

Empirical Paper

Piotr Ciżkowicz[✉], Jarosław Janecki^{*}, Jakub Olipra[✉], Wiktor Wojciechowski[✉]

Local agricultural markets and external shocks – the case of Poland

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Abstract:

We quantify the role of individual factors in shaping the domestic prices of selected grains and oilseeds in Poland and test the hypothesis of whether a favorable supply situation can isolate the domestic market from external shocks. We carried out estimations using error correction and local projection econometric models. The results lead to the following conclusions. First, futures contracts have a significant impact on domestic prices of wheat, corn, and rapeseed. Second, an important factor that determines the prices of wheat, corn, and rapeseed is the EUR/PLN exchange rate. However, the strength of this influence and its time horizon differs strongly depending on the analyzed commodity. Third, the influence of other factors is limited. The obtained results indicate that Poland's relatively high degree of self-sufficiency in the production of wheat, corn, and rapeseed does not isolate the prices of these agricultural commodities from the impact of external factors.

Keywords: ECM model, exchange rate, food security, grains prices, local projections model, oilseeds prices
JEL Classification: D25, G32, G33

1 Introduction

Some market participants believe that a favorable supply situation should isolate domestic agricultural markets from external shocks occurring on the global market, and that domestic prices should be determined primarily by local factors. This contradicts empirical observations indicating a growing degree of integration of the domestic agricultural markets with the world market, which is conducive to a growing correlation of domestic and foreign prices. For this reason, the main objective of this study is to quantify the factors that influence the domestic agricultural prices and to test whether a favorable domestic supply situation isolates the local market from external shocks.

We based our research on the example of Poland, as this country is a relatively big producer of agricultural commodities, integrated with the European Union (EU) market. Furthermore, Poland had one of the largest exposures to the effects of war in Ukraine, owing to its location. Hence, we consider that Poland serves as a suitable example to test whether a favorable market situation can isolate the domestic market from external shocks and verify the most important factors that affect domestic prices.

This study was conducted on a sample of three commodities: wheat, corn, and rapeseed in 2015–2023. There are several arguments for such a selection of commodities. First, wheat, corn, and rapeseed are relatively homogeneous commodities which support the price transmission mechanism between markets. Second, Poland has a favorable domestic supply situation in the case of these three commodities. Third, the

***Corresponding author: Jarosław Janecki**, Collegium of Management and Finance, SGH Warsaw School of Economics, Warsaw, Poland. E-mail: jjanec@sgh.waw.pl

Piotr Ciżkowicz and Wiktor Wojciechowski, Collegium of Economic Analysis, SGH Warsaw School of Economics, Warsaw, Poland.
Jakub Olipra, Collegium of Management and Finance, SGH Warsaw School of Economics, Warsaw, Poland.

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prices of wheat, maize, and rapeseed were among the most affected markets due to the outbreak of war in Ukraine in 2022, which serves as a good sensitivity analysis for our estimates. Fourth, Poland was directly affected by the elevated imports of Ukrainian grains and oilseeds after the outbreak of war in Ukraine.

As part of the research, estimations were carried out using three types of econometric models: error correction, local projection, and local projection models with additional analysis of the conditions prevailing on the currency market. Among the potential determinants of the prices of grains and oilseeds on the domestic market were the prices of futures contracts for wheat, corn, and rapeseed; the level and volatility of the exchange rate; sea freight prices; the volume of domestic crops; and seasonal factors.

We structure our paper as follows: In Section 2, we analyze the characteristics of the grains and oilseeds market. In Section 3, we analyze the literature on the main subject of the research and give an analysis of changes in the domestic prices of grains and oilseeds. In Section 4, we provide an econometric analysis of the examined relationships, and in Section 5 we conclude.

2 General characteristics of the market of grains and oilseeds

2.1 Grains and oilseeds market in Poland

According to Eurostat data, in 2021 Poland ranked fourth in the EU in terms of grain export volume (after France, Romania, and Germany). In the structure of Polish grain exports in 2015–2021, wheat and corn were the most important, accounting for 53.4% and 20.5% of its volume, respectively. It is worth noting the increasing share of corn in Polish exports of grains, which is a result of the above-mentioned growing domestic production.

Due to the geographical conditions of Poland, the domestic production of oilseeds is dominated by the production of rapeseed. In the years 2015–2021, its average annual production amounted to ≈ 2.7 million tons, which was the third highest in the EU (after France and Germany). The average annual consumption of rapeseed in Poland in 2015–2021 amounted to 2.7 million tons, and in the analyzed period it was in an upward trend. Thus, although at the beginning of the analyzed period Poland recorded a surplus in rapeseed trade, in recent years it has become its net importer. It should be noted that the domestic demand for high-protein crops is not limited only to rapeseed, and due to the growing domestic animal production, Poland is heavily dependent on imports of oilseed meals (in particular, soybean meal) and vegetable oils.

3 Literature review

In empirical research on the factors that determine the prices of cereals and oilseeds, the key aspect is the theory of price transmission in the agricultural sector. The reactions of local agricultural markets to external shocks are also examined, including the impact of exchange rates on prices in agricultural markets. It should be noted that various quantitative methods are used in the study of pricing mechanisms. All these elements are presented later in the paper.

