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## TRENDS IN THE LIVESTOCK AND PORK MARKET IN POLAND WITH REGARD TO THE ENVIRONMENTAL IMPACT OF THIS PRODUCTION DIRECTION

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**ABSTRACT:** After joining the European Union, the market economy continued to drive structural changes in meat production and processing. Unfortunately, the functioning of meat markets was impacted by several threats with significant adverse influence. Phenomena such as the spread of ASF disease, the United Kingdom's exit from the European Union or the Covid-19 epidemic added instability to the already cyclical pork market. The study aims to evaluate the functioning of Poland's pork market and to identify the main trend in this market. Livestock and pork meat production in Poland form a significant economic sector; however, it creates considerable environmental challenges. The study focuses on key aspects such as greenhouse gas emissions, water usage, feed consumption, and waste management. The study covers the years 2004-2021, i.e., the period of seventeen years after Poland's accession to the European Union. The statistical data analysis methods showed four to three-year cycles in pork live stock with a decreasing amplitude over time and high and relatively stable domestic demand for pork. This provides a favourable foundation for future production direction. However, the systematic changes in the structure of meat consumption and price development led to a steady increase in the share of poultry meat at the expense of pork and bovine during the observed year span.

**KEYWORDS:** agricultural economics and policy, food economics, food security, productivity and efficiency, Poland, environment

## Introduction

After joining the European Union, the market economy continued to drive structural changes in meat production and processing. The main phenomenon is the concentration of production, resulting in fewer but larger livestock farms. As a result of decreasing unit profits on the sale of livestock, it is unprofitable to raise small herds. The meat industry is also undergoing concentration. The gradually decreasing number of meat-processing plants and, consequently, the increasing distance of supply from points of sale is another factor discouraging livestock production. The use of intermediaries in the purchase of livestock leads to a significant decrease in the prices paid to the farmers (Olszańska, 2017; Zawadzka, 2018).

There are also various environmental threats, the effects of which may be important for the functioning of meat markets. One of them is the spread of ASF disease on the territory of Poland (Sadowski, 2015), which has a significant negative impact not only on the pig market but also on the economic situation in other meat markets.

The short- and long-term effects of the COVID-19 pandemic aren't fully predictable. There is substantial evidence suggesting that the pandemic has accelerated certain trends in food purchasing and consumption, and previous consumer behaviours and habits may not return. During the pandemic and the restrictions put in place, some of the trade and logistics links were cut. The HoReCa sector, in particular, was adversely affected. It's therefore difficult to predict how meat consumption will change, what export opportunities there will be and when and in what form the former outlets will be rebuilt.

Another major problem is the mediocre reputation of Polish products in some countries of the European Union. Regularly emerging information and problems related to the quality of Polish meat products put them in a bad light, and as we know, such opinions sometimes tend to be "sticky", i.e. to be long-remembered and quickly spread. Reversing them is a long-term and costly process while building a strong brand is laborious. The consequences also include relatively lower prices achievable when selling Polish products in foreign markets. The United Kingdom's exit from the European Union is also a threat. Its consequences for the functioning of meat markets in Poland haven't yet been fully recognised and assessed, especially as the consequences of the Covid 19 epidemic and the associated demand restrictions and logistical problems have overlapped. The UK is a major importer of meat and meat products from Poland. Therefore, the study aims to assess the functioning of the pork market in Poland and identify its main trends.

The study spans the years 2004-2021, i.e. the period of seventeen years after Poland's accession to the European Union. The study uses secondary data published in the CSO and the Institute of Agricultural and Food Economics, studies of the National Research Institute, data from the Integrated Agricultural Market Information System of the Ministry of Agriculture and Rural Development and other scientific publications on the topics covered. Basic methods of statistical data analysis are used in the study. In particular, a time series analysis model was used to identify cyclical fluctuations in pork production.

## Literature research

The course of the phenomenon can be influenced by the following groups of factors (Kowalewski, 2009):

- factors that interact continuously over a long period of time,
- factors that occur at regular intervals, in each fixed period,
- random fluctuations which are so irregular that they cannot be captured by any general model.

Consequently, the time series may consist of several components (Józwiak & Podgórski, 1997; Pułaska-Turyńska, 2008):

- Development trend – a general, long-term, unidirectional, and sustainable trend in the change of the phenomenon over time,
- Business cycle fluctuations – systemic, wave-like fluctuations in the phenomenon observed over periods longer than a year. They move in a pendulum-like motion with some degree of regularity. They result from self-reinforcing internal mechanisms expressed in the expansion or contraction

of economic activity around the trend line. The repeatability of the phenomena is usually expressed only in the sequence of phases (rise and fall), while the amplitudes vary,

- Seasonal, periodic fluctuations – a systematic variation of the phenomenon, such as on an annual basis,
- Random, irregular fluctuations – non-cyclical changes in activity caused by one-off events and unrelated to the nature of the phenomenon.

In the analysis of the pork production data for the study period, a multiplicative time series model is used. When analysing more detailed data, e.g. on a monthly basis, the model takes the following form (Lira, 2011):

$$Z_t = f(t) * c(t) * si(t) * e(t), \quad (1)$$

where:

$z_t$  – the level of the phenomenon in period  $t$ ,

$f(t)$  – the value of the trend function in period  $t$ ,

$c(t)$  – the value of the cyclical fluctuation function in period  $t$ ,

$si(t)$  – the value of the seasonal fluctuation function in the  $i$ -th sub-period of the periodicity cycle,

$e(t)$  – the value of the irregular component in period  $t$ .

The analysis of cyclical fluctuations reveals the following features (Barczyk, 1997; Barczyk & Kowalczyk, 1993; Hübner et al., 1994; Jöhr, 1953; Kowalczyk, 1982; Marczewski et al., 2006; Tichy, 1976; Vosgerau, 1978):

- nature of the lower and upper turning points,
- length of individual phases and cycles,
- frequency, amplitude, and intensity,
- symmetry and asymmetry,
- the structure of fluctuations (in terms of subject and time).

As the analysis covered annual data, its scope had to be limited. Therefore, the overall model was slightly modified. The trend line of the phenomenon was defined as a 4-year centered moving average. Cyclical fluctuations were determined by fluctuations around the trend line. Seasonal fluctuations and random fluctuations were not extracted. In this case, they fall within cyclical fluctuations. Cycles of livestock and crop production are described in the literature (Breimyer, 1952; Burns & Mitchell, 1946; Coase & Fowler, 1937; Ezekiel, 1938; Hannau, 1928; Piech & Pangsy-Kania, 2003):

