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PIG LIVESTOCK PRICE FLUCTUATIONS COMPARED TO CHICKEN, TURKEY, AND CATTLE PRICES FROM 2006–2022 IN POLAND

Katarzyna Utnik-Banaś✉

University of Agriculture in Krakow, Poland

ABSTRACT

Aim: To present the type and level of fluctuations of pig livestock prices against chicken, turkey, and cattle price fluctuations from 2006 to 2022. **Methods:** The data consisted of a monthly time series of pig, broiler chicken, turkey, and cattle livestock prices from the Integrated Agricultural Market Information System (ZSRIR). Price fluctuations were analyzed by a time series decomposition using the Census X11 method. **Results:** Nominal prices of pig livestock have increased by 82% over the last seventeen years (2006–2022), while real prices have remained at the same level. Pig prices in 2006 were similar to those of turkeys, 50% higher than chickens and 45% lower than cattle. In 2022, pig prices were 20% lower than turkeys and 42% lower than cattle, while they were only 16% higher than chickens. The cyclical fluctuations accounted for 44%, seasonal for 42%, and random for 14% of the total annual fluctuations of pig prices. **Conclusions:** Pig prices fluctuated similarly to chicken prices. These two types of livestock are distinguished by a high seasonality of prices. Also, irregular changes affect pig and chicken prices more than cattle or turkey prices. From the point of view of price risk, the nature of the fluctuations is important. Regular seasonal fluctuations or long-term trends allow them to be considered in the decision-making process. On the other hand, short-term random fluctuations and medium-term changes with a large deviation from the expected price level represent a risk.

Key words: pigs, livestock price, time series, seasonality, cyclical fluctuations

JEL codes: C22, Q11

INTRODUCTION

The price fluctuations of agricultural products are of great importance to agricultural producers in the context of optimizing the production objective function and consumers making purchasing choices for specific products. At the same time, the analysis of price levels provides an indirect means of assessing market efficiency. The price level of agricultural commodities is mainly influenced by the biological-technical nature of agricultural production, the low short-term elasticity of supply, inter-market linkages, and linkages to world prices [Assefa et al. 2017, Boroumand et al. 2017, Öhlund et al. 2017, Bergevoet et al. 2020]. The occurrence of price fluctuations in agricultural markets is inevitable. Still, it is important to understand the causes of these fluctuations to anticipate and prevent sudden changes in price levels.

In recent years, there has been a significant increase in the prices of agricultural raw materials and inputs in Poland and worldwide. At the same time, there has been an increase in their fluctuations, which is a manifestation of price risk. Negative consequences of the increase in price fluctuations concern all market par-

Katarzyna Utnik-Banaś https://orcid.org/0000-0002-5008-9301
✉katarzyna.utnik-banas@urk.edu.pl

ticipants – agricultural producers, processors, traders, and consumers [Hamulczuk 2014].

Characteristic components of price fluctuations in agriculture are annual seasonal fluctuations and longer, periodically recurring cyclical fluctuations. The best known are the so-called pig cycles in pig production. Despite many studies and a relatively well-described mechanism for the formation of 'pig cycles', it has not been possible to eliminate them. The level of prices in livestock production is also significantly influenced by the existence of complementarities and linkages between pig, poultry, or cattle prices [Goodwin et al. 2000, Miller et al. 2001, Serra et al. 2006]. The fluctuations in prices of particular types of livestock or meat were analyzed by: Idzik [2009], Olszańska [2012], Szymańska [2012], and Utnik-Banaś [2012, 2017a, b, 2018].

Price dynamics and price transmission in the pig market were studied by: Abdulai [2002], Hamulczuk [2006, 2020], Bakucs and Fertö [2009], Xu et al. [2012], Carsten and Stephan [2013], Holst and Cramon-Taubadel [2013], and Babula and Miljkovic [2016]. An outbreak of African Swine Fever (ASF) strongly influenced the pig market and would lead to an economic disaster, not only for those farms hit, or where a transport ban came into force, but also for the rest of the country due to market disruptions [Bergevoet et al. 2020, Hoste 2020]. Price fluctuations are a key aspect of price risk for all market members: producers, processors, as well as consumers [Assa and Wang 2021]. Agricultural prices in European food markets have become more volatile over the past decade, exposing agribusinesses to risk and uncertainty [Assefa et al. 2017]. Havlícek et al. [2020] analyzed the efficiency of pig production on an international scale. They stated that half of the monitored EU countries were ranked as full-efficiency producers.