3.1 Price transmission within the agricultural sector

The concept of price transmission has its roots in the Law of One Price. According to this concept, the price difference between the same goods in two different markets is at most equal to the trade costs between these markets [Baffes, 1991; Mundlak and Larson, 1992; Fackler and Goodwin, 2001]. Economists have noticed that price transmission depends on many factors. We see this in the extensive literature on price transmission. Six factors can be distinguished as follows [Olipra, 2020]:

- (1) Product uniformity [Minot, 2010];
- (2) Transport infrastructure – the worse it is, the higher the costs [Balcombe et al., 2007; Taravaninthorn and Raballand, 2009; Jaramillo-Villanueva and Benítez-García, 2016; Kabbiri et al., 2016];

- (3) Market institutions and competition, including, for example, the number of traders in a given market [Goodwin and Schroeder, 1991; Morisset, 1998; Azzam, 1999; Goodwin and Holt, 1999; Wohlgemant, 1999; McCorriston et al., 2001; Ghoshray, 2007; Minot, 2010; McLaren, 2015];
- (4) Access to price information – the possibility of price arbitrage [Bayes, 2001; Abraham, 2006; Jensen, 2007, 2010; Donner, 2008; Muto and Yamano, 2009; Minot, 2010; Jaramillo-Villanueva and Benítez-García, 2016; Kabbiri et al., 2016];
- (5) Frequency and scale of trade – the larger the trade volume, the greater the degree of price transmission [Gabre and Zaude, 2001; Gonzales-Rivera and Helfand, 2007; Jensen, 2010];
- (6) Government policies, including tariff barriers, import/export quotas and import/export bans [Conforti, 2004; Minot, 2010; Ghoshray, 2011; Arnade et al., 2017], intervention mechanisms and minimum/maximum prices [Conforti, 2004; Minot, 2010; Ghoshray, 2011], and manipulation of exchange rates [Conforti, 2004].

To sum up, price transmission research focuses on several different areas, the main ones being as follows [Olipra, 2020]:

- The impact of market deregulation and trade liberalization on the transmission of prices on agricultural markets;
- The direction of the relationship between prices on agricultural markets;
- Effectiveness of government intervention in deregulated agricultural markets;
- Identification of the role of local factors in determining prices (e.g., seasonality).

3.2 Selected empirical research on local agricultural markets and external shocks

The subject of the impact of exchange rates on the prices of agricultural products is extremely rich. For example, according to Schuh [1974, 1984], the exchange rate plays a key role in all aspects of agriculture. Bessler and Babula [1987] assessed the effects of changes in exchange rates on the prices and sale of wheat, including transport prices. Bradshaw and Orden [1990], on the other hand, using Granger causality, tested the effect of exchange rates on agricultural prices and exports. Most studies confirm that exchange rates are an important factor that determine the prices, supply, and demand in the agricultural market [Paarlberg et al., 1994]. While the very impact of exchange rates on the processes of setting prices for agricultural products and the value of trade is indisputable, there is still no consensus about how important their role is. It is pointed out that their impact on individual commodity groups differs [Tweeten, 1992], and that the sensitivity of grains to exchange rate changes depends on whether more of them are exported than consumed domestically [Rausser et al., 1986]. The attention of economists was also drawn to the issue of the impact of monetary shocks (a sharp increase in the money supply) on the prices of agricultural products. For example, Orden and Fackler [1989] showed that a shock change in the money supply also contributes to the volatility of agricultural prices.

In addition, it is also an open question to determine the macroeconomic variables that may affect price processes in the agricultural market. Empirical studies show different results in this case. A broad discussion of this issue can be found in a literature review on the relationship between exchange rates and prices of agricultural products, by Kristinek and Anderson [2002]. Their study discussed in detail the issue of the role of the exchange rate in agriculture, emphasizing that most studies confirm the relationship between exchange rate changes and prices of agricultural products and their exports. An interesting study was conducted by Johnson et al. [1977], who compared the effect of the exchange rate with the effect of foreign trade policy on US wheat prices. They found that foreign trade policy, designed to protect consumers from rising prices, had a greater impact on domestic wheat prices than US monetary policy. They determined that the devaluation of the dollar had a positive effect on domestic wheat prices through increased export demand and thus lower domestic supply.

The results of research conducted by Rembeza and Seremak-Bulge [2009] draw attention to the analysis of price transmission between domestic and foreign markets. Their study for the years 1996–2008 shows

that domestic and foreign grains prices are co-integrated. Foreign prices strongly influence corn prices in Poland, but there was practically no impact of Polish grains prices on foreign ones.

3.3 Quantitative methods in the study of agricultural commodity prices

Various types of econometric models are used in studies of the situation on the grain market. Often, these are models of extrapolation of the trend function, which are the simplest way to forecast phenomena characterized by a trend. In the case of time series of prices of agricultural products, medium-term deviations in the form of quasi-cyclic fluctuations can be observed. Therefore, models extended with an autoregressive component are used. In addition, adaptive models are also used, where the parameters of the models adapt to changes over time. This group of models includes exponential smoothing models, the Holt model with a fading trend. Models with explanatory variables, VAR and VECM vector autoregressive models, and partial equilibrium models of the agricultural sector are also used for forecasts.¹

They include classic time series decomposition,² regARIMA methods, simple Holt model, or Holt model with a smoothing factor.³ It should also be noted that the frequently highlighted problems relating to the time series of prices of agricultural products are their lack of stationarity and the occurrence of seasonality. However, the methods do not take into account long-term relationships and the assessment of the impact of these relationships in response to a given shock.