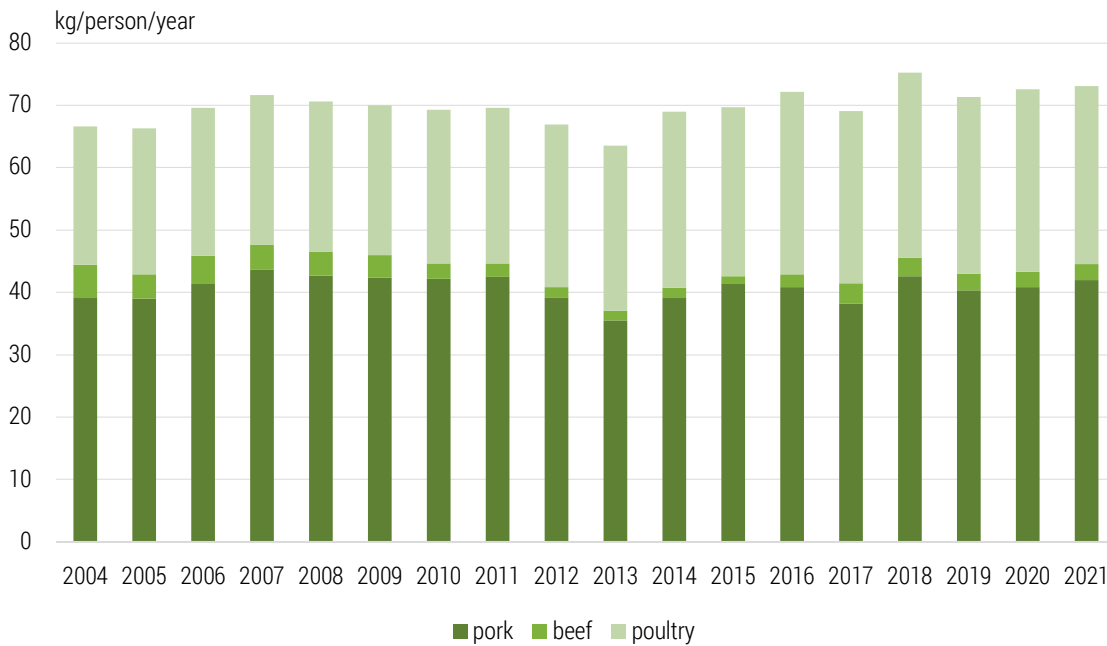
- pig production cycle of 3-4 years,
- cattle production cycle (Netherlands – 5 years, USA – 17 years),
- American cotton cycle (2 years),
- coffee cycle (15–16 years).

Agricultural cycles are strongly influenced by disturbance factors, i.e., weather anomalies (which are currently gaining in importance), and other factors, e.g., government policy towards agriculture and, in particular intervention policy. Cyclical fluctuations in agriculture are beyond the system; they have occurred in both centrally planned and market economies (Baldock, 1999; Shepherd, 1963).

This is not the only method that was used to try to explain the complexity of business cycles in agriculture (Holst & Cramon-Taubadel, 2012). In particular, Fourier methods were used for this purpose (Talpez, 1974). Other approaches include non-linear models, chaos theory, and autoregressive models (TV-STAR) (Holt & Craig, 2006; Holzer et al., 1993; Chavas & Holt, 1991; Streips, 1995).

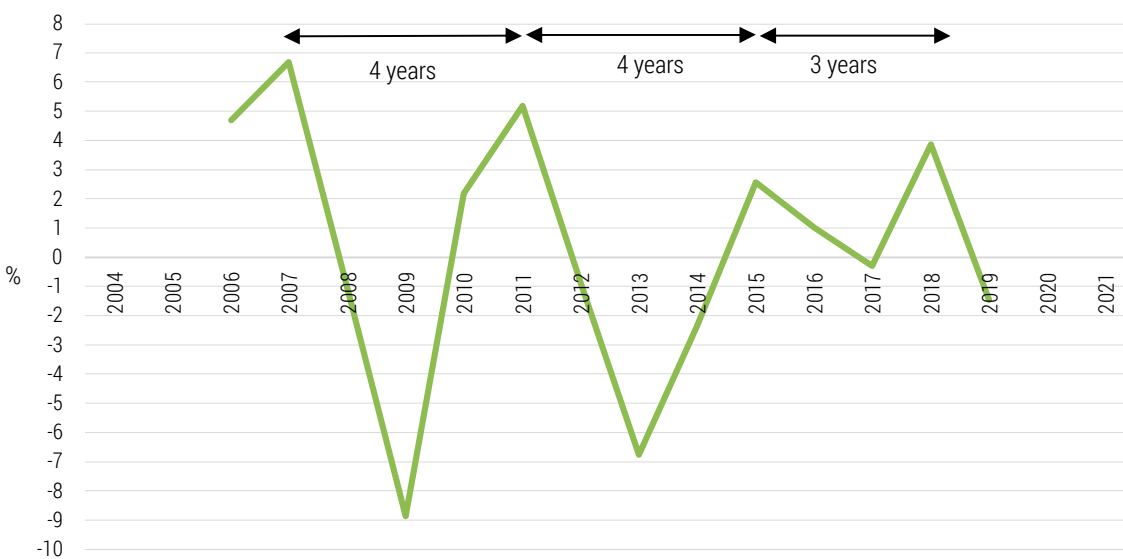
## Own model and discussion

For decades, pork has been the most commonly consumed meat among Polish consumers (Figure 1). The annual consumption of pork in Poland was also the highest in the period under study. It was estimated at about 40 kg per capita and fell below the value in only a few years.



**Figure 1.** Consumption of basic meat types in Poland in the years 2004-2021 [kg/person/year]

Source: authors' work based on IERiGŻ (2003a, 2003b, 2004a, 2004b, 2005a, 2005b, 2006a, 2006b, 2007a, 2007b, 2008a, 2008b, 2009a, 2009b, 2010a, 2010b, 2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2014a, 2014b, 2015a, 2015b, 2016a, 2016b, 2017a, 2017b, 2018a, 2018b, 2019a, 2019b, 2020a, 2020b).



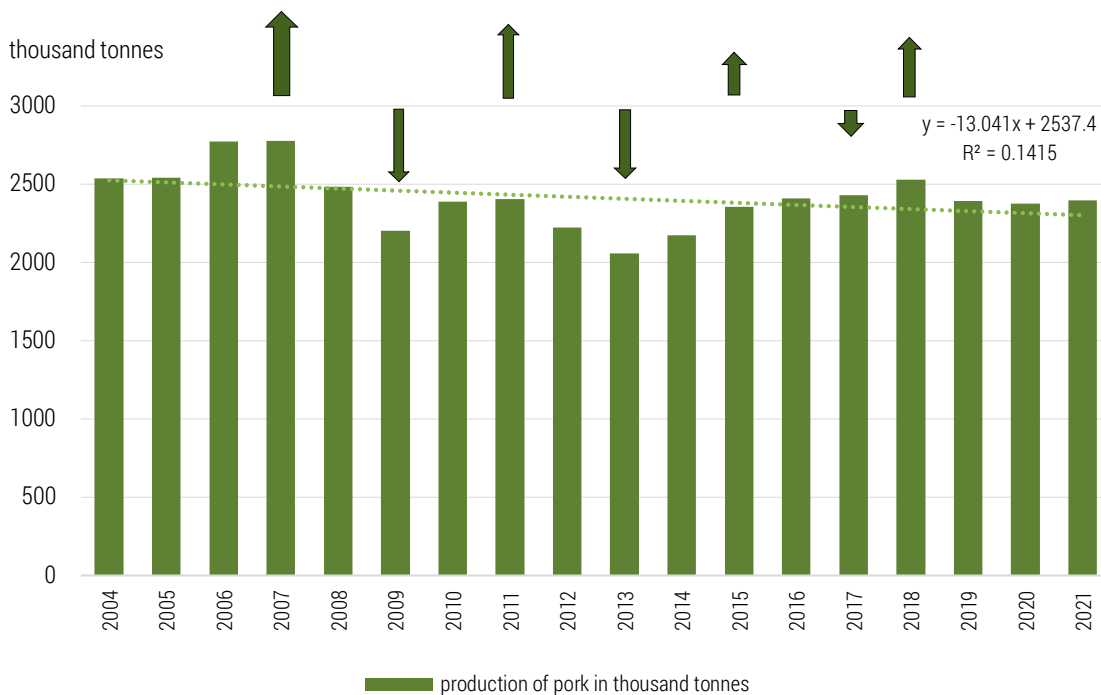
**Figure 2.** Cyclical fluctuations in pig livestock production in Poland from 2004 to 2021 (without the trend line) [%]

