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SPATIAL PRICE TRANSMISSION OF MILK PRICES AMONG VISEGRAD COUNTRIES

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Abstract: When trading with homogenous goods, consumers are not able to distinguish between individual goods and thus are not willing to pay a higher price, if the same product is available for lower price. This leads to an interesting effect, when prices of homogenous goods in different locations in an open market tend to get closer. It is the result of the so-called Law of one price. Because of the Law of one price, producers are affected not only by vertical price transmission but also horizontally. The aim of this paper is to assess the linkage and patterns among the prices of cow's raw milk in the V4 countries. We apply the price transmission methodology, such as unit root tests, cointegration tests and error correction models. Monthly data for producer prices of raw milk are used, covering the period from January 2005 to June 2017. Our results confirm the existence of the Law of one price when milk producer prices in different locations are co-integrated.

Keywords: spatial price transmission, cointegration, milk production

JEL Classification: Q11, C32

INTRODUCTION

Assuming the absence of transportation costs and trade restrictions, the perfect arbitrage at commodity prices ensures that each product has equal price worldwide. Producer and consumer prices, therefore, depend mainly on the two types of price transmission: horizontal and vertical price transmission. Price transmission at various stages of vertical chain got a lot of attention in the literature (Capps & Sherwell, 2007; Fernández-Amador et al., 2010; Stewart & Don, 2011; Bakucs et al., 2012; Bonnet et al., 2015; Zeng & Gould, 2016 and others). These changes are determined by the speed, magnitude and the nature of the adjustments, which respond to market shocks at the different levels of the chain (Vavra et al. 2005). The price movements between spatially differentiated markets at the same stage of the supply chain are also known as the spatial price transmission (Garcia-German et al., 2014). According to the EU's Common Agricultural Policy, the agricultural products are required to become spatially integrated within member states. A common prerequisite for the Law of one price is the homogeneity of goods. This is however frequently discussed a problem and some argue that the quality across different EU member states is not the same. In the case of well-functioning integrated markets in standard conditions, the price changes on the world market should be reflected into the domestic prices, relatively smoothly, with a short-lag that is needed to transfer between markets. Prices of commodities in different locations, as is the case of different V4 countries, should move together and there should be a long-term relationship among them.

Recent literature aims to characterize and to describe better the spatial price relations within homogenous products to explain the concepts such as market integration, market efficiency or spatial arbitrage. International economic integration is one of the aims of the European Union. Market integration can explain the differences between prices in markets related to each other. Fackler and Goodwin (2001) found out that market integration refers rather to the traceability of products between spatially different markets and may express the degree of price transmission among these