To sum up, in the case of Poland, more detailed analysis is required to quantify the factors that influence the domestic prices of agricultural products. Moreover, it should be checked whether in the event of external shocks, factors such as a favorable supply situation in the country may isolate the local market.

4 Data and methodology

The purpose of the econometric analysis is to empirically verify the factors determining the purchase prices of selected grains and oilseeds in Poland in the period from January 2015 to October 2023.

Among the explanatory variables, the prices of futures contracts were analyzed, as well as the exchange rate, sea freight prices, the volume of domestic crops, and seasonal factors. Taking these variables into account allowed to verify the importance of global factors (prices of futures contracts, freight prices) and domestic factors (exchange rate, size of domestic yields, and seasonal effects) in shaping the prices of grains and oilseeds on the Polish market. In addition, the subject of the study was to determine whether the level of the exchange rate and its volatility have a significant impact on the extent to which futures prices affect the domestic prices of grains and oilseeds.

The basis for the inference was estimation of the parameters of a number of econometric models using monthly data on domestic prices of grains and oilseeds published by the Central Statistical Office and the Ministry of Agriculture, monthly data on prices of futures contracts for these commodities published by Euronext, annual data on the yields of grains and oilseeds in Poland, available in the Eurostat database, as well as monthly and daily National Bank of Poland (NBP) exchange rates (daily data were used to determine the volatility of the exchange rate in individual months). A detailed description of the data used in the analysis is provided in Table 1.

The inference was made based on the estimation results of the following types of econometric models:

1. *Error correction models*: These were used to verify long- and short-term relationships between domestic grain and oilseed prices, futures prices, and the exchange rate.

¹ These include, for example, the AGLINK-COSIMO models used by the FAO-OECD, and the FAPRI model used by the FAPRI Institute.

² This method is resistant to structural changes; its advantage is the ability to forecast the cyclical component using expert knowledge.

³ Hamulczuk [2013, pp. 61–62].

Table 1. Variables used in models

Variable	Description	Source
wheat_pln	Purchase price of wheat (PLN/t)	CSO in Poland
corn_pln	Purchase price of corn (PLN/t)	CSO in Poland
rapeseed_pln	Purchase price of rapeseed (PLN/t)	Ministry of Agriculture
wheat_crop	Wheat harvest volume in Poland (annual data)	Eurostat
corn_crop	Corn harvest volume in Poland (annual data)	Eurostat
rapeseed_crop	Rapeseed harvest volume in Poland (annual data)	Eurostat
wheat_eur_f	Wheat futures price at the end of the month (EUR/t)	Euronext
corn_eur_f	Corn futures price at the end of the month (EUR/t)	Euronext
rapeseed_eur_f	Rapeseed futures price at the end of the month (EUR/t)	Euronext
eurpln	EUR/PLN exchange rate at the end of the month	NBP
eurpln_sd	Standard deviation of the EUR/PLN exchange rate in each month calculated from daily quotations	Own calculations, NBP
freight	Sea freight price index on the European grain market at the end of the month (2013 = 100)	Own calculations, IGC*

Note: All data are in natural logarithms (excl. eurpln_sd and freight).

*IGC- International Grain Council

NBP, National Bank of Poland.

2. *Response function models:* These were used to determine the impact of futures prices on the domestic prices of grains and oilseeds over a 6-month horizon. Models of this class were also used to determine the reaction function of domestic prices of grains and oilseeds depending on the level and volatility of the exchange rate. In contrast to vector autoregression models, which are commonly used in price analyses on agricultural markets, the applied method allows for direct estimation of the response function parameters separately for each time horizon. This approach does not impose dynamic constraints, does not require high-frequency data, and is more resistant to erroneous specifications of the data generation process than VAR models [Auerbach and Gorodnichenko, 2012].

5 Results

5.1 Error correction models for prices of grains and oilseeds

The analysis of domestic prices of grains and oilseeds with the use of error correction models was carried out using a two-stage procedure proposed by Engel and Granger [1987].⁴ The parameters of the error correction model were estimated in the following form:

$$\Delta y_{i,t} = \beta_0 + \theta(y_{i,t-1} - \alpha_1 x_{j,t-1} - \alpha_2 f x_{t-1} - \alpha_0) + \beta_1 \Delta y_{i,t-1} + \beta_2 \Delta x_{j,t-1} + \beta_3 \Delta f x_{t-1} + \epsilon_t \quad (\text{M. 1})$$

where:

$y_{i,t}$ – natural logarithm of commodity purchase prices i in period t ;

$x_{j,t}$ – natural logarithm of the futures price j in period t ;

$f x_t$ – natural logarithm of the EUR/PLN exchange rate used to quote futures prices for wheat, corn, and rapeseed in the period t ;

⁴ A detailed results for stationarity and cointegration tests are available upon request.