Source: authors' work based on IERiGŻ (2003a, 2003b, 2004a, 2004b, 2005a, 2005b, 2006a, 2006b, 2007a, 2007b, 2008a, 2008b, 2009a, 2009b, 2010a, 2010b, 2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2014a, 2014b, 2015a, 2015b, 2016a, 2016b, 2017a, 2017b, 2018a, 2018b, 2019a, 2019b, 2020a, 2020b).

The minimum consumption was recorded in 2013 (35.5 kg/person/year) and the maximum in 2007 (43.6 kg/person/year). In 2021, pork consumption was 4.9% higher compared to 2004. When analysing the data from all years, a slight downward trend in pork consumption can be observed (-0.037 kg/person/year on average). Total consumption of the three types of meat we focused on showed a slight upward trend (average 0.252 kg/person/year). However, the main cause was the systematic increase in consumption of poultry (average 0.419 kg/person/year), which, analysed sep-

arately, showed a very good fit of a linear trend. Beef consumption was marginal throughout the period and trended downwards. It increased slightly in 2016-2017 but declined in the following years. The lowest beef consumption was recorded in 2015 (1.2 kg/person/year). In recent years, it has been consumed around 2.5 kg/person/year. The total consumption of all three surveyed meat types varied between 63.5 and 75.2 kg/person/year. Despite the widely discussed new consumption trends of giving up meat and replacing it with other products (most large meat-processing plants already offer such products), they did not manifest yet. We observed no major change, even during the pandemic years.

Figures 2 and 3 show the cyclical fluctuations pattern in Polish market pork supply from 2004 to 2021. Already mentioned slight decrease shows poor fit to a linear trend line as its nature is cyclical.



**Figure 3.** Changes in the volume of pork livestock production in Poland from 2004 to 2021 [in thousands of tonnes]

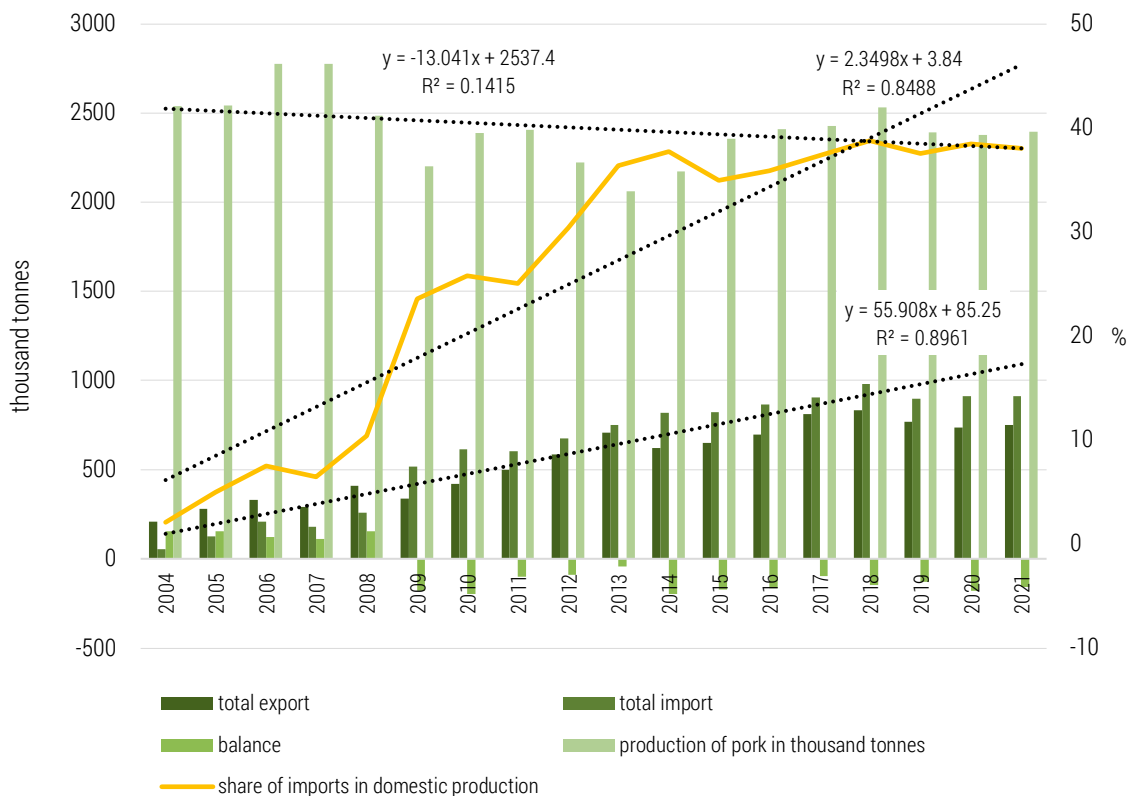
Source: authors' work based on IERiGŻ (2003a, 2003b, 2004a, 2004b, 2005a, 2005b, 2006a, 2006b, 2007a, 2007b, 2008a, 2008b, 2009a, 2009b, 2010a, 2010b, 2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2014a, 2014b, 2015a, 2015b, 2016a, 2016b, 2017a, 2017b, 2018a, 2018b, 2019a, 2019b, 2020a, 2020b).

Pork production fluctuated considerably during the study period, manifesting an average decrease rate of around 13 thousand tonnes per year. Significant cyclical fluctuations are typical for the pork market. We identified a decrease in fluctuations amplitudes over time. Last years of lower volume volatility were undoubtedly beneficial for the stability of the market. In the period from 2009 to 2013, production was at its lowest during the survey period. Thereafter, production increased and was much more stable in the following years than in the years before. Considering the problems this market is facing, such development is positive. This is true for 2015-2019 and the following years (due to the calculation procedure, the data for the first two and the last two years aren't shown). Overall, three complete cycles (with the periods between the peaks) were identified over the study year span. The first two cycles occurred in the years 2007-2010 and 2011-2014. These cycles lasted four years, and the phases of output decline were shorter than their growth phases. However, the decline phases brought greater volume reduction than the growth phases added. The amplitudes of the fluctuations in the first two cycles were greater (especially in the first) than those of the third cycle. The third cycle showed a clearly different pattern. It lasted three years. The decline and growth phases were comparable in time and volume. Also, the amplitudes of the fluctuations were much

smaller. There was only a slight decline in production volumes in 2017 (the minimum in this cycle). Smaller fluctuations are beneficial for both livestock farmers and consumers; they lead to a more stable market situation and lower price fluctuations.