This study aims to present the type and level of fluctuations of pig livestock prices compared to chicken, turkey, and cattle price fluctuations from 2006 to 2022.

MATERIAL AND METHODS

The research material consisted of a monthly time series of pig, broiler chicken, turkey, and cattle livestock prices for the years 2006–2022 from the Integrated Agricultural Market Information System [ZSRIR 2023]; (Fig. 1). To eliminate the impact of inflation, which varied widely during the study period, all price series were adjusted to real prices [Idzik 2009] using an inflation index given by Statistics Poland [GUS 2023].

The data presented in Fig. 1 indicates the potential structural break in time series; therefore, the Zivot and Andrews [1992] (Z-A) non-stationarity test with the presence of one endogenous structural break was used. This test indicated a point in the time series of a potential structural break but did not state if such a break is significant. To confirm or reject the significance of the breakpoint occurrence indicated by the Z-A test, we applied the Chow test [1960].

The analysis of the fluctuations in pig livestock prices was carried out using a time series decomposition. The following components can be distinguished in the time series [Gujarati 2003, Dittmann 2008]:

- Trend (T) shows the long-term tendency for one-way price changes (increase or decrease). It is understood as the effect of the influence of a constant set of factors,
- Cyclic fluctuations (C) – they are formed as long-term, rhythmically repetitive price fluctuations around the developmental tendency in time intervals longer than one year,
- Seasonal fluctuations (S) – are price fluctuations of the observed variable (price) around the developmental tendency and repeat in a time interval of no longer than one year.
- Random fluctuations – random element – (I).

Given the mutual relation between the long-term trend (T) and cyclic fluctuations (C) formed by similar factors, the elements of the time series are treated in the paper as a whole trend-cycle element (T_tC_t). To describe the time series for turkey livestock prices, a multiplicative model was used in the form of the following formula [Ramanathan 2002, Čechura and Šobrová 2008, Dittmann 2008, Stańko 2013]:

$$Y_t = T_t C_t S_t I_t \quad (1)$$

where:
Y_t – livestock price in time t,
T_t –trend,

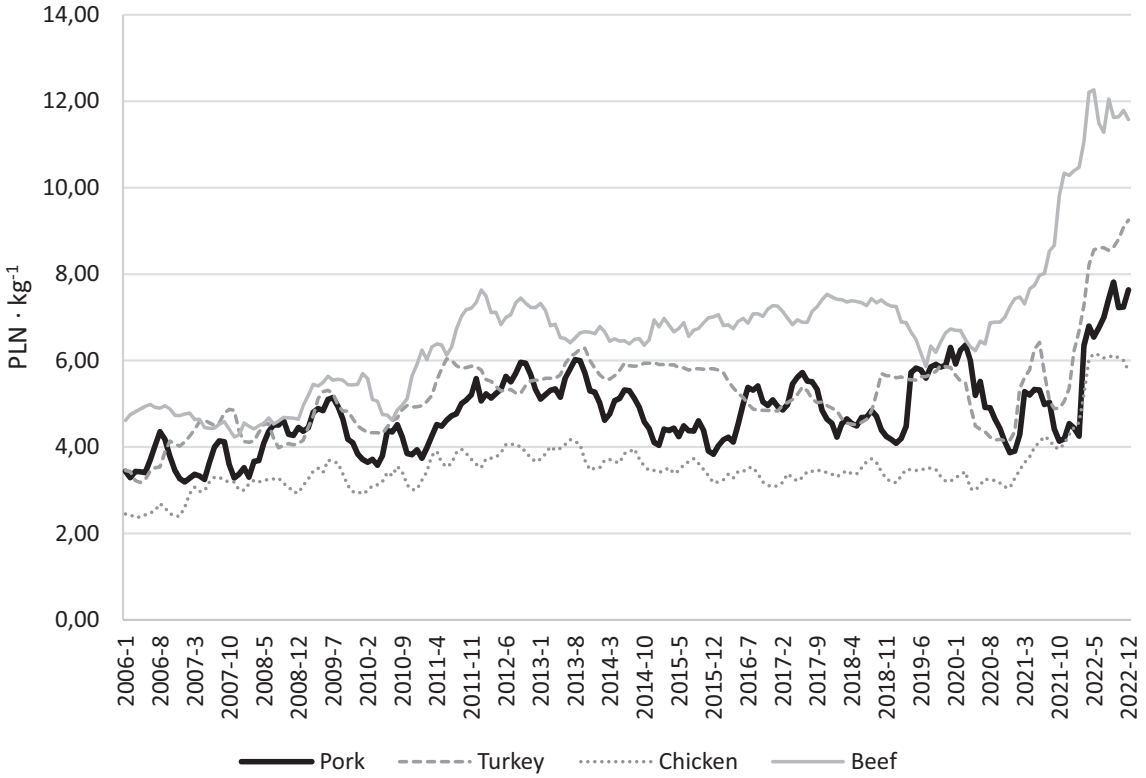

Fig. 1. Nominal prices of the selected types of livestock from 2006 to 2022
Source: own calculations based on ZSRIR [2023].

C_t – cyclic fluctuations,
S_t – seasonal fluctuations,
I_t – random fluctuations.

The Census II/X11 [Shiskin et al. 1967, Idzik 2009] method was used to determine the seasonality of indicators. The advantage of Census II/X11 is, among others, the ability to calculate seasonal fluctuations for each year separately, allowing for an analysis of possible changes in seasonality models in longer periods. Seasonality was eliminated from the original series, dividing the empirical price values by the corresponding seasonality coefficients. The significance of seasonal fluctuations (p <0.01) was evaluated using the F test. Trend-cycle (T-C) was extracted from the time series as a Henderson mean. In turn, (I) was obtained by dividing the seasonally adjusted time series by the trend-cycle (TC).

The separation of the cyclical component from the trend was done using the Hodrick–Prescott filter to isolate a stochastic, smoothly varying trend [Hodrick and Prescot 1997; Ravn and Uhlig 2002]. In the Hodrick–Prescott method, the value of the time series is represented as a sum of a long-term trend and a cyclical component:

$$X_t = T_t + C_t \quad (2)$$

where: X_t – value of the time series,
T_t – value of the long-term trend,
C_t – value of the cyclical component.

The smoothing parameter was set to a level of λ = 14,400 as monthly data were used. In order

to determine the effects of the studied types of fluctuations on overall price variability, the share of their variances in the overall variance was determined for different time horizons of change. The calculations were carried out with a forecasting and time series analysis package using Statistica 13.1 software.

RESULTS

The nominal price of pig livestock in the last seventeen years has increased from PLN 3.65 kg^{-1} in 2006 to PLN 6.62·kg^{-1} in 2022 (Table 1). On the other hand, real prices (taking average prices in 2006 as a reference point = 100%) in the same period even decreased slightly to the level of PLN 3.32·kg^{-1} in 2022. Between 2006 and 2010, real prices were close to nominal prices, but as inflation increased, the differences widened. By the end of 2022, real prices were around 120% lower than nominal prices.

Comparing the different types of livestock, in 2006, pig prices were similar to those of turkeys, 50% higher than those of chickens and 45% lower than cattle (Table 1). In subsequent years, the price relationships changed in favor of other types of livestock. In 2022, pig prices were 20% lower than turkeys and 42% lower than cattle, while they were only 16% higher than chickens. Pig prices were the most volatile. Coefficients of variation of prices for 2022, for example, were highest for pigs at 17.3%, followed by turkeys at 11.6%, chickens at 10.9%, and the lowest for cattle at 5.3%.

The prices of the analyzed livestock were significantly correlated with each other, with the price of pigs being the most strongly correlated with the price of chickens (r = 0.739) and turkeys (0.738) and less with the price of cattle (0.660).