θ – parameter defining the rate of return of the dependent variable to long-term equilibrium;

ϵ_t – random error.

In a properly defined long-term relationship, parameters α_1, α_2 should be positive, which is identical to the assumption that in the long run, the prices of futures contracts for a given agricultural commodity, the EUR/PLN, and domestic prices of a given agricultural commodity remain in a constant relationship. Its occurrence can be interpreted as a stable, long-term relationship to which the variables return when they deviate from equilibrium. This means that in the long term, domestic prices of the analyzed grains and oilseeds are determined by the prices of futures contracts and the level of the EUR/PLN. Similarly, it can be expected that the short-term parameters β_1, β_2 should be positive, which means that an increase in futures prices or depreciation of PLN leads to an increase in domestic grain prices. In the error correction model, the parameter θ should be negative, which ensures that deviations from the long-term relationship are gradually corrected. The closer the parameter θ is to -1 , the faster the rate of return to this relation is, while the closer it is to 0 , the slower the rate of return to equilibrium.

The obtained estimation results of the error correction models (Table 2) indicate as follows:

- *Wheat*: There is a long-term co-integration relationship between domestic wheat prices and wheat futures prices and the level of EUR/PLN. Deviations of domestic wheat prices from the long-term relation are systematically corrected. The point value of the parameter $\theta = -0.245$ means that 24.5% of these deviations are corrected within 1 month. Short-term parameters indicate that a 10% increase in wheat futures prices increased domestic wheat prices by $\approx 2.1\%$. Among the three analyzed grains, the short-term impact of the exchange rate on domestic prices was found only in the case of wheat.
- *Corn*: There is a long-term co-integration relationship between domestic corn prices and corn futures prices and the level of EUR/PLN. The point value of the parameter $\theta = -0.530$ means that 53.0% of deviations are corrected within 1 month. The rate of return of domestic corn prices to the long-term relationship turned out to be twice as fast as for domestic wheat prices. Surprisingly, the EUR/PLN appeared to be statistically significant and negative, which suggests that a lagged increase in the exchange rate (i.e., depreciation of PLN against EUR) lowers the domestic corn prices. This may be due to the relatively high speed of convergence coefficient (in absolute terms). Contrary to wheat, the short-term parameters for corn futures prices did not prove to be statistically significant. Interestingly, lagged changes in domestic corn prices turned out to be twice as large as for wheat and highly significant. This indicates that the domestic corn prices are predominantly determined at the national level.
- *Rapeseed*: There is a long-term co-integration relationship between the domestic prices of rapeseed and prices of rapeseed futures, and the level of EUR/PLN. The point value of the convergence parameter $\theta = -0.511$ means that 51.1% of deviations are corrected within 1 month. Similar to corn, the pace of return of domestic rapeseed prices to the long-term relationship is therefore twice as fast as in the case of domestic wheat prices. Short-term parameters for futures prices and the EUR/PLN did not turn out to be statistically significant.

5.2 Reaction function for domestic prices of grains and oilseeds

In this part of the study, the parameters of the reaction function of domestic prices of grains and oilseeds were estimated to changes in the prices of futures contracts, and then the parameters of the reaction function were also analyzed, distinguishing between the level and volatility of EUR/PLN.

In the analyzed models of the reaction function of the domestic prices of wheat, maize, and rapeseed in PLN, the main determinants were the prices of futures contracts for these agricultural commodities on the European market (in EUR), the exchange rate, the sea freight price index, and

Table 2. Error correction models

	Wheat	Corn	Rapeseed
eurpln	0.665*** (0.237)	0.948* (0.529)	0.898*** (0.260)
wheat_eur_f	1.05*** (0.040)		
corn_eur_f		0.922*** (0.091)	
rapeseed_eur_f			0.946*** (0.43)
cons	0.157 (0.226)	0.347 (0.474)	0.487* (0.250)
EC term ($t - 1$)	-0.245** (0.079)	-0.530*** (0.0876)	-0.511*** (0.0723)
Δ eurpln ($t - 1$)	0.488 (0.248)	-1.510** (0.568)	-0.265 (0.213)
Δ wheat_pl ($t - 1$)	0.217* (0.098)		
Δ wheat_eur_f ($t - 1$)	0.211* (0.101)		
Δ corn_pl ($t - 1$)		0.417*** (0.093)	
Δ corn_eur_f ($t - 1$)		0.085 (0.186)	
Δ rapeseed_pl ($t - 1$)			0.218** (0.071)
Δ rapeseed_eur_f ($t - 1$)			0.008 (0.10)
Cons	0.001 (0.004)	0.002 (0.009)	0.002 (0.003)
R2	0.401	0.380	0.604
N	104	104	104

Note: Standard errors of parameter estimates are given in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

the volume of domestic harvest of grains and oilseeds. The base specification of the model is as follows:

$$\Delta y_{i,h} = y_{i,t+h} - y_{i,t-1} = \alpha_0 + \alpha_{1,h} \Delta x_{i,t}^F + \alpha_2 f x_t + \alpha_3 freight_t + \alpha_4 crop_t + \alpha_5 month + \varepsilon_t \quad (M.2)$$

where:

$y_{i,t+h}$ – natural logarithm of domestic commodity purchase prices i in PLN, in period $t + h$, where $h = 0, 1, \dots, 6$;

$x_{i,t}^F$ – natural logarithm of commodity futures prices i in EUR, in period t ;

fx_t – natural logarithm of the EUR/PLN exchange rate at which futures contracts for wheat, corn, and rapeseed are quoted in the period t ;

$freight_t$ – change in the sea freight price index in period t ;

$crop_t$ – volume of domestic commodity harvest i in period t (the same value for all months of the year);

$month$ – vector of binary variables specifying monthly seasonal effects;

ϵ_t – the error term.