Cyclical fluctuations in pig production result from decisions made by agricultural producers about changing the level of livestock production in subsequent periods. Research shows that these decisions are mainly influenced by current purchase prices and prices for basic feed. Cyclical fluctuations in this market occur in all economies. However, they differ in their extent. The higher the degree of horizontal and vertical integration in the livestock and pork production and distribution chains, the smaller the fluctuations. Cyclical fluctuations in livestock lead to cyclical fluctuations in the purchase quantities and purchase prices of livestock and to fluctuations in the production quantities and prices of pork products in the subsequent production and distribution chains. The possibility to trade with foreign countries and easily substitute pork products, e.g. with poultry products, also has a mitigating effect on cyclical fluctuations in production and prices (Olszańska, 2012).

The pork market in Poland is a significant part of the EU market. Large quantities of this meat are traditionally consumed by Polish consumers, and the consumption shows a steady trend. This renders the pork market large and attractive from the supply perspective. However, Poland's shares in the structure of the pig population and pork production, while still significant in the EU, have been systematically decreasing over the span of the surveyed year. Meanwhile, the share of production from Germany and Spain has risen significantly to the extent that they achieved and kept a dominant position in the EU market for many years. In terms of the pig population and production volume, France has surpassed Poland, and in terms of production volume, same applied to Denmark and the Netherlands (Olszańska, 2016; Palát & Palátová, 2022; Stępień & Polcyn, 2016).



**Figure 4.** Domestic production, exports and imports of Polish pork in the years 2004-2020 [thousand tonnes, %] (estimates for 2021)

Source: authors' work based on IERiGŻ (2003a, 2003b, 2004a, 2004b, 2005a, 2005b, 2006a, 2006b, 2007a, 2007b, 2008a, 2008b, 2009a, 2009b, 2010a, 2010b, 2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2014a, 2014b, 2015a, 2015b, 2016a, 2016b, 2017a, 2017b, 2018a, 2018b, 2019a, 2019b, 2020a, 2020b).

Figure 4 shows the changes in the total supply of pork in the Polish market and the possible increase in domestic production due to the export opportunities of pork. Until 2008, the trade balance for pork was favourable. Between 2009 and 2020, the balance was consistently negative, albeit to varying degrees. It should also be noted that exports and imports increased fairly steadily until 2018. In the following three years, both exports and imports reached lower levels than in previous years however they remained relatively stable. As a result, the values indicating the share of imports in relation to domestic production also increased. These values were increasing till 2014 and then became almost stable.

There are fundamental differences between the structure of exports and imports (Figures 5 and 6).

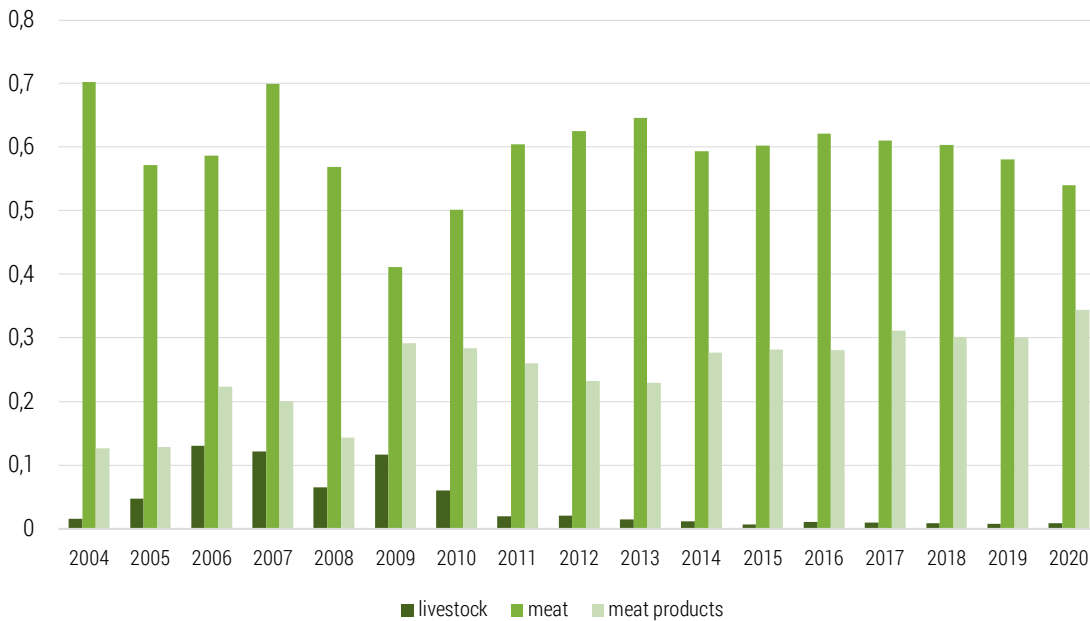


Figure 5. Share of the main pork commodity groups in the total volume of its exports in the years 2004-2020

Source: authors' work based on IERiGŻ (2003a, 2003b, 2004a, 2004b, 2005a, 2005b, 2006a, 2006b, 2007a, 2007b, 2008a, 2008b, 2009a, 2009b, 2010a, 2010b, 2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2014a, 2014b, 2015a, 2015b, 2016a, 2016b, 2017a, 2017b, 2018a, 2018b, 2019a, 2019b, 2020a, 2020b).

