$
- Model 8: $\Delta v_{3t} = 0.313202\ \Delta v_{3t-1} + 0.370267\ \Delta v_{5t-1}$

The study of disturbance term properties allowed adopting the hypotheses of normality and lack of autocorrelation. Next parameters of models (1) and (2) were estimated, which allowed using the Granger test. The following conclusions have been drawn on the basis of the Granger test results (Table 5):

- Δv_1 is a cause of Δv_3
- Δv_2 is a cause of Δv_3
- Δv_3 is a cause of Δv_4
- Δv_4 is a cause of Δv_3
- Δv_5 is a cause of Δv_3

Table 5 The values of Granger test statistic and critical value of χ^2

	F	$\chi^2(q)$ ($\alpha = 0.05$)	$\chi^2(q)$ ($\alpha = 0.01$)
Δv_3 is a cause of Δv_1 (1)	1.11768	3.841459	6.634897
Δv_1 is a cause of Δv_3	21.93248	3.841459	6.634897
Δv_3 is a cause of Δv_2	0.90064	3.841459	6.634897
Δv_2 is a cause of Δv_3	29.17598	3.841459	6.634897
Δv_3 is a cause of Δv_4	13.39903	3.841459	6.634897
Δv_4 is a cause of Δv_3	19.54195	3.841459	6.634897
Δv_3 is a cause of Δv_5	3.177839	3.841459	6.634897
Δv_5 is a cause of Δv_3	24.1092	3.841459	6.634897

Source: author's own calculations
Zdroj: vlastné výpočty autora

Tabuľka 5 Hodnoty štatistík Granger testu a kritická hodnota χ^2 (1) je príčinou

The obtained results allowed identifying one-way causal relationships between the analyzed variables. On the basis of the statistics F we can conclude that the variables Δv_1, Δv_2, Δv_4, Δv_5, which constitute first increment of milk prices in France, Germany, Slovakia and the Czech Republic are the causes of variable Δv_1, i.e. the first increment of milk prices in Poland. Additionally, Δv_1 variable, i.e. the first increment of milk prices in Poland is a cause for variable Δv_4 – the first increment of milk prices in Slovakia. In other cases, the differences between the models (1) and (2) are negligible, so there is no causality in Granger test sense.

Summary

VAR models are useful tools for investigation of the causal links between economic variables. In the present research the results of analysis of the relationships between changes in milk prices in the selected EU countries and the prices of milk in Poland are presented. The research shows that milk prices in Poland depend on the prices in France, Germany, the Czech Republic and Slovakia, while milk prices in Slovakia are dependent on milk prices in Poland. The identification of the causal relationships in the sense of Granger test allows forecasting efficiently short-and medium-term prices of milk.

Súhrn

Grangerov test kauzality bol použitý na posúdenie závislostí medzi cenami mlieka vo vybraných krajinách Európskej únie. Tento test je založený na vektorových autoregresných modeloch – VAR. Výsledky výskumu identifikovali kauzálne závislosti medzi cenami mlieka krajín Poľska, Nemecka, Francúzska, Českej republiky a Slovenskej republiky. Boli zistené nasledovné vzťahy: Poľské ceny mlieka závisia na cenách mlieka vo Francúzsku, Nemecku, Českej republike a Slovensku, kým ceny mlieka na Slovensku sú závislé na cenách poľských cenách mlieka.

Kľúčové slová: Grangerov test, VAR model, kauzálne vzťahy, ceny mlieka

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