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

PRÓBA IDENTYFIKACJI ZWIĄZKÓW PRZYCZYNOWYCH MIĘDZY CENAMI MLEKA W WYBRANYCH KRAJACH UE

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

Słowa kluczowe: test Grangera, model VAR, związki przyczynowe, cena mleka

Abstract. 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 autoregression models – VAR. The conducted research allowed to identify causal relationships between the prices of milk in the following countries: Poland, Germany, France, the Czech Republic, Slovakia.

Introduction

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 EU countries. The milk market and milk product market in the EU is the most supported and regulated market. Regulating 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 selected EU countries (France, Germany, Poland, Slovakia, the Czech Republic) were taken into consideration.

Empirical material

In this study, the average monthly prices of milk in euro per 100 kg from May 2004 to October 2010 as the empirical material were used, which is the 78 observations in the following countries: France, Poland, Germany, Slovakia and the Czech Republic. Data were obtained from the Integrated Agricultural Market Information System [www.minrol.gov.pl]. In this study, the following symbols were used:

v1 – average monthly prices of milk in France in Euro per 100 kg,
v2 – average monthly prices of milk in Germany in Euro per 100 kg,
v3 – average monthly prices of milk in Poland in Euro per 100 kg,
v4 – average monthly prices of milk in Czech Republic in Euro per 100 kg,
v5 – average monthly prices of milk in Slovakia in Euro per 100 kg.

Table 1. The basic characteristic of the individual time series
Tabela 1. Podstawowe charakterystyki pojedynczych szeregów czasowych

Zmienne/*Value*	***v1***	***v2***	***v3***	***v4***	***v5***
$\overline{x}$	30.95	29.08	26.15	26.06	27.53
S	3.62	4.32	3.71	4.05	3.75
V [%]	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: own study
Źródło: opracowanie własne

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 euro/100 kg, while the highest average monthly price was recorded in France – 30.95 euro/100kg. 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 milk prices are characterized by variability on a similar average level of about 14-15%.

Methodology

To verify the hypothesis about the causality between variables, the Granger[1] test was used constructed on VAR models. VAR models are presented in econometric literature, therefore in this paper the general characteristics of this model are presented[2]. The variables, which will be used in Granger test, should be stationary, therefore the rank of integration should be known[3]. Then the two-dimensional VAR model was estimated, which is presented by the formula:

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

where:
Z_t – is an observation vector,
A_i – matrix of parameters standing for the delayed variable vector,
Z_{t-i}, $\acute{I}_t$ – is a disturbance term.

The Schwarz criterion was used to identify the rank of delay[4]. The use of VAR models requires a normal distribution and the lack of autocorrelation from the disturbance term[5]. The procedure of the Granger causality test begins with the estimation of model parameters:

$$y_t = \alpha_0 + \alpha_1 y_{y-1} + ... + \alpha_p y_{t-p} + \varepsilon_t \tag{1}$$

$$y_t = \alpha_0 + \alpha_1 y_{y-1} + ... + \alpha_p y_{t-p} + \beta_1 x_{t-1} + \beta_2 x_{t-2} + ... + \beta_q x_{t-p} + \eta_t \tag{2}$$

where:
x_t – empirical value of the variable X,
y_t – empirical value of the variable Y,
p – rank of delay of the variable,
$\acute{I}_t$, ς_t – disturbance term of the models.

The Granger test verifies the hypotheses:

$$\begin{aligned} H_0 &: \sigma^2(\varepsilon_t) = \sigma^2(\eta_t) \\ H_0 &: \sigma^2(\varepsilon_t) \neq \sigma^2(\eta_t) \end{aligned} \tag{3}$$

and the test statistic is presented by the formula:

$$F = \frac{n \cdot \left(s^2(\varepsilon_t) - s^2(\eta_t)\right)}{s^2(\varepsilon_t)} \tag{4}$$

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

The results of the 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,…,5. The decision was made that the first differences are stationary (Tab. 2 and 3).

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1 Granger Causality: x is simply granger causal to y if and only if the application of an optimal linear function leads to $\sigma^2\left(y_{t+1}\middle|I_t\right) < \sigma^2\left(y_{t+1}\middle|I_t - \overline{X}_t\right)$; 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 [Charemza, Deadman 1997].

2 The VAR model are presented in work: Jusélius [2006], Cromwel et al. [1994], Lutkepohl [2006].

3 To test the stationarity of the variables augumented test Dickey-Fuller was used, it is presented in: Zivot, Wang [2003], Sarris, Hallam [2006].

