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Price linkage between milling and feed wheat prices in Poland and Germany

Abstract. The aim of the paper was to analyse spatial price transmission in the wheat market in Poland and Germany. The analysis was conducted with the use of weekly milling and feed wheat price series and cointegration framework. The results confirm high linkage between prices in Poland and Germany as well as allow us to identify Germany as the price-leading market. However, as the self-sufficiency in the German wheat market has deteriorated, there are signals of growing importance of the Polish market in the milling wheat price formation.

Key words: wheat prices, price transmission, cointegration, VECM models

Introduction

Prices, being to certain extent a factor responsible for output (production) and consumption (use), are of key importance in economic theory. Over time agricultural prices have been much more volatile than the prices of non-agricultural goods and services, especially for the previous 10 years. Such a situation adversely affects both economic and social spheres in every country.

The prices of agricultural commodities are an exceptional field for research on price drivers. The prices of agricultural commodities, in particular the prices of cereals, result from a wide variety of systems ranging from almost entirely based upon administrative regulations to classic examples of free market [Tomek and Robinson 2001].

Poland after the accession to the EU became a part of common market – a large and well-organised market, directly linked with world markets. Since then the position of Poland as regards grain trade has changed significantly, which implies certain changes in cereal price setting mechanisms. Therefore, there is a need to investigate the direction of price transmission, the price factors and the pattern of price adjustments on the cereal market.

Vertical price transmission illustrates linkages along a supply chain, while horizontal transmission, which is our focus in the paper, refers to linkages between different markets at the same level of the food chain. Most often it refers to price relationships across markets, i.e. to spatial price transmission as well as the transmission between various agricultural commodities (cross-commodity price transmission) [Esposti and Listorti 2011], and non-agricultural versus agricultural commodities (namely, energy versus agricultural prices) [Serra and Hassouneh 2011], and finally between different contracts for the same

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commodity (usually, futures versus spot markets and vice versa) [Baldi et al. 2011]. From an economic point of view, the crucial issue here is spatial arbitrage and the Law of One Price (LOP). Unlike in the case of cross-commodity price transmission, the changes in linked prices in most cases reflect the possibilities of substitution and also complementary interactions between the products [Ardeni 1989; Saadi 2011] or, as it is the case here, pure price differentials.

A great part of the research on market integration and price transmission, both spatially and vertically, has been done with the use of different quantitative techniques and has underlined several factors hampering the transmission of price signals. Distortions imposed by administrative regulations, i.e. policies such as border restrictions and price support mechanisms, impeded linkages between particular markets. The instruments of agricultural policies, namely intervention, import tariffs, tariff rate quotas, export subsidies or taxes and macro tools such as exchange rate policies, insulate domestic markets and considerably slow down and reduce the transmission of international price signals through the impact on excess demand or supply schedules within internal commodity markets [Gardner 1975; Mundlak and Larson 1992; Quiroz and Soto 1996; Baffes and Ajwad 2000; Abdulai 2000; Sharma 2002].

Taking into account the above, this paper is focused on statistical investigation of the linkages between wheat prices on Polish and German markets. The analysis is conducted on the basis of weekly price series of consumption and feed wheat, and takes into account the possibility of the existence of two regimes connected with the impact of biofuel policy, which differentiates this search from other examinations concerning the Polish wheat market [*vide* Rembeza 2010].

Wheat market characteristics

Assuring approximately 20% of the world's calorie supply [Mitchell and Mielke 2005], wheat is considered one of the crucial food crops. It is produced in numerous countries (ca 120) under a variety of climatic conditions with the use of a broad range of technologies. Roughly 60% of wheat is produced in developing countries. Since that output has been growing faster than in developed countries, this proportion has increased over time. Over the last 5 decades, world wheat production has been increasing steadily, although there have been minor fluctuations in trends. Recently wheat output has roughly been 3 times higher than at the beginning of 1960s.