markets. Determining the significance of individual factors affecting international trade allows us to understand the characteristics and relationships of the market under examination. For these reasons, spatial analysis of market integration, or the tradability of goods and services between spatially different markets, can provide meaningful information for both the private sector as well as for policymakers.
Integrated agricultural markets are considered to be efficient markets. To estimate the market efficiency is often performed through the examination of spatial integration. As a result, the analysis of horizontal linkage is considered as a common tool in market integration analysis (Karikallio, 2015). Price transmission reflects the extent of market integration and market efficiency. It is important to keep in mind that perfect price transmission is not realistic. Price movements may differ, sometimes greatly, sometimes slightly, due to differences in economies, domestic policies, government restrictions, transfer costs, market imperfections, different price shocks, and other factors. Barrett (2001), Holst and von Cramon-Taubadel (2013) discuss the differences between market efficiency (as a consequence of price equilibrium in spatially different regions) and market integration (as a consequence of physical trade flows). These terms are often used interchangeably because of the lack of comparable trade data. The arbitrage takes advantage of a price difference between two or more separate markets. In an equilibrium concept, in a well- functioning market, the price shocks occurring in one market, cause responses in other markets. As a consequence, the prices of the same products in two separate locations will differ by the transport cost from the cheapest market to the most expensive one (Serra & Goodwin, 2006).There is a bulk of literature estimating the price transmission mechanism between different regions covering different periods. Ghoshray (2011) estimates the relationship between international prices and domestic prices in selected Asian countries. He found out that long-term world market price impact on Thai beef prices, but the short-term effects were insignificant. Study of Bakucs et al. (2015) provides an empirical analysis of the wheat producer pricing behavior in two neighboring wheat markets Hungary and Slovenia. Their results show that Hungary is the price leading market and Slovenian wheat prices are determined by Hungarian prices. Other recent studies focusing on spatial price transmission analyze wheat prices (Bessler et al., 2003, Dawson et al. 2006; Jin & Miljkovic, 2008; Brosig et al., 2011), peach prices (Raper, 2009), tomato markets (Ihle et al., 2010; Santeramo, 2015), fish markets (Asche et al., 2015; Ohen et.al. 2007) or meat markets (Liu, 2011; Serra, 2011; Karikallio, 2015). Particular attention of literature is paid also to milk markets. Acosta et al. (2014) found out that there is an evidence of price transmission from world prices to domestic markets for milk prices by using an (asymmetric) error correction model. Bakucs et al. (2015) analyze the spatial integration of raw milk in 20 EU member states. Results suggest that cointegration of milk prices is less prominent than that of other agricultural sectors (e.g. pork or cereals).
Milk as a major livestock product has recently taken a lot of attention in the literature and over the last decade studies regarding the milk price transmission has grown rapidly. Milk, as a traditional commodity, plays an important role in the agricultural sector and in 2016 the yearly production of raw cow milk in the European Union is equivalent to approximately 168.3 million tonnes (Eurostat). Though the milk and dairy products are in the most of the countries of EU competitive on the market the cooperation and trade are also important in the integrated market of EU. Until 2015 the milk production was regulated by milk quotas. It was one of the significant policy measures used by governments in the European Union to intervene in agriculture. The purpose was to bring rising milk production under the control, which affected all member states.
The objective of this study is to analyze the link among raw cow's milk markets in the following central European countries: Slovakia, Czech Republic, Poland and Hungary and to quantify the extent of price transmission among each other. The Czech Republic is the most important milk producer in the region, followed by Poland and Hungary. The lowest production is reached by the Slovak Republic. Another objective is to analyze the existence of a long-term equilibrium relationship between milk prices in the countries and the rate of adjustment to the price shocks, i. e. to examine the linkage between the countries in terms of the horizontal price transmission. In the next part of the paper, we discuss

the econometric methods used in our analysis. The final part summarizes obtained results and brings conclusions.

1. DATA AND METHODS

In this paper, we apply time-series modeling techniques to evaluate horizontal price transmission between the countries: Slovakia, Poland, Czech Republic, and Hungary. Because time series often contain unit roots, and the methodology used in our paper is sensitive to unit roots, at the very beginning of our analysis we check the existence of unit roots in price series, in other words, we examine the order of integration of individual series.

As the first step, we test the stationarity of time series using the Augmented Dickey-Fuller (ADF) root test. If the time series has a unit root, it is considered to be non-stationary. The ADF test is based on the principle of testing the presence of a single root in the autoregressive model. We use the test with the trend (t) and constant (α0):

$$\Delta y_t = \alpha_0 + \theta y_{t-1} + \gamma t + \alpha_1 \Delta y_{t-1} + \alpha_2 \Delta y_{t-2} + \ldots + \alpha_p \Delta y_{t-p} + a_t \quad (1)$$

The number of lags of a dependent variable is determined by the Akaike Information Criterion (AIC).

$$AIC = ln|\hat{\Omega}| + (p^2 k)\frac{2}{T} \quad (2)$$

where T is the length of the time series, Ω is the residual covariance matrix, p is the number of variables, k is the degree of lag of the model. The lag with the minimum value of the calculated criterion is selected as the appropriate lag.

In order to use the error correction model models, the following conditions must be met: Each variable is said to be a non-stationary, “integrated of order 1” or I(1). The variable is a random walk process, but its first difference is stationary. If the two non-stationary series move together over time then we say they are “cointegrated.” If the variables are cointegrated, there is a linear combination of variables that is stationary. We consider a regression model for two I(1) variables (prices) over the time, P1t and P2t, given by

$$P_1=\alpha+\beta P_2+\varepsilon \quad (3)$$

$$\varepsilon=P_1- \alpha- \beta X_2 \quad (4)$$

The term, ε, is interpretable as the deviation from the relation in (2). If P1 and P2 are cointegrated, then the deviation is a stationary process with mean zero.