Among the control variables in the M.2 model, the first lags of changes in domestic prices of grains and oilseeds, futures prices, EUR/PLN, and changes in the freight price index were taken into account. In addition, the model specification includes changes in the prices of futures contracts for these agricultural commodities, the level of exchange rate, and changes in the sea freight price index for each analyzed horizon h . The model estimates obtained in this way are not biased by changes in these parameters in the analyzed horizon. For example, for $h = 2$, the model specification for wheat includes changes in wheat futures prices, EUR/PLN, and changes in the freight price index in the period $t + 1$ and $t + 2$. In the model M.2, the dependent variables were defined as the difference in the logarithms of the prices of the relevant agricultural commodities, determined separately for each time horizon $h = 0, 1, \dots, 6$. As a result, the parameter $\alpha_{i,h}$ should be interpreted as the cumulative change in prices of commodity i in the horizon h for the change in prices of futures contracts for commodity i on the European market in the period $t = 0$. Since we wanted to verify the impact of the exchange rate and futures prices on the development of domestic prices of agricultural commodities, the estimation results are supplemented with charts illustrating the impact of the hypothetical depreciation of PLN against EUR by 1% and an increase in futures prices by 1% on the domestic prices of wheat, corn, and rapeseed within 6 months.

The results of the estimation of the reaction function (Table 3) indicate as follows:

- (a) *Wheat*: Changes in wheat futures prices are very quickly reflected in changes in domestic wheat prices: a 1% change in wheat futures prices causes an immediate (i.e., at $t = 0$) increase in domestic wheat prices by about 0.5%, and from the following month (i.e., from period $t = 1, \dots, 6$) also by $\approx 1\%$. The depreciation in EUR/PLN raises domestic wheat prices, but these effects take place with a 1-month lag. The increase in domestic wheat prices does not prove to be driven by changes in the sea freight prices. The cumulative change in domestic wheat prices in response to the depreciation of the PLN against the EUR is statistically different from 0 from the first month of the projection and the response to futures prices turns out to be significant immediately (i.e., from month 0).
- (b) *Corn*: Changes in corn futures prices turned out to impact domestic corn prices, albeit these effects show up with a longer lag than it was the case for wheat. The weaker impact of the global situation on domestic corn prices is also evidenced by the fact that the effects of EUR/PLN are statistically significant only at the end of the analyzed horizon. Sea freight prices have not turned out to be a significant factor for shaping domestic corn prices. The domestic corn market is therefore very poorly integrated with the global market. Therefore, the results are consistent with the earlier analysis of the error correction model, in which the lagged changes in domestic corn appeared to play a significant role. The cumulative change in domestic corn prices in response to the depreciation of PLN against EUR is statistically different from 0 only from the fifth month after the occurrence of changes in the currency market.
- (c) *Rapeseed*: Changes in rapeseed futures prices are strongly reflected in the domestic prices of rapeseed over the whole analyzed horizon. It is worth noting that, unlike corn, rapeseed prices adjust to changes in EUR/PLN, albeit with a slight lag (i.e., around 2 months) compared with wheat. Sea freight prices did not prove to be a significant determinant of domestic rapeseed prices. The cumulative change in domestic rapeseed prices in response to the depreciation of PLN against EUR is statistically different from 0 since the second month of the projection. The obtained results prove a strong integration of the domestic rapeseed market with the world market, similarly as in the case of wheat.

Table 3. The reaction function of wheat prices in Poland (PLN) to changes in the price of futures contracts for wheat (in EUR)