The wheat market is very well concentrated; however, a few new producers have recently emerged. Since the early sixties, a group of five countries (China, India, USA, Russia and EU) has accounted for more than two-thirds of the world's wheat output. But presently there are new competitors, such as Canada, Australia, Pakistan, Turkey and Argentina in first turn and Russia, Ukraine and Kazakhstan as the most recent newcomers. All the above-mentioned countries account for much more than 80% of the world wheat production. Therefore one can assume without any doubt that any shift in the market fundamentals in these countries has a certain impact on world prices. Apart from that, there is another division of the big players in respect to self-sufficiency. On one side, there are big exporters – Argentina, Australia, Canada EU, USA and recently Russia, Ukraine and Kazakhstan, as well as big importers like China, India and Japan.

Simultaneously, the consumption of wheat over the concerned period increased more than 2.5 times, significantly exceeding 600 tonnes. The increase reflects the following:

- wheat is a staple food for humans, and can be replaced by very few other products;
- accelerating population growth, particularly in developing countries;
- migration from rural to urban areas where wheat is more common in diets;
- growing food aid from developed to poor countries;
- growing non-food uses (particularly biofuels).

Growing demand overlapping with poor crop and low inventories as well as with the influence of capital markets triggered recent price rises (2007-2008 and from 2010 to 2013) and induced price volatility.

Neighbouring Poland and Germany are two of the largest wheat producers in the EU, occupying 2nd and 4th place respectively. However, the markets in these countries are considerably different, beginning from the structure of producers (extremely fragmented in Poland) and ending up with farm size which in Germany is more than two times bigger than in Poland. The Polish share in the European cereal market is much lower than the German one (especially in the case of wheat). Both countries account for ca 25% of the EU cereal market.

About 2/3 to 3/4 of the output in Germany is traded while in Poland the proportion rarely exceeds 50%. Since the accession Polish cereal exports, particularly wheat, have considerably increased. The bulk of the growth has been sold on the German market as the situation for the German balance sheet of wheat has apparently deteriorated since 2009. Such a situation in Germany reflects growing cereal use in the biofuel sector. So the deficit in the German market is at least partly fed with Polish wheat. At the same time Germany is an active exporter to third countries so world prices to a certain extent are reflected there, especially in the Western part of the country.

The above implies at least a couple of questions with the most important for the purpose of the paper: how Polish prices reflect the situation on the German market and what is the direction of price signals. There are also issues of price transmission which have recently drawn considerable attention. No doubt the attractiveness of this topic has grown since the first food crisis (the price rise in 2007-2008) was observed on international agricultural markets which were under the turmoil of rising volatility of prices with a possibility of the change in the long-term downward trend of agricultural prices [European Commission 2008, 2011; Irwin and Good 2009].

Methods applied

To analyse different aspects of price linkage between the German and Polish wheat market several methods were applied. The price series (y_t) were decomposed into long-term trend (TC_t), seasonal (S_t) and random fluctuations (I_t) using multiplicative model: $y_t=TC_tS_tI_t$. Seasonality effect was identified using regression model with seasonal dummy variables (0/1). The long-term trend was estimated through smoothing using Hodrick--Prescott filters. This part of the analysis allowed us to evaluate the share of seasonal and long-term fluctuations in the total variance of the price series.

Price series usually behave as non-stationary processes, so in order to verify this presumption each of the series was tested for unit root using the Augmented Dickey-Fuller (ADF) test. Null hypothesis states that time series is non-stationary (has unit root) against the alternative of stationarity. ADF test statistic is based on *t*-statistic of coefficient φ from OLS estimation of the following formula [Lütkepohl, Krätzig 2007]:

$$\Delta y_t = \alpha_t + \varphi y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta y_{t-i} + \varepsilon_t \tag{1}$$

where: y_t – analysed price series, α_t – deterministic term (constant, trend), p – the number of lags ensuring white noise properties of random component ε_t, δ_i – coefficients describing the short-run persistence of Δy_t. The number of lags p was determined with the use of Akaike's Information Criterion (AIC).