Results of the Zivot-Andrews test revealed that time series are non-stationary and, at the same time, indicated the occurrence of potential structural changes between February 2020 and May 2020 (Table 2). The results of the Chow test confirm that the detected structural breaks are statistically significant (p <0,001). The structural breaks coincide with the outbreak of the COVID-19 pandemic.

Table 1. Price characteristics of selected types of livestock in 2006 and 2022

Prices	Year	Pigs	Turkeys	Chickens	Cattle
Nominal average [PLN·kg^{-1}]	2006	3.65	3.60	2.47	4.84
	2022	6.62	8.21	5.72	11.49
Real average [PLN·kg^{-1}]	2022	3.32	4.13	2.89	5.82
Coefficient of variation [%]	2006	10.0	9.6	3.8	2.3
	2022	17.3	11.6	10.9	5.3
Price relationship: pigs to other livestock	2006	1	1.01	1.48	0.75
	2022	1	0.81	1.16	0.58
Correlation coefficient (2006–2022)		1	0.738	0.739	0.660

Source: own calculations based on ZSRIR [2023].

Table 2. Zivot-Andrews test for non-stationarity with one potential structural break and the Chow test for a structural break for price series from 2006 to 2022

Price time series	Zivot-Andrews test	Structural break	Chow test F
Pigs	–4.042	2020-03	21.340***
Cattle	–3.356	2020-02	22.691***
Chickens	–4.145	2020-04	28.806***
Turkeys	–3.454	2020-05	38.092***

In the Z-A test, the critical value, including intercept and trend, is – 5.57 and – 5.08 at a 1% and 5% significance level, respectively; *** denotes rejection of the null hypothesis (H_0: no structural change) in the Chow test at a p <0.001 significance level.

The decomposition of the time series of pig prices indicates the presence of regular fluctuations: seasonal, cyclical, and irregular random fluctuations. The results of the stable seasonality test confirmed that the seasonal fluctuation of pig prices is statistically significant (p <0.0001, F-statistic value = 22.98).

During the analyzed period, there was a clear change in the pattern of seasonality and a reduction in the amplitude of seasonal fluctuations. In 2006, pig livestock was the cheapest (92%) in the winter months (December–February), and the most expensive (112%) in the summer months (July–September). The amplitude of seasonal changes was 20% (Fig. 2 and Fig. 3).

In subsequent years, there was a gradual reduction in the amplitude of fluctuations to 15% in 2014. In the most recent period, a shift of the seasonal peak of prices to the spring and early summer periods (April––June) is observed. The share of seasonal fluctuations amounted to 47% of the total price fluctuations at a horizon of 1 month, while the highest impact of seasonal fluctuations of 63% was observed at a changing horizon of 4 months, which was associated with a significant reduction in the impact of irregular fluctuations (Table 2).

Analyzing the pig price fluctuations against the background of other livestock prices, we found that

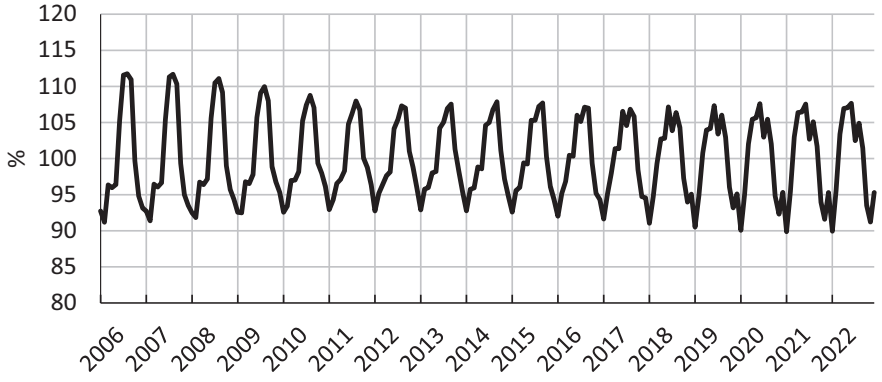

Fig. 2. Seasonal fluctuations in pig livestock prices from 2006 to 2022
Source: own calculation based on ZSRIR [2023].