		Month						
		0	1	2	3	4	5	6
Wheat	$\Delta \text{wheat_pl}(t-1)$	0.262*** (0.080)	0.437*** (0.122)	0.500*** (0.155)	0.415** (0.188)	0.324 (0.201)	0.431* (0.218)	0.426* (0.238)
	$\Delta \text{wheat_eur_f}$	0.494*** (0.053)	0.869*** (0.081)	0.999*** (0.102)	1.090*** (0.125)	1.142*** (0.131)	1.195*** (0.139)	1.101*** (0.144)
	$\Delta \text{wheat_eur_f}(t-1)$	0.253*** (0.067)	0.322*** (0.101)	0.402*** (0.133)	0.545*** (0.158)	0.637*** (0.167)	0.503*** (0.177)	0.583*** (0.189)
	Δeurpln	-0.020 (0.171)	0.375 (0.273)	0.569 (0.362)	0.845* (0.431)	0.748 (0.464)	1.035** (0.504)	1.000* (0.529)
	$\Delta \text{eurpln}(t-1)$	0.333* (0.179)	0.580** (0.277)	0.868** (0.353)	0.697 (0.426)	0.858* (0.458)	0.903* (0.481)	0.792 (0.502)
Corn	$\Delta \text{corn_pl}(t-1)$	-0.018 (0.112)	-0.215 (0.149)	-0.181 (0.168)	-0.156 (0.188)	-0.163 (0.208)	-0.318 (0.226)	-0.293 (0.233)
	$\Delta \text{corn_eur_f}$	0.228 (0.153)	0.331 (0.210)	0.742*** (0.239)	0.837*** (0.269)	1.014*** (0.292)	1.061*** (0.320)	0.988*** (0.338)
	$\Delta \text{corn_eur_f}(t-1)$	0.157 (0.154)	0.618*** (0.207)	0.695*** (0.239)	0.885*** (0.263)	0.946*** (0.300)	0.886*** (0.324)	0.931*** (0.333)
	Δeurpln	0.839* (0.458)	0.431 (0.650)	0.789 (0.771)	0.508 (0.864)	0.754 (0.973)	1.883* (1.045)	2.641** (1.074)
	$\Delta \text{eurpln}(t-1)$	-0.169 (0.479)	0.358 (0.665)	0.286 (0.754)	0.232 (0.862)	0.950 (0.954)	2.165** (0.998)	1.011 (1.062)
Rapeseed	$\Delta \text{rapeseed_pl}(t-1)$	0.172** (0.082)	-0.017 (0.111)	-0.033 (0.115)	0.152 (0.131)	0.248* (0.143)	0.347** (0.158)	0.343* (0.181)
	$\Delta \text{rapeseed_eur_f}$	0.318*** (0.070)	0.706*** (0.101)	1.037*** (0.104)	1.070*** (0.117)	0.864*** (0.126)	0.979*** (0.136)	1.041*** (0.144)
	$\Delta \text{rapeseed_eur_f}(t-1)$	0.412*** (0.081)	0.826*** (0.108)	0.846*** (0.116)	0.677*** (0.127)	0.704*** (0.135)	0.744*** (0.149)	0.831*** (0.156)
	Δeurpln	0.263 (0.213)	0.377 (0.296)	0.538* (0.317)	0.881** (0.341)	1.304*** (0.367)	1.484*** (0.414)	1.396*** (0.442)
	$\Delta \text{eurpln}(t-1)$	-0.078 (0.223)	0.164 (0.304)	0.458 (0.315)	0.578 (0.350)	0.910** (0.375)	0.788* (0.406)	0.812* (0.428)

Note: The table does not present estimates for monthly seasonal variables, the intercept, the freight prices, and crop volumes. The latter two turned out to be insignificant in most cases. Standard errors of model parameter estimates are given in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.3 Reaction function of grain prices to futures prices depending on FX market conditions

In this part of the study, it was verified whether the level and volatility of the exchange rate affect the parameters of the response function of domestic prices of grains and oilseeds to changes in futures prices. The level and volatility of the exchange rate refer here to the average values of these measures observed in the analyzed period, that is, January 2015–October 2023. The basis for inferring the impact of the situation

on the currency market on the prices of grains and oilseeds was estimation of the parameters of the modified M.2 model specification of the following form:

$$\begin{aligned} \Delta y_{i,h} = & \alpha_0 + \alpha_{11,h}^L F(x_t) \Delta x_{j,t} + \alpha_{12,h}^L F(x_t) \Delta x_{j,t-1} \\ & + \alpha_{21,h}^H (1 - F(x_t)) \Delta x_{j,t} + \alpha_{22,h}^H (1 - F(x_t)) \Delta x_{j,t-1} + month + \varepsilon_t \end{aligned} \quad (M.3)$$

where:

$$F(x_t) = \frac{\exp(-\gamma * x_t)}{1 + \exp(-\gamma * x_t)}, \quad \gamma > 0$$

is the so-called “smooth transition function” proposed by Auerbach

and Gorodnichenko [2012], for estimating the parameters of the function of the economy’s response to fiscal shocks in various macroeconomic conditions. Function F uses the logistic transformation of the standardized parameter x , which in our application illustrates the conditions on the domestic currency market identified by the level or volatility of the EUR/PLN.⁵ The estimated parameters of the model have the following interpretations:

- Sum of parameters $\alpha_{11,h}^L + \alpha_{12,h}^L$ means a cumulative change in the prices of the analyzed commodity in PLN in response to a change in the price of futures contracts in EUR in the horizon of h months in conditions of a low EUR/PLN or low EUR/PLN volatility;
- Sum of parameters $\alpha_{21,h}^H + \alpha_{22,h}^H$ means a cumulative change in the prices of the analyzed commodity in response to a change in the price of futures contracts in EUR in the horizon of h months in conditions of a sufficiently high level of EUR/PLN or high volatility of EUR/PLN.

To assess whether the reaction functions differ significantly depending on the situation on the currency market, the standard Student’s t -test was used to verify the equality of the following linear combination of parameters: $\alpha_{11,h}^L + \alpha_{12,h}^L = \alpha_{11,h}^H + \alpha_{12,h}^H$. The null hypothesis in this test is that the sums of the two parameters do not differ from each other. The sums of both parameters and the significance level of the linear restriction test for each projection horizon are presented in the tables with the estimation results.