Evaluating the nature of the relation between wheat prices, the concept of Granger causality was employed. A variable x is said to Granger-cause y if we can better forecast y using lagged values of x than we can without them [Kusideł 2000, Lütkepohl and Krätzig 2007]. Applied Granger causality test formula is presented below:

$$y_t = a_0 + \sum_{j=1}^{k} \alpha_j y_{t-j} + \sum_{j=1}^{k} \beta_j x_{t-j} + \varepsilon_t \tag{2}$$

where a_0, α_j, β_j, are model parameters, y and x are analysed variables, k – the greatest lag length, ε_t – white noise. Null hypothesis, stating no Granger causality, assumes that $\beta_1=\beta_2=\ldots=\beta_k=0$ against alternative of these coefficients statistically significant. Determining the number of lag length we applied Vector Autoregression Model (VAR) and AIC.

Vector Autoregression Model consists of regression of every non-lagged variable on all lagged variables. Its formula is presented below [Kusideł 2000; Tsay 2010]:

$$Y_t = \psi D_t + A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots. + A_p Y_{t-p} + u_t \tag{3}$$

where Y_t – stochastic processes collected in $n \times 1$ vector, D_t – deterministic variables vector, Ψ – matrix of deterministic variables parameters, A_i are $(n \times n)$ coefficient matrices, p means order of VAR model.

To test the existence of the long-term relationship of series a Johansen cointegration framework based on Vector Error Correction Model was applied. The nonstationary time series are cointegrated if there is a linear combination of them that is stationary I(0). The linear combination of two series is referred to as a long-run equilibrium relationship. The VECM can be presented in a form [Tsay 2010]:

$$\Delta Y_t = \psi D_t + \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + u_t \tag{4}$$

where: $\Pi = A_1 + \ldots + A_p - I_n$ and $\Gamma_i = -\sum_{j=i+1}^{p} \Pi_j$, i= *1,…, p-1*. The matrix Π is called the long-run impact matrix and Γ_i are the short-run impact matrices. Matrix Π can be decomposed

Π=*αβ'*, where *α* – matrix of parameters expressing adjustment to the long-run relationship, *β* – matrix of cointegration vectors expressing long-run relationship [Kusideł 2000; Tsay 2010].

Since the rank of the long-run impact matrix *Π* gives the number of cointegrating relationships in Y_t, Johansen formulates likelihood ratio (LR) statistics for the number of cointegrating relationships as LR statistics for determining the rank of *Π*. The trace statistic LR_{trace} is as follows:

$$LR_{trace} = -T \sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i) \tag{5}$$

where: *T* is the sample size and $\hat{\lambda}_i$ is the *i-th* largest canonical correlation (eigenvalues of the matrix Π). The trace test tests the null hypothesis of *r* cointegrating vectors against the alternative hypothesis of *n* cointegrating vectors.

Data and preliminary analysis

Empirical analysis of price linkage between Polish and German markets was conducted on the basis of weekly procurement prices of milling (M) and feed (F) wheat (Fig. 1). Source of the statistical information was European Commission. The price series consisted of 439 observations and covered the period from January 2005 to May 2013.