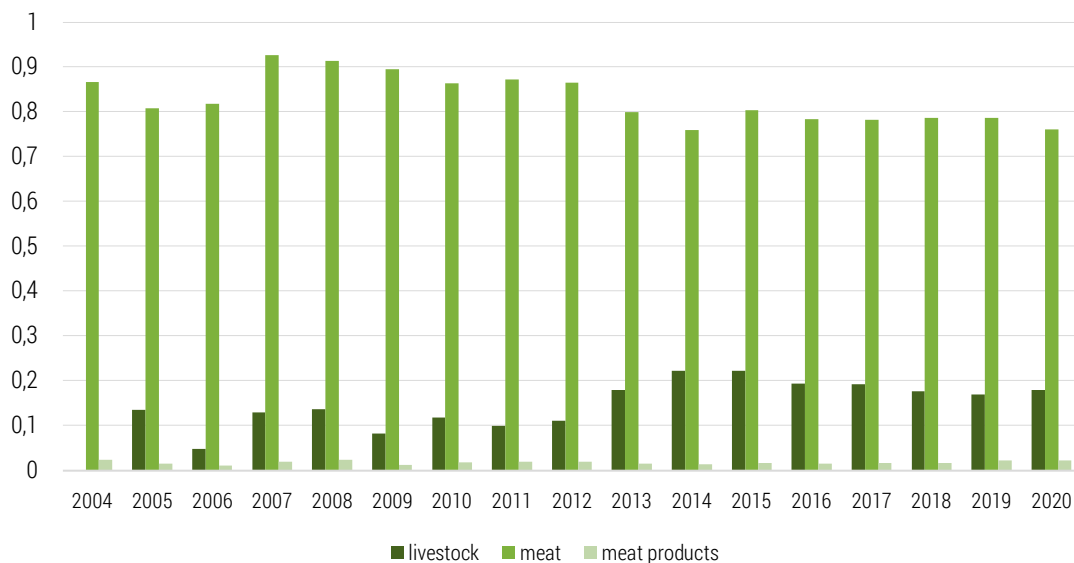
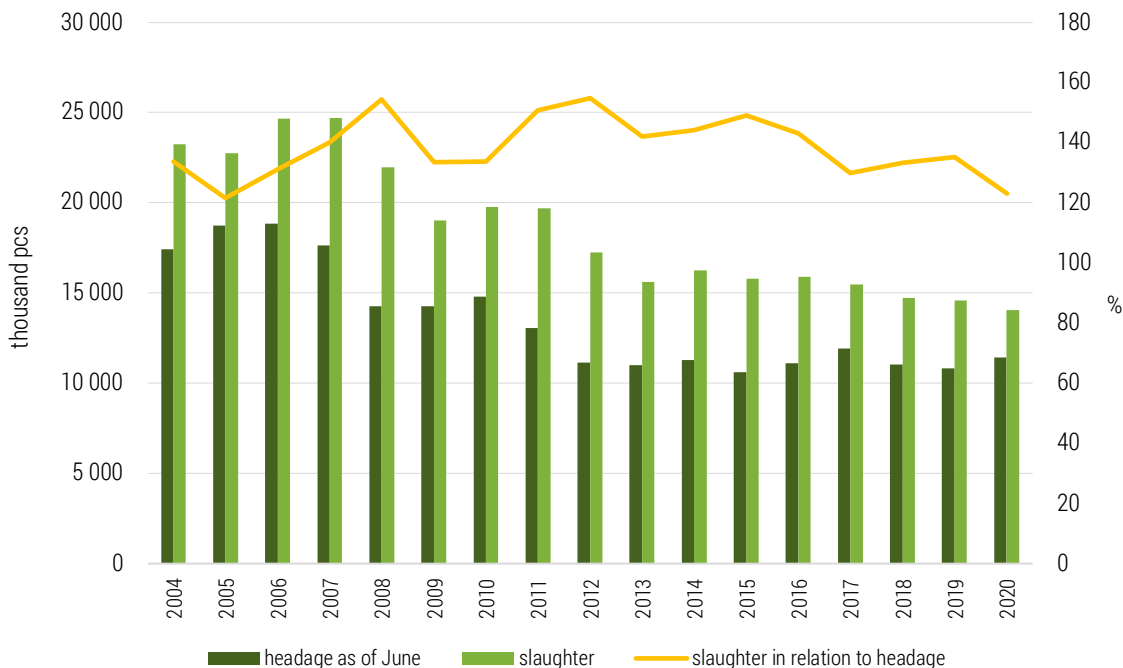


Figure 6. Share of the main pork commodity groups in the total volume of its imports in the years 2004-2020

Source: authors' work based on IERiGŻ (2003a, 2003b, 2004a, 2004b, 2005a, 2005b, 2006a, 2006b, 2007a, 2007b, 2008a, 2008b, 2009a, 2009b, 2010a, 2010b, 2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2014a, 2014b, 2015a, 2015b, 2016a, 2016b, 2017a, 2017b, 2018a, 2018b, 2019a, 2019b, 2020a, 2020b).

The meat had the largest pork commodity share in both exports and imports, although it was higher in imports. In 2004 and 2007, meat accounted for 70% of exports. The lowest share of meat in exports was recorded in 2009, when it was just over 40%. In the following years, this share was relatively stable, ranging from 50% in 2010 to 64.5% in 2013. The share of meat products was significantly lower. Its share has increased significantly since 2010 and has been relatively stable: It ranged from 23% in 2012-2013 to 34.4% in 2020. The share of livestock in exports has been marginal since 2011 (from 2% to less than 1%).

The share of meat in imports ranged from 76% in 2014-2020 to 92.6% in 2007, while it has been relatively stable over the last five years, ranging from 76% to 78.6%. Imports of canned goods were marginal. However, the second most important item was live cattle import. Its share has increased significantly since 2013, ranging from 17 % in 2019 to 22.2 % in 2014-2015. According to data from the Central Statistical Office (Statistics Poland, 2022), animals weighing up to 50 kg destined for further fattening in Poland have had a dominant share in livestock imports since 2013. The purchase of breeding material on this scale is firstly caused by the tendency to obtain genetically superior animals in order to increase the profitability of fattening. Secondly, there is a shift from of pig farmers from closed-loop pig farming in favor of specialisation in the final fattening of animals. The share of imports of pigs weighing up to 50 kg in the total volume of slaughterings in a given year jumped from 24.1% in 2013 to 46.3% in 2018 (2008 – 2.9%, 2012 – 11.4%).



**Figure 7.** Headage (as of June) and slaughter of pigs in Poland in the years 2004-2020 [thousand pcs, %]

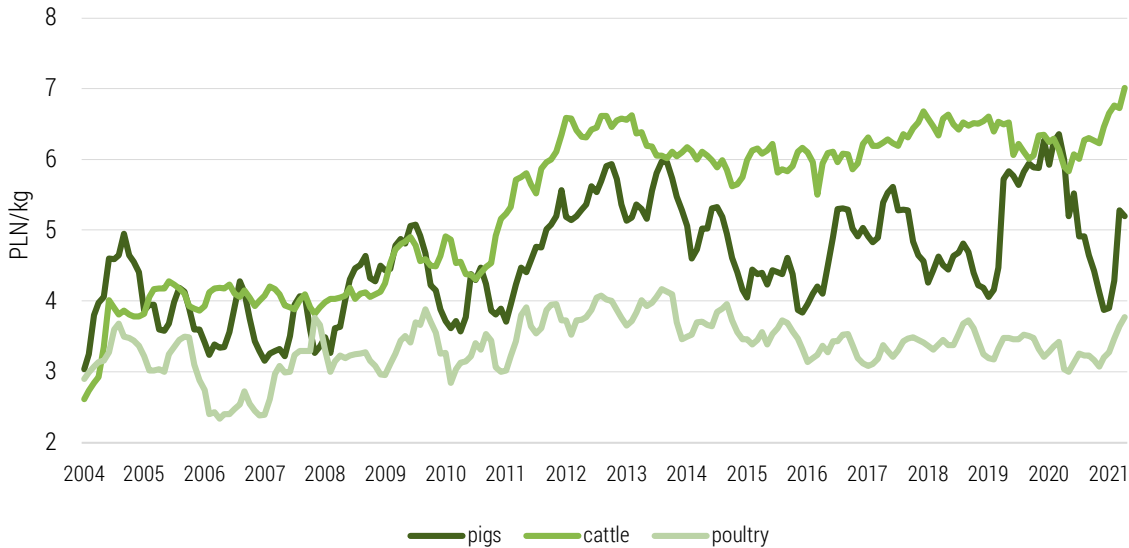
Source: authors' work based on IERiGŻ (2003a, 2003b, 2004a, 2004b, 2005a, 2005b, 2006a, 2006b, 2007a, 2007b, 2008a, 2008b, 2009a, 2009b, 2010a, 2010b, 2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2014a, 2014b, 2015a, 2015b, 2016a, 2016b, 2017a, 2017b, 2018a, 2018b, 2019a, 2019b, 2020a, 2020b).