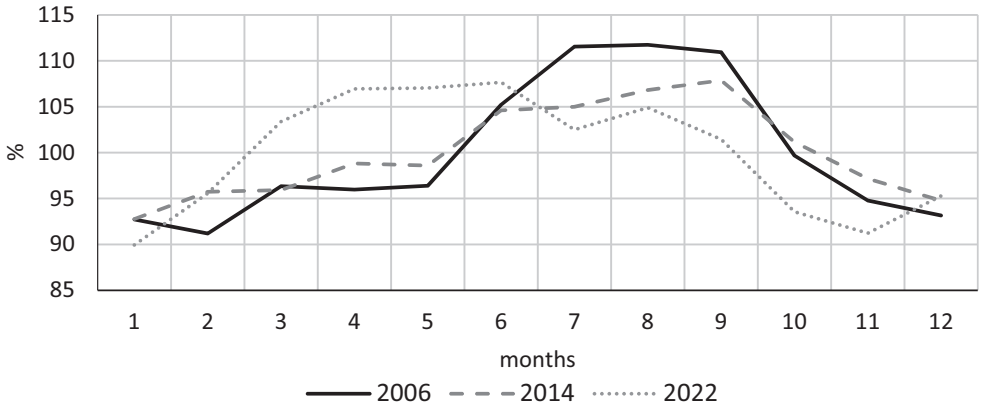

Fig. 3. Changes in the seasonality pattern of pig livestock prices between 2006 and 2022
Source: own calculation based on ZSRIR [2023].

Table 2. Contribution of seasonal cyclical and irregular changes to the total variability of livestock prices from 2006–2022

Livestock	The horizon of change (months)	Changes [%]		
		irregular	cyclical	seasonal
Pigs	1	41.1	11.5	47.4
	4	9.6	27.0	63.3
	6	7.0	36.9	56.1
	Annual average	13.7	43.8	42.4
Cattle	1	32.3	25.7	41.9
	4	6.1	58.3	35.6
	6	4.1	69.9	26.0
	Annual average	8.8	66.1	25.2
Turkeys	1	22.3	55.7	22.0
	4	4.0	83.0	13.0
	6	2.6	87.8	9.6
	Annual average	5.7	83.9	10.4
Chickens	1	30.4	7.5	62.2
	4	8.5	17.9	73.5
	6	6.2	29.7	64.1
	Annual average	11.1	36.1	52.8

Source: own calculation based on ZSRIR [2023].