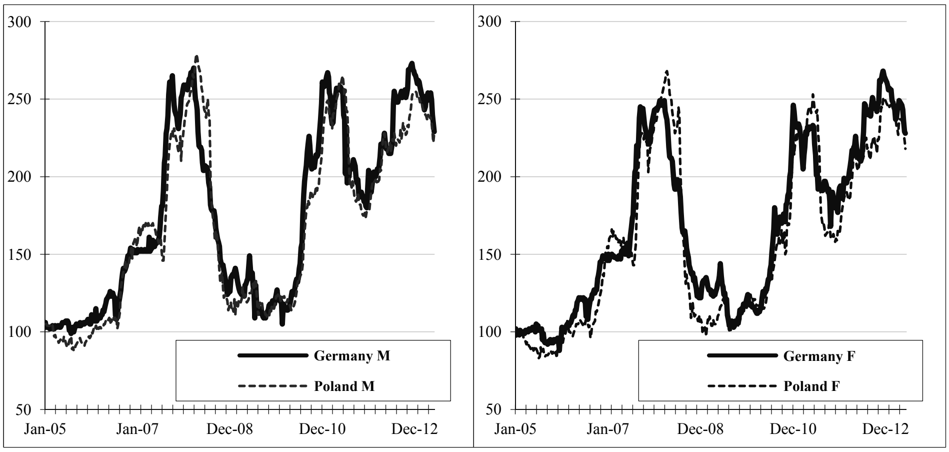

Fig. 1. Weakly procurement milling (M) and feed (F) wheat prices in Poland and Germany denominated in euro/tonne

Source: own calculation based on European Commission data.

A cursory analysis of the chart indicates the upward trend of all price series and the existence of high correlation between them. To analyse the patterns existing in the data, decomposition of price series was applied. Obtained long-term tendency patterns are similar in Poland and Germany. There is no substantial time lag between price cycles in Poland and Germany. The cross-correlation coefficients for corresponding price series (seasonally adjusted and smoothed) are the highest for the lag of one week.

The analysis allowed us also to evaluate the share of seasonality in the total variance of the price series (Fig. 2). According to the results obtained, seasonality is not important as the long term tendency part of the price series variation. Seasonality is responsible for 0.3-1.3% of the total variation of prices. Seasonality patterns in Poland are lagged a few weeks in comparison to seasonality observed in Germany. Such a shift (more visible in the case of feed prices) is due to time lag in harvest in Poland and the impact of earlier time of harvest in southern European countries on German market (geographical location of Germany).

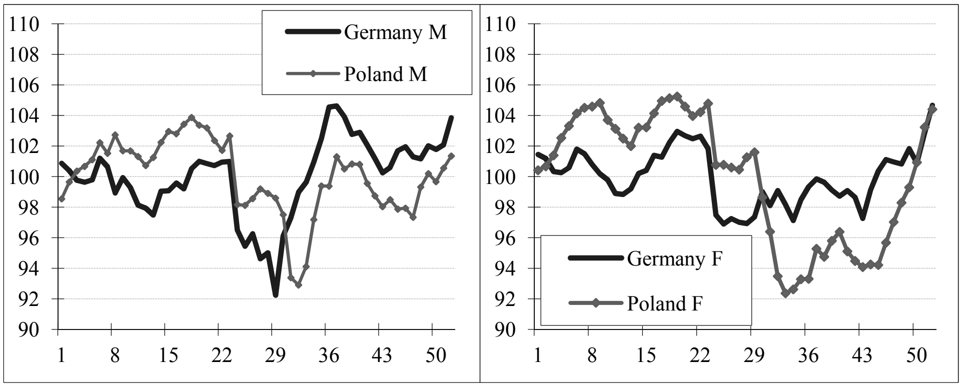

Fig. 2. Seasonal indices for wheat price series (multiplicative model)

Source: own calculation.

One of the most important features of price series that influence the choice of method applied is the order of integration of such series. Price series usually behave as non-stationary (unit root) processes. In order to verify this presumption each of the series (in natural logs) was tested for existence of unit root using the Augmented Dickey Fuller test (ADF). Null hypothesis stating that a given price series follows unit root processes cannot be rejected for procedures: with constant as well as with constant and linear trend. When applying the considered test for the first differences of price series the null hypothesis was rejected, which leads us to the conclusion that all price series are integrated in order one I(1). Use of the ADF test for seasonally adjusted data does not change the final outcomes.