As the second step, a cointegration test is used to determine if the time series are cointegrated, whether the linear combination of the examined variables is stationary. Cointegration analysis allows us to identify the short-term relationships and also helps to find the long-term, equilibrium cointegration relationship between variables, which is known as equilibrium. If the cointegration test indicates the existence of a long-term equilibrium relationship between a pair of variables, then we estimate the Error correction model (ECM):

$$\Delta Pt= \alpha+ \theta pt-1+ \Sigma qk=1\delta k\Delta Pt-k+ \varepsilon t \quad (5)$$

Where pt is the vector of n price variables, Δ is the first difference (ΔPt=Pt-Pt-1), εt is the error term for the residuals, α is the vector of estimated parameter locating constants, θ is the nXn matrix of estimated parameters which describe the long-term relationship and error correction, δk is the set nXn matrix of estimated parameters which describe the short-term price relationship for each of the q lags included in the model. For this analysis, Vector error correction model (VECM) is simplified as a follows:

$$\Delta P^h_t= \alpha+ \theta(P^h_{t-1}-\beta P^w_{t-1})+ \delta\Delta P^h_{t-1} + \rho\Delta P^h_{t-1} + \varepsilon t \quad (6)$$

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Where P_{ht} is the home price in logarithmic form, P_w is the foreign price in logarithmic form, Δ is the first difference, α, β, θ, δ, ρ are estimated parameters and ε_t is the residual deviation.

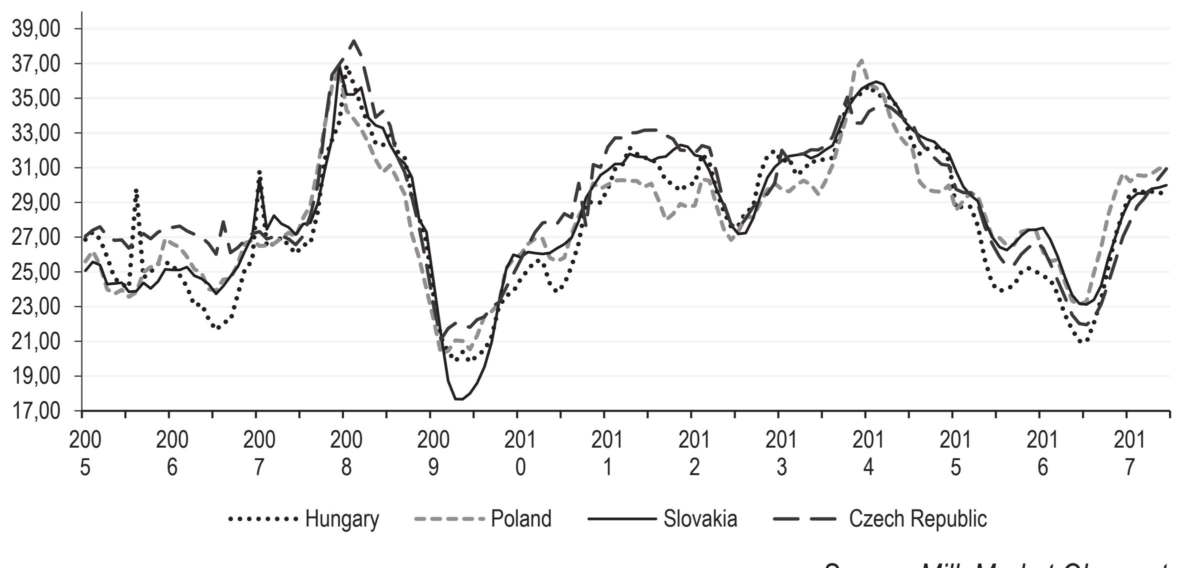
If the prices are expressed in logarithmic form, cointegration coefficient can be easily interpreted as a long-run elasticity of domestic to foreign prices, thus β is the elasticity of price transmission in long-run. The expected value of imported commodity is the interval between 0 and 1 and for exported more than 1. The Coefficient of error correction (θ) shows the deviation rate from the long equilibrium. The expected value is from -1 to 0. The higher absolute value of the correctional coefficient, the faster home prices return to the long-term equilibrium relationship. The coefficient of change (δ) in world prices is the short-term elasticity of domestic prices in relation to foreign prices. It represents the percentage adjustment of domestic prices after one percent (1%) of price shock in foreign market. The coefficient ρ is an autoregressive coefficient showing the impact of the change in domestic prices on prices in the next time period. The expected value of this coefficient is in the interval -1 to 1 (Gujarati, 2004; 2012; Minot, 2010).