From the data in Figure 7, it can be seen that both the number of animals and the number of slaughterings show a downward trend over the period studied. The number of slaughterings decreased on average by 690.5 thousand animals per year and the number of animals by 517.7 thousand. Cyclical fluctuations were observed in both cases. The ratio of slaughterings to pig numbers in June fluctuated between 121.5% in 2005 and 154.8% in 2012, and this ratio has been trending downwards since 2012. Comparing this result with the pig production figures for the surveyed years (Figure 3), it can be seen that the decreasing number of animals and the size of slaughterings haven't led to a significant decrease in pork livestock production. The lowest production level was recorded in 2009



and 2012-2014, when low herd sizes were also observed. The production stabilized in the following years at a higher level in relative terms than in 2010-2011, i.e., the years of the second cycle peak when also slaughter sizes were at a much higher level. This is the result of a continuous improvement in the quality of the livestock and its meatiness.

The next figure (Figure 8) shows data on purchase prices for live pigs and prices for other types of live animals competing with pork.

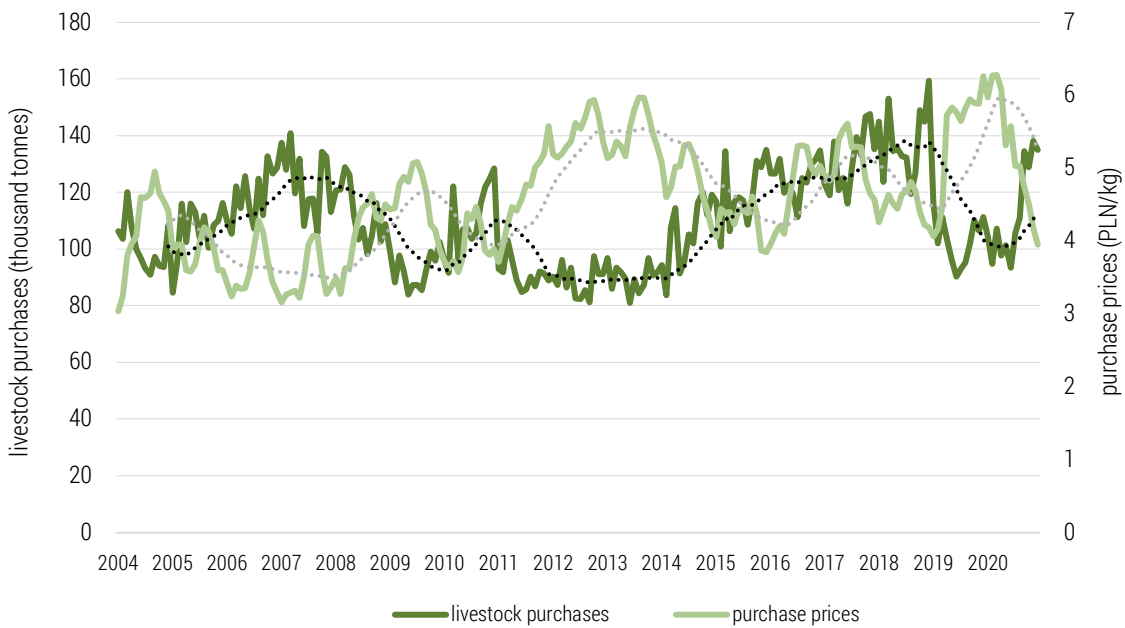


**Figure 8.** Purchase prices of pig, bovine and poultry livestock in Poland in 2004-2020 [monthly data, PLN/kg live weight]

Source: authors' work based on Ministry of Agriculture and Rural Development of Poland (2022); Statistics Poland (2022).

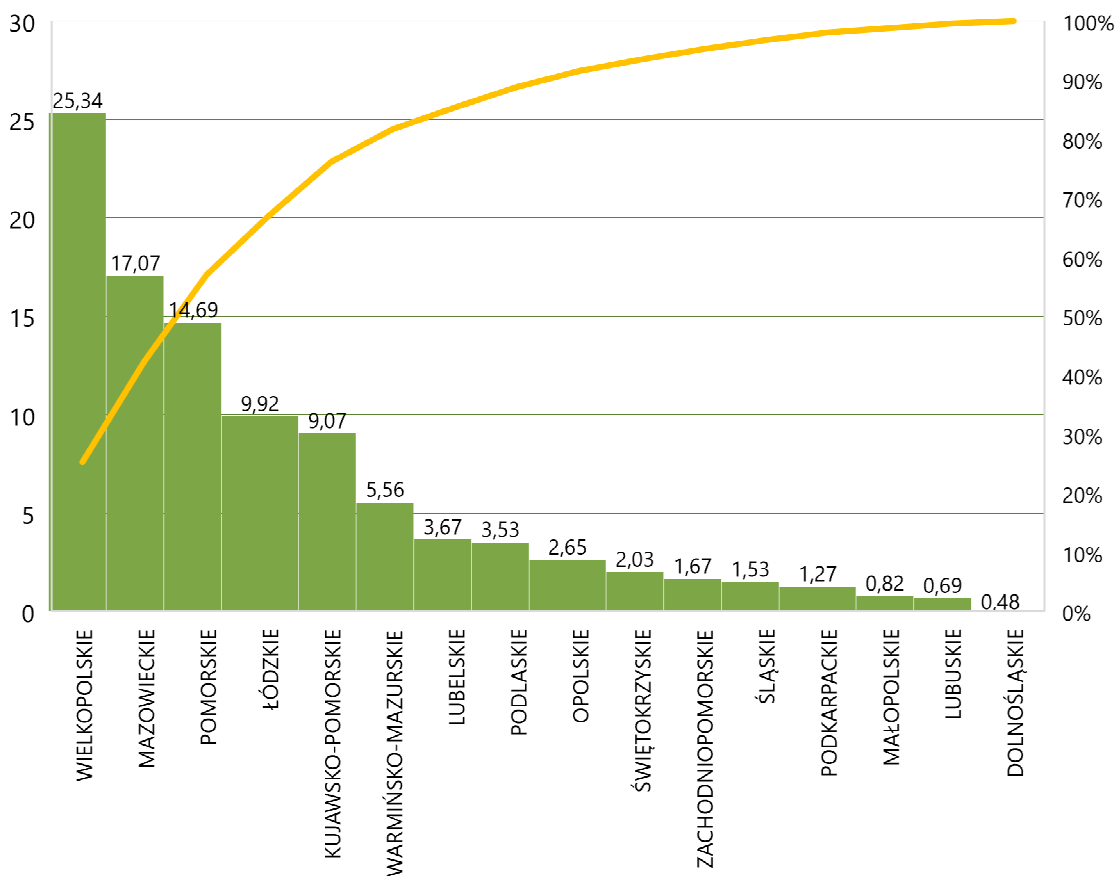
Price developments in the individual markets did not follow the same pattern, although some similarities can be found. Until mid-2010, purchase prices for these three types of animals remained at low, similar levels. Live cattle prices were regularly lower than live pig prices despite a much longer cattle fattening period. Purchase prices for live poultry were generally lower than purchase prices for live pigs. Prices in all markets started to increase in mid-2010 (the period of pig production peak in the 2008-2012 cycle). The high prices in the beef market manifested relatively little fluctuation until the beginning of 2020 when another phase of price increase began. Purchase prices for live cattle were among the highest for most of the surveyed period, and their changes in the following months were relatively small. Poultry prices also fluctuated in the following months. The extent of these fluctuations in short periods was greater than in the case of the beef market. The price level was more stable than between 2004 and 2010, but it followed a general downward trend. In April 2020, the average monthly prices for poultry reached the level of PLN 3.04/kg, i.e., they were at the level observed in 2009-2010. On the contrary, the purchase prices for live pigs changed significantly in the following months, and the price volatility was greater in 2010-2020 than in the previous decade. Live pig prices were below 4 PLN/kg from January to May 2010, from October 2010 to February 2011, and from November 2015 to January 2016, and they returned to this level again in December 2020 and January 2021. On the contrary, the price from February to April 2020 was 50% higher at 6 PLN/kg. Such price fluctuations are disruptive and create a certain challenge for farmers' decision-making. As a result, many farmers under such price volatility, and thus the profitability unpredictability, made the decision to withdraw from the troublesome market.