Price transmission analysis

In this chapter the issue of linkage between corresponding wheat prices in Poland is considered. As there are some premises which may suggest different behaviour of relationships till 2008 and since 2009, some of the analyses were conducted for two separate sub-periods.

One of the most important questions in economics concerns the direction of causality. In other words, we are interested in answering the question: what are the causal mechanisms between the wheat prices in Poland and the wheat prices in Germany. To test it a Granger causality test in the framework of VAR model was applied. As all price series are integrated in order one and the seasonality effect is negligible, all price series were in first differences of their logs (d_l). All lags were chosen according to AIC criterion.

Results presented in Table 1 indicate that in most cases there are two-way relationships. However, the impact of German prices on Polish ones is much stronger than vice versa. Most research done on the basis of monthly data suggests one-way Granger-causality. When going into details some changes of direction of causality are observed. In the case of milling wheat prices in 2005-2008 there was no impact of Polish prices on German ones. In line with the deterioration the self-sufficiency ratio in Germany, the impact of conditions in the Polish market on German milling wheat prices seems to be higher (period 2009-2013). The situation is the opposite in the case of feed wheat prices. After 2009, Polish feed prices are not the cause in the Granger sense for Germans ones. The reasoning of such a change might be decrease of demand for feeders due to dramatic drop of pig population in Poland after 2008.

Table 1. Granger causality test results

Independent variable	Dependent variable	Milling wheat prices		Feed wheat prices	
		F-statistic	P-value	F-statistic	P-value
2005-2013					
d_l_Poland	d_l_Germany	3.23	0.012	2.72	0.020
d_l_Germany	d_l_Poland	17.42	0.000	9.77	0.000
2005-2008					
d_l_Poland	d_l_Germany	0.72	0.610	3.49	0.017
d_l_Germany	d_l_Poland	7.85	0.000	5.87	0.001
2009-2013					
d_l_Poland	d_l_Germany	3.16	0.015	1.41	0.236
d_l_Germany	d_l_Poland	9.17	0.000	11.12	0.001

Source: own calculation.

Even though there are short-run relationships between prices there might also be a long-run relationship implying the fact that prices follow the same trends. Figure 1 and the graph presenting the percentage differences between corresponding German and Polish wheat prices (Fig. 3) suggest the existence of such long-run association. Let's start from analysing that, over the analysed period Polish prices have been by 4.4% (milling) and 5.7% (feed) on average lower than German prices. However, there were quite considerable short-term divergences between corresponding prices (+/-25%). There might be different reasons for price differential (market fundamentals, delayed adjustment of prices due to market imperfections, etc.).

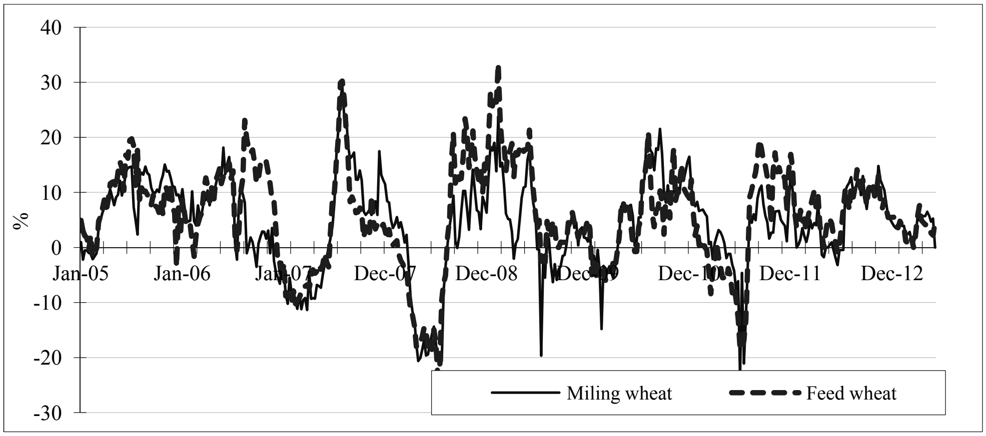

Fig. 3. Percentage difference between German and Polish wheat prices

Source: own calculation based on European Commission data.