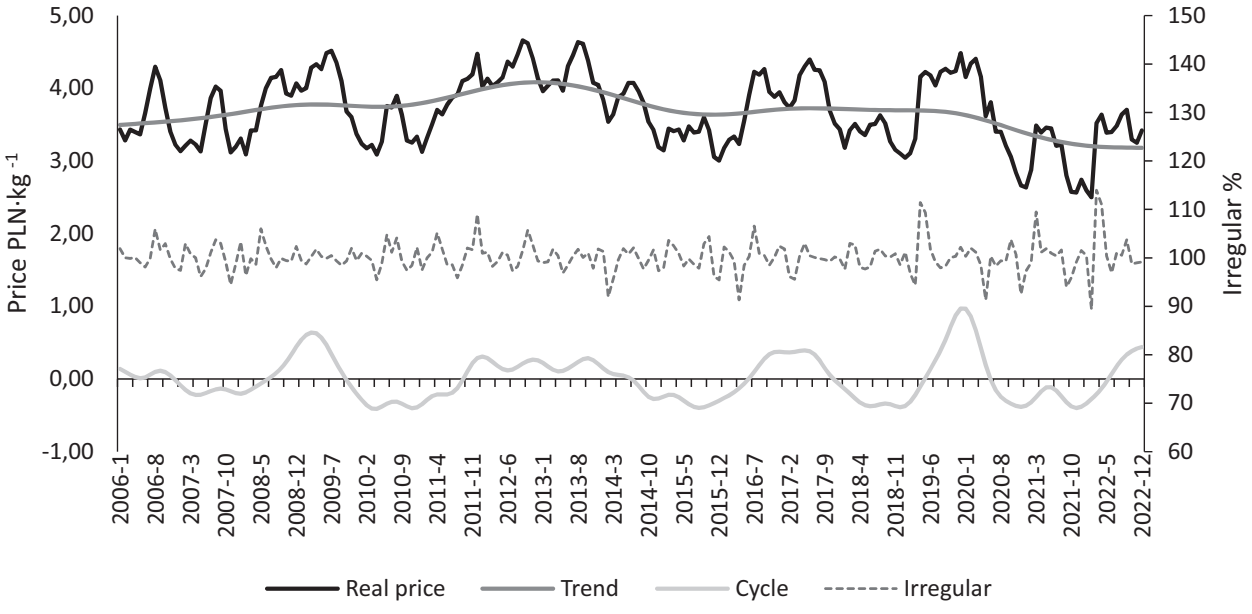

Fig. 4. Results of the decomposition of the time series of real pig livestock prices
Source: own calculation based on ZSRIR [2023].

pig prices fluctuated similarly to chicken prices. A high seasonality of prices distinguishes these two types of livestock: 52.8 and 42.4% for chickens and pigs, respectively (Table 2). Also, irregular changes affect pig and chicken price fluctuations more (13.7% and 11.1%, respectively) than cattle or turkey prices (8.8 and 5.7%, respectively). This type of fluctuation causes sudden changes that are difficult to predict, interacting adversely with the process of price risk management. Changes in pig livestock prices between 2006 and 2022 were characterized by pronounced cyclical fluctuation with cycle lengths of three to five years (Fig. 4).

The upper turning points (tops) were: June 2009, December 2012, July 2017, and January 2020. The value of MCD = 3.79 indicates that it is possible to speak of a new cycle after four months of unidirectional changes. Cyclical fluctuations in the 1-month change horizon accounted for 11.5%, while in the 9 months, their share was 66% of the total variability (Table 2). Irregular fluctuations at the monthly change horizon accounted for 41% of total price variability, while at the 4-month horizon, their share was less than 10%. On an annual average, cyclical fluctuations accounted for 44%, seasonal fluctuations for 42%, and random fluctuations for 14% of the total variability of pig livestock prices.

DISCUSSION

Price fluctuations are a characteristic of a free market, operating based on the law of equilibrium between demand and supply. Price variability represents an important risk factor for supply, especially in agricultural products. Agricultural prices tend to be more volatile due to seasonality, inelastic demand, and production uncertainty [Holt and Moschini 1992]. Rezitis and Stavropoulos [2009] highlight that price fluctuations translate into a significant price risk. Thus, an increase in price volatility implies higher uncertainty about future prices, a fact that can affect producers' welfare, especially in the absence of a hedging mechanism. Szymańska and Tatarczak [2010] analyzed changes in pig livestock prices from 1995 to 2008 and found that monthly purchase prices of pig livestock are characterized by reasonably high levels of cyclical fluctuation with an average cycle length of about 3.5 years. The results obtained in this article confirm pronounced cyclical fluctuation with cycle lengths of three to five years. Stańko [2008] studied trends in pig production, foreign trade, and consumption in Poland between 1990-2008 and found that cyclical, trend, and seasonal fluctuations are of primary importance in explaining price volatility in the pig market, explaining about 92.0% of price volatility, while the remaining 8.0% of volatility is caused by random fluctuations. Our results show a higher share of random fluctuations (14%), which indicates this type of fluctuation in recent years. The increase in the irregular fluctuation of pig prices in Czechia in 2019 due to African swine fever is also pointed out by Sirohi et al. [2023].

This research indicates a clear seasonality of pig livestock prices, with the lowest prices occurring during the winter months (92%) and the highest during the summer months (112%). A similar pattern of seasonality in pig livestock prices for the Iowa/Minnesota market (USA) was indicated by Schulz [2020], reporting that lower-than-average annual prices occur during the months of January to March (90%) and September to December (90%), while higher-than-average prices occur from May to August with the peak in July (114%). The tendency for prices to show seasonal weakness during the fall and winter results from larger pig production during these periods than during the summer months, and pig slaughter remains highest in the fourth quarter. Similarly, Bergevoet et al. [2020] reported a significant increase in pig slaughtering in the month of December. Rezitis and Stavropoulos (2009) analyzed price fluctuation in the Greek pig market and stated that the seasonal components are statistically significant, indicating the presence of a strong seasonal effect during December.