The conducted analysis shows as follows (Table 4):

- Wheat*: The impact of futures changes on the domestic wheat prices varies depending on the level and volatility of EUR/PLN. In the conditions of PLN depreciation, an increase in wheat futures prices results in stronger fluctuations of domestic wheat prices than in the conditions of PLN appreciation. These differences are statistically significant up to the fourth month from the moment of changes in futures prices. The increased volatility of EUR/PLN also contributes to strengthening of the reaction of domestic prices to changes in futures prices, with this effect being statistically significant only in the month in which changes in futures prices occur. These results therefore indicate that in conditions of significant depreciation and (often accompanied by) high volatility of the exchange rate, domestic prices are adjusted to a greater extent to world prices, probably due to the potentially higher costs of not adjusting, than in the case of a strong and stable zloty exchange rate.
- Corn*: The impact of futures changes on domestic corn prices is no different depending on the level and volatility of EUR/PLN.
- Rapeseed*: Point estimates of parameters indicate that when EUR/PLN is above its average values observed in the sample, the rising prices of rapeseed futures are accompanied by an increase in prices of this commodity on the domestic market. On the other hand, for the low level of EUR/PLN in relation to its average level in the sample, this effect did not turn out to be statistically significant. The volatility of EUR/PLN did not have a significant impact on the scale of impact of changes in futures contracts on domestic rapeseed prices.

⁵ Similar to Auerbach and Gorodnichenko [2012], we assumed the value of the scaling parameter $\gamma=1.5$ in our study.

Table 4. Wheat: the reaction function to changes in the price of futures contracts for wheat, corn, and rapeseed (EUR) depending on the level and volatility of the EUR/PLN exchange rate

		Month						
		0	1	2	3	4	5	6
Wheat	Appreciation	0.630*** (0.187)	0.922*** (0.326)	1.078** (0.528)	1.340* (0.720)	1.278 (0.879)	1.267 (1.042)	1.386 (1.212)
	Depreciation	0.823*** (0.114)	1.379*** (0.200)	1.467*** (0.324)	1.485*** (0.444)	1.652*** (0.561)	1.601** (0.672)	1.816** (0.786)
	Difference	0.455	0.309	0.594	0.884	0.760	0.819	0.801
	Low Vol.	0.570*** (0.154)	1.134*** (0.264)	1.405*** (0.421)	1.716*** (0.580)	1.886*** (0.710)	1.824** (0.841)	1.612* (0.963)
	High Vol.	0.968*** (0.154)	1.442*** (0.264)	1.512*** (0.424)	1.467** (0.581)	1.565** (0.709)	1.622* (0.833)	2.375** (0.961)
	Diff (t-test)	0.139	0.502	0.885	0.806	0.794	0.889	0.647
Corn	Appreciation	-0.192 (0.528)	-0.474 (0.703)	0.746 (0.836)	1.768* (0.999)	1.618 (1.135)	0.910 (1.289)	1.500 (1.394)
	Depreciation	0.675** (0.318)	1.847*** (0.427)	1.934*** (0.520)	1.877** (0.622)	2.571*** (0.720)	3.100*** (0.816)	3.126*** (0.905)
	Difference	0.234	0.018	0.310	0.938	0.550	0.228	0.408
	Low Vol.	-0.370 (0.466)	-0.247 (0.627)	1.245* (0.747)	1.800** (0.877)	2.379** (1.008)	3.551*** (1.142)	3.542*** (1.232)
	High Vol.	1.008*** (0.376)	2.073*** (0.516)	1.983*** (0.639)	2.244*** (0.746)	2.552*** (0.849)	1.894* (0.968)	2.390** (1.058)
	Diff (t-test)	0.060*	0.021**	0.541	0.753	0.914	0.367	0.560
Rapeseed	Appreciation	0.498 (0.311)	0.720 (0.441)	0.804 (0.625)	0.526 (0.920)	0.342 (1.206)	0.067 (1.391)	-0.122 (1.563)
	Depreciation	0.782*** (0.124)	1.789*** (0.175)	2.340*** (0.249)	2.403*** (0.366)	2.449*** (0.491)	2.710*** (0.568)	3.078*** (0.642)
	Difference	0.456	0.050	0.047	0.097	0.152	0.119	0.094
	Low Vol.	0.810*** (0.203)	1.621*** (0.286)	1.735*** (0.403)	1.727*** (0.573)	1.563** (0.755)	1.471* (0.865)	1.103 (0.942)
	High Vol.	0.701*** (0.170)	1.594*** (0.246)	2.343*** (0.348)	2.422*** (0.493)	2.570*** (0.638)	2.974*** (0.729)	3.794*** (0.802)
	Diff (t-test)	0.738	0.954	0.357	0.457	0.405	0.277	0.077

Note: Only aggregated coefficients of the impulse response functions for low and high EUR/PLN FX level (upper panel) and low and high EUR/PLN volatility (lower panel) are presented. Detailed results are available upon request. Standard errors are given in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6 Discussion of the results