To test the presence of a long-run relationship the Johansen procedure for a pair of price series was applied. Results obtained (Table 2) indicate the existence of one cointegration vector which is evidence of a long-run equilibrium relationship between Polish and German prices. In other words, they follow the same trends and if any discrepancies (Fig. 3) occur there are forces which push them to long-run equilibrium. If there is a linear relationship between two data series, there must also be a causal relationship. Granger [1969] introduced the concept of causality and noted that cointegration implies causality. Accordingly, finding prices to be cointegrated can be regarded as evidence of causality, although it need not be bi-directional.

Table 2. Johansen cointegration test (LR trace) results between logs of corresponding wheat prices in Poland and in Germany (model with unrestricted constant)

H_0	Milling wheat prices (lag 5)			Feed wheat prices (lag 4)		
	Eigenvalue	Statistic	P-value	Eigenvalue	Statistic	P-value
r=0	0.042	21.665	0.004	0,055	27.290	0.001
r≤1	0.007	2.9525	0.086	0.006	2.457	0.117

Source: own calculation based on European Commission data.

Table 3 presents selected results of VECM models estimation. For all cases beta coefficients are close to 1 so the shape of Error Correction Term (ECT) is analogous to the price differences presented in Figure 3. The values of β vector (close to 1) suggest the presence of LOP and its strengthening over time. Coefficient α (called speed-of-adjustment coefficient) expresses the response of prices to the previous period's deviation from long-run equilibrium. For the whole period and both types of wheat prices we can observe that adjustment to the long-run equilibrium is mostly on the Polish side. The speed-of-adjustment coefficients for German prices are not statistically significant which leads us to the conclusion that German price series are weakly exogenous in the system of prices. In the case of milling wheat we can note the increase of speed-of-adjustment coefficients for Polish as well as for German prices over the examined period. In the second period (2009-

2013) there are some noticeable signs of adjustment to the long run-equilibrium on the German side too (α =0.083, p=0.069) which confirm results from Granger-causality test.

Table 3. Estimation of VECM models– cointegration relationship (β) and coefficients of the long-run convergence (α) – model with unrestricted constant

Beta / Dependent variable	2005-2013		2005-2008		2009-2013	
	α	p-value	α	p-value	α	p-value
Milling wheat prices						
β vector	1; -1.051		1; -1.145		1; -0.979	
l_Poland B	-0.068	<0.001	-0.060	0.008	-0.111	<0.001
l_Germany B	0.021	0.302	0.012	0.553	0.083	0.069
Feed wheat prices						
β vector	1; -1.056		1; -1.107		1; -1.018	
l_Poland F	-0.081	0.000	-0.084	<0.001	-0.085	<0.001
l_Germany F	-0.008	0.590	-0.011	0.570	0.001	0.966

Source: own calculation based on European Commission data.

Assuming (according to the results of Granger test and VECM) that the main direction of price transmission is from German (which represent foreign markets) to Polish prices, a decomposition of forecast error variance was calculated. The variance decomposition indicates the amount of information each variable contributes to the other variables in the model. According to the results presented in Figures 4 and 5, the influence of domestic factors on the Polish prices prevails over the foreign market factors in the horizon of 6-8 weeks. In the long perspective, internal factors are responsible for 7-20% of the total Polish wheat price variance. It is worth noticing that the analysis indicates an increasing importance of domestic factors in the Polish market of milling wheat (Fig. 4).