Using the Zivot-Andrews test for non-stationarity and occurrence of the potential structural break, we found the price series integrated in the first order and confirmed the breakpoint in the pig price time series in the period of the COVID-19 pandemic outbreak (March 2020). Similarly, Wan and Li [2022] used the Zivot-Andrews test to analyze price volatility in the Chinese pig market, found price series integrated into

the first level, and confirmed breakpoints coincide with the food price crisis of 2007. Sirohi et al. [2023] also reported a price shock in the pig price series caused by the COVID-19 pandemic outbreak.

CONCLUSIONS

In this paper, the fluctuations of pig livestock prices in comparison to other kinds of livestock were analyzed. The decomposition of time series prices revealed the presence of seasonal, cyclical, and irregular random fluctuations. Pig prices fluctuated similarly to chicken prices. These two types of livestock are distinguished by a high seasonality of prices: 52.8 and 42.4% for chickens and pigs, respectively. Also, irregular changes affect pig and chicken price fluctuations more (13.7% and 11.1, respectively) than cattle or turkey prices (8.8 and 5.7%, respectively). The research findings are significant from the price risk point of view. Regular seasonal fluctuations or long-term trends allow them to be considered in the decision-making process. On the other hand, short-term random fluctuations and medium-term changes with a large deviation from the expected price level represent a risk.

Further research on the more detailed connection between different types of livestock is needed, especially in the short term, by performing causality tests, and in the long term, using cointegration methodology.

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FLUKTUACJE CEN ŻYWCA WIEPRZOWEGO W PORÓWNANIU Z CENAMI KURCZĄT, INDYKÓW ORAZ WOŁOWINY W LATACH 2006–2022 W POLSCE

STRESZCZENIE

Cel: Przedstawienie rodzaju wahań cen żywca wieprzowego w porównaniu z cenami kurcząt, indyków i wołowiny w latach 2006–2022. **Metody:** Materiał badawczy stanowiły miesięczne szeregi czasowe cen żywca wieprzowego, kurcząt brojlerów, indyków i żywca wołowego pobrane ze Zintegrowanego Systemu Rolniczej Informacji Rynkowej (ZSRIR). Analiza fluktuacji cen została przeprowadzona za pomocą dekompozycji szeregów czasowych przy użyciu metody Census X11. **Wyniki:** Nominalne ceny żywca wieprzowego wzrosły o 82% w ciągu ostatnich siedemnastu lat (2006–2022), podczas gdy ceny realne pozostały na tym samym poziomie. Ceny wieprzowiny w 2006 roku były zbliżone do cen indyków, 50% wyższe niż kurcząt i 45% niższe niż wołowiny. W 2022 roku ceny wieprzowiny były o 20% niższe od cen indyków i 42% niższe od cen wołowiny, oraz tylko o 16% wyższe od cen kurcząt. Wahania cykliczne stanowiły 44%, sezonowe 42%, a przypadkowe 14% całkowitej rocznej zmienności cen wieprzowiny. **Wnioski:** Pomiędzy fluktuacjami cen wieprzowiny i kurcząt występuje wyraźne podobieństwo. Te dwa rodzaje żywca wyróżniają się wysoką sezonowością cen, a ponadto wahania nieregularne wpływają na ceny wieprzowiny i kurcząt w znacznie większym stopniu niż na ceny wołowiny czy indyków. Z punktu widzenia ryzyka cenowego istotny jest charakter wahań. Regularne wahania sezonowe lub długoterminowe trendy pozwalają na ich uwzględnienie w procesie decyzyjnym. Nieregularne wahania krótkookresowe i zmiany średniookresowe z dużym odchyleniem od oczekiwanego poziomu stanowią ryzyko cenowe.

Słowa kluczowe: wieprzowina, ceny żywca, szeregi czasowe, sezonowość, wahania cykliczne, fluktuacje cen