Data used in our analysis contain the average monthly cow's raw milk prices for each V4 country. The time-series cover the period from January 2005 to June 2017. Producer prices were obtained from the European Commission's milk market observatory. The prices of each country are transformed and utilized in the Euro currency. All the variables are in natural logarithms.

2. EMPIRICAL RESULTS

The development of raw milk prices in analyzed countries follows similar trend and patterns suggesting there may be a long-term relationship present among the prices (Figure 1). The most significant increases in prices are recorded over the period 2007-2008 and in the year 2014. In 2008 - 2009 milk prices have fallen from their historical maximum by approximately 40-50%. This development was caused by the reduction in demand for dairy products due to economic recession and surplus of supply in international markets. As a result, stocks of some milk products as butter and milk-powder increased, particularly in the US and EU countries. This situation had very damaging effects to the dairy sector, with some countries starting to rethink their long-term strategies. These strategies and also mitigation of economic crises caused the milk prices to increase and climb up to their maximum in 2013. High milk prices in 2013 reflected in lower demand and increased milk production in China together with the embargo of the Russian Federation led to the decrease in milk prices again.

Fig. 1 The development of cow's raw milk in EUR/100kg



Source: Milk Market Observatory

Table 1. Descriptive Statistic

Variable	Observations	Mean	Median	Min	Max	Standard Deviation
Hungary	150	27.9	28.24	19.8	36.87	4.142
Poland	150	28.09	28.26	20.28	37.17	3.493
Slovakia	150	28.42	28.02	17.67	36.88	4.09
Czech Republic	150	28.94	27.98	21.12	38.3	3.825

Source: own calculations

To check whether there is a significant long-run relationship between analyzed we applied Engle-Granger model. Before specifying and estimating the Engle-Granger model, it was necessary to examine the order of integration, because cointegration and error correction models require the use of non-stationary variables.

The results of the ADF tests for stationarity of the variables are presented in Table 2. As seen from the table, the T- statistics for all the variables (milk prices in Czech Republic, Hungary, Poland, Slovakia) are greater than the critical values at 5% level of significance (the constant and trend term were included). Thus, the results proved that the null unit root hypothesis can not be rejected, suggesting that all the variables are non-stationary in their levels. In the next step, we tested the first differences. The results assume that all analyzed time series are integrated of the first order I (1).

Table 2 Augmented Dickey Fuller test results

Variables	Augmented Dickey Fuller (ADF) test	
	Level form	1st differences
Czech Republic	-3.3596	-4.6238
Hungary	-2.8474	-5.2163
Poland	-3.2630	-4.0363
Slovakia	-3.0082	-3.8160

Source: own calculations

Note: The critical value at the 5%level of significance is -3.44

To find out whether the variables under estimation are cointegrated, the ADF unit roots tests were employed on the residuals. This way we verified the assumption that the markets are integrated and that there is a mutual long-term relationship between the prices. The cointegration tests consist of testing the stationarity of the residues from the cointegration regression of the investigated price pairs. If these residues are stationary, we can conclude that the price pairs are cointegrated. The cointegration tests were conducted for each examined price pair. These results suggest that between the variables there exist long-term relationship. From the table below the T-statistics on residuals for each price pair is less than the critical value at 1% level except for Polish and Czech market. This price pair is integrated at the 10% level of significance. Our results suggest that there is a long run relationship between individual milk prices in V4 countries. Based on the results of the cointegration tests, the next analysis examines the linkage between the prices in countries.