The aim of the article was to quantitatively assess the role of individual factors in shaping the domestic prices of selected grains and oilseeds (wheat, maize, and rapeseed) and test the hypothesis of whether a relatively favorable supply situation can isolate the domestic market from external shocks. As a part of

the study, estimations were carried out using three types of econometric models: error correction, local projection, and local projection models with additional analysis of the conditions prevailing on the currency market. The obtained results allowed formulation of the following conclusions:

(a) *Wheat prices:*

- There is a long-term co-integration relationship between domestic wheat prices and wheat futures prices, and the level of EUR/PLN. Deviations of domestic wheat prices from the long-term relation are systematically corrected (24.5% of these deviations are corrected within one month). Short-term parameters indicate that domestic wheat prices are increasing as a result of increase in wheat futures prices.
- Wheat futures prices are key in explaining the volatility of domestic wheat prices. A change in wheat futures prices by 1% results in an immediate increase in domestic wheat prices by $\approx 0.5\%$, and from the next month by $\approx 1\%$. The level of EUR/PLN raises domestic wheat prices, but these effects take place with a 1-month lag. Sea freight prices do not prove to contribute to the increase in domestic wheat prices. The impact of seasonal effects on domestic wheat prices, which in our specification can be identified with domestic factors, is relatively small.
- The impact of changes in futures contracts on domestic wheat prices varies depending on the level and volatility of EUR/PLN. In conditions of a high level of EUR/PLN (PLN depreciation), the increase in wheat futures prices results in a stronger increase in domestic wheat prices than in the conditions of a low level of PLN. Increased volatility of EUR/PLN also contributes to the increase in domestic wheat prices, but this effect is statistically significant only in the month in which changes in futures prices occur.

(b) *Corn prices:*

- There is a long-term co-integration relationship between domestic corn prices and corn futures prices and the level of EUR/PLN (53.0% of deviations are corrected within 1 month). Domestic corn prices return to a long-term relationship twice as faster as wheat prices. Short-term parameters for futures prices did not turn out to be statistically significant.
- The relationship between changes in corn futures prices and changes in domestic corn prices is revealed with a delay and is much smaller than in the case of the wheat market. The effects of EUR/PLN are statistically significant only at the end of the analyzed horizon. Sea freight prices have not been found to be a significant factor in shaping domestic corn prices. Local factors reflected by seasonal effects play a key role in domestic corn prices. The domestic corn market is therefore relatively poorly integrated with the global market.
- The impact of changes in corn futures contracts on domestic corn prices does not differ depending on the level and volatility of EUR/PLN.

(c) *Rapeseed prices:*

- There is a long-term co-integration relationship between domestic rapeseed prices and rapeseed futures prices and the level of EUR/PLN (51.1% of deviations are corrected within 1 month). The rate of return of domestic rapeseed prices to the long-term relationship is twice as fast as for wheat prices. Short-term parameters for rapeseed futures prices and EUR/PLN did not turn out to be statistically significant.
- Changes in rapeseed futures prices and changes in EUR/PLN are strongly reflected in the domestic rapeseed prices throughout the analyzed horizon. Unlike wheat, rapeseed prices adjust to changes in EUR/PLN without a 1-month lag. Sea freight prices did not prove to be a significant determinant of domestic rapeseed prices. The variance decomposition shows that, as in the case of wheat, domestic rapeseed prices are mainly determined by futures prices and not by local seasonal factors. This proves the strong integration of the domestic rapeseed market with the world market.
- Point estimates of parameters indicate that when the level of EUR/PLN is above its average values observed in the sample, the growing prices of rapeseed futures are accompanied by an increase in prices of this commodity on the domestic market. On the other hand, for the low

level of EUR/PLN in relation to its average level in the sample, this effect did not turn out to be statistically significant. The volatility of EUR/PLN did not have a significant impact on the scale of impact of changes in futures contracts on domestic rapeseed prices.

To sum up, along with the integration of the Polish market of grains and oilseeds with the world market, the importance of external factors in shaping domestic prices increases, whereas the importance of domestic factors decreases. Thus, the fact that Poland has relatively high levels of self-sufficiency in production of wheat, corn, and rapeseed does not protect it against external shocks on the market of grains and oilseeds. What is especially noteworthy is that the effect of external shock associated with the war in Ukraine manifested mainly via the MATIF prices, while the impact of excessive supply of Ukrainian grains and oilseed in the local market was limited to the regions bordering Ukraine. The obtained results also indicate that, apart from futures prices on the Euronext exchange, an important factor determining domestic prices of wheat, corn, and rapeseed is EUR/PLN. This indicates the need for participants of the domestic grains and oilseeds market to take into account the problem of exchange rate risk in their business decisions. The results also have important implications for policymakers as they contribute to the discussion on whether countries should strive for food self-sufficiency in order to stabilize domestic prices and improve food security.

At the same time, the results can be used as a starting point for analysis of the impact of external factors on the domestic prices of other agricultural commodities like poultry and beef, in which also Poland has large surpluses in production, whereas these markets are much less integrated with the global markets. It may turn out that the role of self-sufficiency in stabilizing prices is much more important in less integrated markets.

The presented results should be, however, interpreted with some caution due to limitations of the analysis. The main limitation is connected with the inability to incorporate directly the policy measures taken by the Polish government to stabilize the market. However, to a large extent the effect of interventions was included indirectly via variables representing MATIF prices.

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