To continue the analysis of the purchase prices for pigs, the purchase prices for live pigs were compared with the purchase volume during this period (Figure 9).



**Figure 9.** Purchase volume and purchase prices of live pigs in Poland in the years 2004-2020 [monthly data, thousand tonnes, PLN/kg]

Source: authors' work based on Ministry of Agriculture and Rural Development of Poland (2022); Statistics Poland (2022).



**Figure 10.** Regional variation of pig livestock production in Poland in 2020 [%]

Source: authors' work based on Statistics Poland (2022).

The analysis of the monthly data, supplemented by a 12-month moving average, makes it possible to observe the course of the individual business cycles and the reactions of purchase prices to changes in the supply of livestock in the individual periods. The business cycles in the pig livestock market had different amplitudes of fluctuation and lengths, but some regularities can be identified. First, according to the principles of a functioning market economy, there is a close correlation between changes in livestock supply and purchase prices. Longer cycles with higher amplitudes of fluctuation were followed by shorter cycles with lower amplitudes. Cyclical fluctuations also occur in pig markets in other countries, and their magnitude depends on the market organisation. The higher the degree of horizontal and vertical integration, the greater the chances of reducing the magnitude of the fluctuations. Cyclical fluctuations are one of the main problems in the pig market, causing fluctuations in supply, prices, and profitability for both livestock farmers and processors.

Another important issue related to the functioning of the pork market in Poland is the development of intensive production regions. According to the data from 2020, more than a quarter of pork purchases came from the Wielkopolskie Voivodeship (Figure 10).

After that, over 17% came from Mazowieckie Voivodeship and over 14.5% from Pomorskie Voivodeship. In total, over 57% of live pigs in 2020 were purchased in these three voivodeships. Intensive production was also carried out in Łódzkie and Kujawsko-Pomorskie voivodeships. The shares of other voivodeships were low. The process of creating regions with intensive pig production in Poland has been observed for many years, and in the following years, this phenomenon became more and more evident (Olszańska, 2012). On the one hand, this is a positive phenomenon. Producers can support each other and learn from the best. Also, the necessary surrounding facilities (feed mills, slaughterhouses and processing plants, veterinary care, etc.) that support and operate this branch of production have developed. On the other hand, however, there are increasing environmental and product safety problems in some areas (Olszańska, 2020).

Undeniably, pig farming has a significant impact on the natural environment. Key aspects to be mentioned include greenhouse gas emissions, water usage, feed consumption and waste management. Firstly, animal farming, including pig farming, is one of the main sources of greenhouse gas emissions in agriculture, especially carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>). Livestock production accounts for approximately 14.5% of total anthropogenic emissions, stemming from both animal digestion processes and waste management (Grossi et al., 2019). Methane, in particular, is a potent greenhouse gas with a warming potential approximately 25 times higher than that of carbon dioxide. Secondly, this type of production requires significant amounts of water for drinking, hygiene, and cleaning processes. Mekonnen and Hoekstra (2012) found that in animal production, the actual water demand depends not only on the species, age, and weight of the animal but also on the feed and the maintenance system. Considering the global water footprint for various livestock, it has been shown that beef cattle constitute the largest share (33%), followed by pigs (19%) and broiler chickens (11%). The average lifetime water footprint in m<sup>3</sup> per animal is 1889 for cattle, 390 pigs, and 6 for broiler chickens (Florek et al., 2017; Mekonnen & Hoekstra, 2012). According to the Institute of Agricultural and Food Economics (IME), producing 1 kg of meat requires between 5,000 and 20,000 litres of water, whereas producing 1 kg of wheat requires between 500 and 4,000 litres of water. Beef production has the highest water footprint, averaging 15,139 litres per kg, followed by lamb at 10,412 litres, pork at 6,299 litres, and poultry at 3,960 litres (Mekonnen & Hoekstra, 2012). Intensive pig farming can lead to excessive water usage, adversely impacting local ecosystems and the availability of water for other economic sectors. The report "Causes of Water Scarcity in Poland" indicates that agriculture, particularly livestock production, alongside industry and municipal management, contributes to the depletion of water resources in Poland. The highest water abstraction for agricultural purposes occurs in areas with intensified livestock production, such as the Wielkopolska Lowland (Wielkopolskie Lakeland) and the Lublin Upland (Malinowska, 2022). Thirdly, pig feed production requires a significant portion of arable land, synthetic fertilisers, and pesticides. Cultivating feed crops can contribute to deforestation, soil erosion, and loss of biodiversity. Moreover, intensive pig farming often relies on imported feeds, resulting in long-distance transportation and associated greenhouse gas emissions. Lastly, pig farming generates large quantities of waste that require proper management. Improper waste management can lead to contamination of both soil and water. In such cases, nutrients and pesticides from the waste contribute to water eutrophication, causing algal blooms and degradation of aquatic ecosystems. Large-scale animal production facilities can also be

a nuisance to nearby residents (smell, noise, traffic). All things considered, the examples given lead to a growing interest in sustainable pig farming practices, including greenhouse gas emissions reduction, efficient waste management, responsible water usage, and cultivating local feed sources. Alternative farming methods, such as free-range farming, may also have a smaller environmental impact, although they come with other challenges, such as disease control and animal welfare (Zdunek, 2022).

In this context, the constantly spreading African swine fever (ASF) is an increasing threat in Poland. ASF causes huge economic losses due to the restrictions imposed on the breeding and export of live pigs and the meat obtained from them. In order to control this disease, the General Veterinary Inspectorate introduced a series of regulations and restrictions and demarcated the appropriate zones (General Veterinary Inspectorate, 2022). This is justified by the strong infectivity of the disease, but at the same time, it has a serious impact on local agricultural production, including a significant drop in the price of pork and often the need to eliminate fattening pigs for a long period of time. The fight against this disease is mainly based on movement control, the use of disinfectants and compliance with biosecurity regulations. Unfortunately, the application of these measures is not effective in practice, and the disease continues to spread.

ASF occurred in Poland in 2014 near the border with Belarus. Originally, the disease occurred in eastern Poland, where livestock production is relatively small. Currently, the disease covers almost the entire area of Poland east of the Vistula River. The disease is also beginning to spread in the Łódź and Lubuskie voivodships, covering a large part of the Wielkopolskie voivodship (gyp). As a result, ASF has covered part of the above-mentioned areas with intensive livestock farming in Poland and poses a real threat to the eastern areas of Germany.