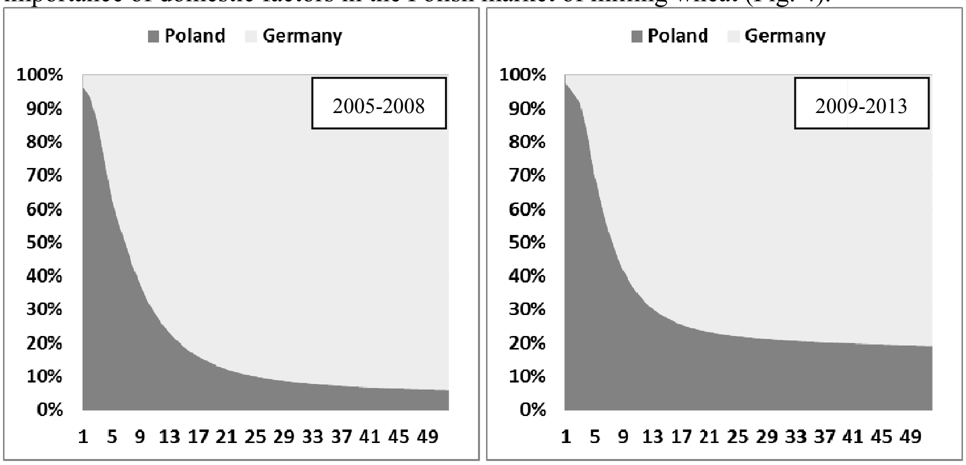

Fig. 4. Variance decomposition of forecast errors for Polish milling wheat prices

Source: own calculation based on European Commission data.

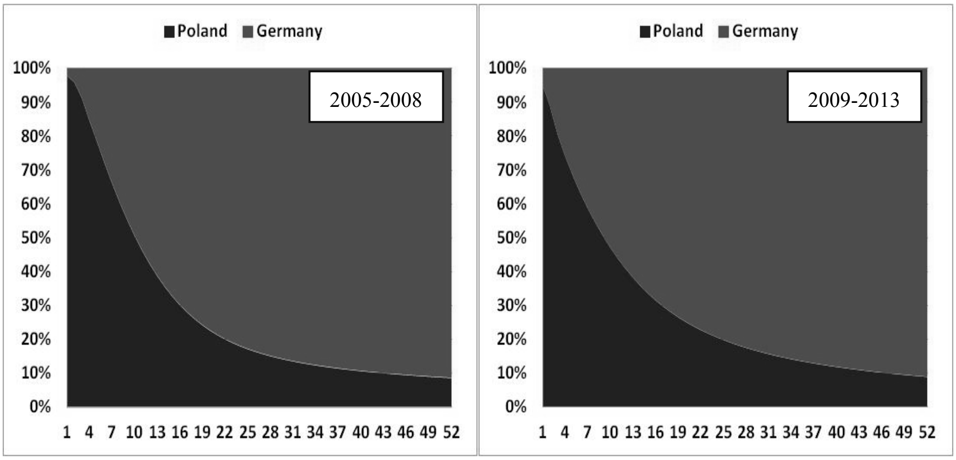

Fig. 5. Variance decomposition of forecast errors for Polish feed wheat prices

Source: own calculation based on European Commission data.

Summary

Over time there were numerous developments on the cereal market such as changes in the structure of production and demand resulting in an increase of prices and their volatility. The recent development of biofuel policies is regarded as one of the most important drivers of wheat prices.

Over the period of 2005-2013 price cycles in Poland and Germany were overlapping. The share of seasonal fluctuations in the total variance of the price series is of minor importance.

The analysis indicated an existence of a long-run equilibrium relationship between Polish and German price series. A great majority of adjustments to the long-run equilibrium take place on the Polish side which is also confirmed by the Granger causality test. After 2009, along with the deterioration of self-sufficiency in the German wheat market, there have been signals of a growing importance of domestic factors in respect to milling wheat price formation in Poland.

Analytical work conducted in this paper can be extended further in the field of asymmetric adjustments testing as well as in respect to regional analysis within the concerned countries. It also may be supplemented with more detailed testing of LOP.

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