4 The BIC statistic is presented in work: Ruppert [2010].

5 The LM test are presented in work Baltagi [2002], Cameron [2005].

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

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

The rank of delays were chosen on the basis of the Shwarz criterion. Optimal rank of delay was chosen when the BIC statistic was the lowest (Tab. 4). 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 to adopt the hypotheses of normality and lack of autocorrelation. Next parameters of models (1) and (2) were estimated, which allowed to use the Granger test. The following conclusions have been drawn on the basis of the Granger test results (Tab. 5):

– *Δv1* is a cause of *Δv3*
– *Δv2* is a cause of *Δv3*
– *Δv3* is a cause of *Δv4*
– *Δv4* is a cause of *Δv3*
– *Δv5* j is a cause of *Δv3*

Table 2. The results of ADF test for variables *vi, i*=1,…5
Tabela 2. Wyniki testu ADF dla zmiennych vi, i=1,…5

Variable/ ***Zmienna***	**ADF/*ADF***	***p*-value/** ***wartość p***
V1	-3.23822	0.01791
V2	-2.59625	0.09369
V3	-2.03587	0.27150
V4	-2.48926	0.11810
V5	-2.36391	0.15220

Source: own study
Źródło: opracowanie własne

Table 3. The results of ADF test for variables *Δvi, i*=1,…5
Tabela 3. Wyniki testu ADF dla zmiennych Δvi, i=1,…5

Variable/ ***Zmienna***	**ADF/*ADF***	***p*-value/** ***wartość p***
ΔV1	-6.05444	8.851e-008
ΔV2	-3.37572	0.011850
ΔV3	-4.12558	0.000876
ΔV4	-2.68761	0.007613
ΔV5	-3.37897	0.011730

Source: own study
Źródło: opracowanie własne

Table 4. The values of BIC statistica for chosen rank of delay models
Tabela 4. Wartość statystyki BIC dla wybranych rang modelu opóźnienia

Model/ ***Model***	**Rank of delay (*q*)/** ***Ranga opóźnienia (q)***	**BIC/*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: own study
Źródło: opracowanie własne

The obtained results allowed to identify one-way causal relationships between the analyzed variables. On the basis of the statistics F we can conclude that the variables *Δv1*, *Δv2*, *Δv4,* Δ*v5*, which constitute first increment of milk prices in France, Germany, Slovakia and the Czech Republic are the causes of variable *Δv1*, i.e. the first increment of milk prices in Poland. Additionally, *Δv1* variable, i.e. the first increment of milk prices in Poland is a cause for variable *Δv4* – 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 sens.

Table 5. The values of Granger test statistic and critical value of χ^2
Tabela 5. Wartości statystyk dla testu Granger'a i wartość krytyczna χ^2

Description/ ***Wyszczególnienie***	**F**	**$\chi^2(q)$ (α=0,05)**	**$\chi^2(q)$ (α=0,01)**
Δv3 is a cuse of *Δv1*	1.11768	3.841459	6.634897
Δv1 is a cuse of *Δv3*	21.93248	3.841459	6.634897
Δv3 is a cuse of *Δv2*	0.90064	3.841459	6.634897
Δv2 is a cuse of *Δv3*	29.17598	3.841459	6.634897
Δv3 is a cuse of *Δv4*	13.39903	3.841459	6.634897
Δv4 is a cuse of *Δv3*	19.54195	3.841459	6.634897
Δv3 is a cuse of *Δv5*	3.177839	3.841459	6.634897
Δv5 is a cuse of *Δv3*	24.1092	3.841459	6.634897

Source: own study
Źródło: opracowanie własne

Conclusions

VAR models are useful tools to investigate the causal links between economic variables. In the present research the results of analysis of the relationships between changes in milk prices in 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 depend on milk prices in Poland. The identification of the causal relationships in the sense of Granger test allows to forecast efficiently short-and medium-term prices of milk.

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Streszczenie

Modele VAR są przydatnym narzędziem do badania związków przyczynowych między zmiennymi ekonomicznymi. W artykule przedstawiono wyniki analizy zależności między zmianami cen mleka w wybranych krajach UE a cenami mleka w Polsce. Z badań wynika, że cena mleka w Polsce zależy od ceny tego produktu we Francji, Niemczech, Czechach i Słowacji, zaś ceny mleka na Słowacji zależą od cen mleka w Polsce. Stwierdzono, iż identyfikacja związków przyczynowo-skutkowych za pomocą testu Grangera, pozwala skutecznie prognozować krótko- i średnioterminowe ceny mleka.

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