## Conclusions

Domestic demand for pork is high and relatively stable. This provides a favourable foundation for this production direction. However, the systematic changes in the structure of meat consumption led to a steady increase in the share of poultry meat at the expense of the other two types of meat. The trade balance for pork was negative in the last thirteen years of the period under study. However, its magnitude was small compared to the total volume of exports and imports. Foreign trade was dominated by meat, a low-processed product, mainly in the form of pork sides. Foreign trade had a limited impact on the domestic market supply. It provided a buffer for processors in times of lower supply in the domestic market. In the case of young animals' imports for further finishing, we found some influence in domestic livestock production. This practice positively impacts the quality of livestock purchased in Poland and deepens the specialisation of Polish fattening farms.

On the other hand, this also indicates an increasing dependence of domestic pig production profitability on the economic situation in the Danish or German market. Pork production exhibited cyclical fluctuations during the studied period, with these cycles showing a significantly lower amplitude of fluctuations since 2015. Production showed an overall downward trend, and a similar situation was manifested in the case of the number of pieces and slaughter sizes. For these quantities, the fit of the trend line is much higher. Therefore, it is highly likely that these trends will continue in the future due to the spread of ASF and the prevailing trends in meat and general food consumption. A comparison of the purchase prices of the basic animal species shows that the swine market has the greatest price fluctuations of three compared to meat markets. In addition, prices tended to fluctuate within limited value ranges despite inflation. After 2012, higher prices could have been expected compared to those observed in the first years of our analysis. It did not happen, and, in general, the price situation in all livestock markets forced a constant production cost-optimization and organisational activities to ensure production profitability. In the livestock market, both purchases and prices fluctuated cyclically. An increase in the market supply of livestock typically leads to price decreases, while periods of lower supply result in price increases. These cycles vary in their waveforms and fluctuation amplitudes. Greater amplitudes led to increased market tensions followed by weaker cycles during which both supply and prices fluctuated just slightly.

The analyses show that a high degree of concentration in pig production has developed in three voivodships. There are both positive and negative aspects of such processes. However, given the

numerous ASF outbreaks in these voivodeships, it may pose a serious threat to the domestic production of live pigs.

Undoubtedly, livestock and pork meat production has a significant impact on the environment in Poland. The natural drive to maximise profits under constant market fluctuations favours process concentration and adoption of industrial forms of production. However, as Mekonnen and Hoekstra (2012) noted, animal products from such production tend to consume and pollute more water resources, both groundwater and surface water, than animal products from grazing or mixed systems. Consumer expectations and, consequently, producers' adaptation to it lead to the growing interest in sustainable practices in this sector. Implementing measures to reduce greenhouse gas emissions, efficiently manage waste, responsibly utilise water resources, and cultivate local feeds can contribute to mitigating the negative environmental impact of livestock and pork meat production. Alternative farming methods, such as free-range farming, may also present an interesting option with a lower environmental footprint.

## Limitations and Implications

We acknowledge that our research is limited by the lack of data within shorter periods than a year and the limited attention the topic gets from the scientific literature. The literature review found a research gap that would be worthwhile to fill in the future. The study covers a relatively long period of 17 years but may not account for recent changes or emerging trends in the pork market in Poland. For instance, the COVID-19 pandemic had a significant impact on the meat industry, but its long-term effects might not fully manifest within the studied period. The article analysed the issue of concentration in pork production in individual provinces in Poland. However, due to a lack of detailed data, we were unable to bring a comprehensive analysis of environmental impact regional disparities. We mentioned several issues related to the environmental consequences of intensive production practices. Yet, we considered issues such as greenhouse gas emissions, water consumption, and waste management to be partly beyond the scope of the article. Therefore, we consider this as a future research area in which a question of environmental damage and resource depletion might lead to a new cost enumeration in a wider context. Excessive concentration of animal production in relatively small areas can also lead to disruptions in the national market in the case an epidemic strikes production-intensive regions. Increasing awareness of the environmental impact of pig farming may lead to the introduction of more stringent regulations in the future. Farmers and processors should prepare to adapt to these regulatory changes. The interesting issue of seasonality and cyclicity in the Polish market and other EU countries also requires more in-depth analysis. We encourage further research regarding Poland's position in the European Union market. In this article, we only touched on this issue, but we acknowledge that issues such as subsidies, the position of farmers in new EU members compared to the old ones, etc., are extensive and deserve further research and a separate article.

In summary, the article provides a development overview of the dynamics of the Polish pork market but also highlights areas where further research and analysis should expand our knowledge of this complex industry and its implications for the economy and the environment.

## The contribution of the authors

Conceptualization, A.O., A.S.K. and I.S.; literature review, A.O., A.S.K., J.S., K.G. and I.S.; methodology, A.O. and A.S.K.; formal analysis, A.S.K., J.S., K.G. and I.S.; writing, A.O., A.S.K. and K.G.; conclusions and discussion, A.O., J.S., and I.S.

The authors have read and agreed to the published version of the manuscript.

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## TRENDY NA RYNKU ŻYWCA I MIĘSA WIEPRZOWEGO W POLSCE Z UWZGLĘDNIENIEM WPŁYWU TEGO KIERUNKU PRODUKCJI NA ŚRODOWISKO

**STRESZCZENIE:** Po przystąpieniu Polski do Unii Europejskiej kontynuowano zmiany strukturalne w produkcji i przetwórstwie mięsa zwierząt zapoczątkowane przez gospodarkę rynkową. Niestety w otoczeniu występuje wiele zagrożeń, których skutki mogą mieć istotne znaczenie dla funkcjonowania rynków mięsnych. Takie zjawiska jak rozprzestrzenianie się choroby ASF, wyjście Wielkiej Brytanii z Unii Europejskiej czy epidemia Covid-19 dodały niestabilności na i tak już cyklicznym rynku wieprzowiny. Celem opracowania jest ocena funkcjonowania rynku wieprzowiny w Polsce oraz identyfikacja głównych trendów na tym rynku przy jednoczesnym uwzględnieniu wpływu tego kierunku produkcji na środowisko. Produkcja żywca i mięsa wieprzowego w Polsce jest istotnym sektorem gospodarczym, ale wiąże się również z poważnymi wyzwaniami związanymi z ochroną środowiska. W opracowaniu skupiono się na głównych aspektach, czyli: emisji gazów cieplarnianych, zużyciu wody, zużyciu paszy i gospodarowania odpadami. Badanie obejmuje lata 2004-2021, czyli okres siedemnastu lat po przystąpieniu Polski do Unii Europejskiej. Metody analizy danych statystycznych wskazują, że krajowy popyt na wieprzowinę jest wysoki i względnie stabilny, co stanowi korzystną podstawę dla tego kierunku produkcji. Systematyczne zmiany w strukturze spożycia mięsa prowadzą jednak do stałego wzrostu udziału mięsa drobiowego kosztem pozostałych dwóch rodzajów mięsa.

**SŁOWA KLUCZOWE:** ekonomika i polityka rolna, ekonomika żywności i bezpieczeństwo żywnościowe, produktywność i wydajność, Polska, środowisko