Table 3 Cointegration tests results

Variables	T-stat	R-square	D.W.
HU-CZ	-4.5992***	0.86	0.58
CZ-SK	-4.7402***	0.84	0.32
CZ-PL	-3.3328*	0.80	0.21
PL-SK	-4.7682***	0.87	0.38
PL-HU	-4.6648***	0.83	0.45
SK-HU	-4.8784***	0.89	0.49

Source: own calculations

*Note: * refers to the significance at 10% level, *** refers to the significance at 1% level*

The Table 4 shows the long-term elasticities of price transmission. Dependent variables can be found in the rows and independent variables are listed in the columns. The results of estimated elasticity with values close to 1 suggest a closer relationship between the prices. The values above 1 indicate the export of commodity from the country, which was set up as a dependent variable.

Table 4 Long-term elasticities

	Czech Republic	Hungary	Slovakia	Poland
Czech Republic	-	0.8201***	0.8127***	0.9528*
Hungary	1.0522***	-	0.9444***	1.1032***
Slovakia	1.0386***	0.9406***	-	1.1243***
Poland	*0.8379***	0.7560***	0.7736***	-

Source: own calculations

*Note: *, **,*** refers to the significance at 10%, 5%, 1% level*

In the next step, the error correction models were estimated for all price pairs and results are presented in Table 5. Error correction model allow us to estimate parameters determining the speed of adjustment to deviations from the long-term equilibrium (error correction parameter) and also the short-term elasticities of the transmission. Error correction coefficients indicate the rate of adaptation of domestic prices to potential price shocks. If it represents the deviation in the short-run, it is considered as the speed of return of prices to a long-term equilibrium relationship. Error correction coefficients need to be significant and negative, ensuring that the price in home country will return back to the equilibrium. The higher absolute value for the error correction coefficient, the faster home prices return to the long-term equilibrium relationship. The coefficient of the error correction term is not statistically significant just in the pair of the Polish and Czech market. The results indicate that the fastest speed of adjustment to the price shocks of other countries is found for Hungarian market, as well as the Slovak market reacts faster to the price shocks in Poland. Data show the opposite for the Polish market were the return to the long-term equilibrium takes longer.

Table 5 The Error-correction model results

		ECM coefficients	Short-run elasticities
Variables		a	b
Dep.:	CZ		
Indep.:	HU	-0.1760***	0.3916***
	SK	-0.1189***	0.5457***
	PL	-0.1417***	0.5962***
Dep.:	PL		
Indep.:	HU	-0.0743	0.3908***
	SK	-0.1191**	0.6272***
	CZ	***-0.0122***	***0.0683***
Dep.:	SK		
Indep.:	HU	-0.1818***	0.5209***
	PL	-0.2796***	0.5284***
	CZ	-0.1603***	0.5997***
Dep.:	HU		
Indep.:	CZ	-0.2769***	0.7483***
	PL	-0.2962***	0.6157***
	SK	-0.2691***	0.8651***

Source: own calculations

*Note: *, **,*** refers to the significance at 10%, 5%, 1% level*

The short-run elasticities reported in part b indicate how the prices in the domestic country react to the price shocks of the foreign countries in the short run. All prices are estimated for both directions. The most sensitive reaction to the price shocks of Hungary milk market is found in Slovak in Czech market. However, the Hungary market reacts the less to the price shocks at the Slovak and Czech markets.

CONCLUSION

This study analyses the relationship among raw cow's milk markets in the Visegrad countries: Slovakia, Czech Republic, Poland and Hungary and assess the linkage and patterns between the prices of raw cow's milk. To clarify the relationships between the prices in the markets the unit root tests, cointegration tests and error correction models were used. We applied monthly data covering the period of January 2005 to June 2017. The cointegration tests confirmed the price pairs are cointegrated and there exists a long-run relationship between variables. The fastest speed of adjustment to the price shocks of the other countries is found for Hungarian market. Slovak market reacts faster to the price shocks of Poland. Data show the opposite situation in Polish market where the return to the long-term equilibrium takes the longest time. The most sensitive reaction to the price shocks of Hungary is found for Slovak and Czech market. The Hungary market reacts the less to the price shocks at the Slovak and Czech markets. Our results suggest that the prices of raw cow's milk are moving together influencing each other. Thus the consumers and producers in the analyzed countries are affected not only by the vertical price transmission in the food supply chain but they are influenced spatially as well. This information together with the knowledge about speed of adjustment and causality among V4 countries is of special interest of milk sector and policy makers.

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