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# Exploring the Impact of Wheat Prices and Annual Income on Pig Carcass Prices in European Countries: A Spatial Panel Regression Analysis

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**Abstract**

In this study, we investigated the spatial and temporal dynamics of pork carcass prices across European Union Member States, focusing on the influence of wheat prices and population income levels between 2014 and 2023. Our analysis revealed that both input costs (reflected by wheat price fluctuations) and income-driven demand factors exert significant and spatially correlated effects on pork carcass prices. The results demonstrate the existence of spatial interdependencies among neighboring countries, indicating that price changes in one region may propagate through the broader European market. By integrating spatial econometric techniques within a panel data framework, this research provides empirical evidence of the interconnected nature of EU agricultural markets, advancing the existing literature by demonstrating how input markets and consumer income dynamics jointly shape price behavior within an integrated regional economy. Our findings contribute to a deeper understanding of price transmission mechanisms in the livestock sector and offer valuable insights for policymakers seeking to enhance market efficiency and resilience within the Common Agricultural Policy context.

**Keywords:** annual income; EU countries; food market interdependencies; panel regression; pig carcass; spatial econometrics; wheat prices

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## 1. Introduction

The price of pork carcasses plays a key role in the agricultural economies of European Union (EU) countries, reflecting the supply and demand dynamics as well as the economic and social conditions of the market [1]. Pork is a significant component of diets worldwide and has a major influence on the livestock industry [2]. Furthermore, its production in the EU accounts for over 20% of global production, holding a strategic position in the global pork market [3]. This high level of popularity drives consistent demand, making prices sensitive to factors such as feeding costs, trade policies, production efficiency, and fluctuating demand [4,5], potentially leading to seasonal and structural fluctuations in the final price of pork carcasses [6,7].

Understanding the determinants of pork carcass prices is therefore of strategic importance for both ensuring market stability and informing policy decisions in the agricultural and food sectors; however, comprehensive price mechanism frameworks remain insufficient.

Moreover, pork production is increasingly being influenced by climate change and its implications for sustainable development. Rising temperatures, extreme weather events, and shifts in precipitation patterns can affect the availability of feed, in addition to animal health and productivity, thereby influencing production costs and market prices; pork production also contributes to environmental pressures, including greenhouse gas emissions, land use, and water consumption, highlighting the importance of sustainable management practices [8,9].

In this study, we aimed to analyze both the spatial and temporal trends of pork carcass prices in EU countries, highlighting how fluctuations in wheat prices and annual income levels influence these prices. To achieve this, a panel econometric regression was employed; a common type of analysis in the specialized literature [10,11].

According to Tluczak [12], the EU pork sector is shaped by a complex interplay of economic, social, and market factors. Although this sector is of vital importance for residents' food security, the specific ways in which these factors influence prices remain unexplored, particularly from the perspective of spatial and temporal disparities among Member States. These research gaps define the central problem of this study.

We therefore set out to answer the following research questions:

(a) How do feed prices, specifically wheat prices, affect pork carcass prices within the EU?
(b) Does the annual income of the population influence the demand and price of pork in different Member States?
(c) How did these interactions evolve during the 2014–2023 period, considering external shocks such as changes in trade policies and global economic contexts?

The primary objective was to analyze, using econometric models, the factors influencing pork carcass prices within the EU during the 2014–2023 period, focusing on the spatial and temporal relationships between the selected economic variables.

Consequently, the hypotheses guiding this research are as follows:

1. Due to rising production costs, higher wheat prices are positively correlated with increased pork carcass prices.
2. Higher income levels lead to increased demand for pork, thereby driving up both demand and prices, although this relationship may vary by region.
3. There is a spatial connection among EU countries, whereby pork carcass prices in one region influence those in neighboring regions.

By integrating these hypotheses within an econometric framework, we aim to provide a deeper understanding of the interactions between economic variables and their impact on pork carcass prices across EU countries. The findings are expected to support policymakers, producers, and researchers in designing more effective agricultural and trade strategies within the EU.

*Literature Review*

Numerous scientific studies have analyzed the economic and social factors influencing pork production and pricing, both globally and within the EU [13–15]. Jeremic et al. [16] examined the pork market in Serbia, highlighting the influence on the demand of factors such as personal consumption and retail prices of pork and beef, and the influence of pork prices on supply. Other relevant studies have focused on markets in Slovakia [17], Vietnam [18,19]; Nigeria [20,21]; the USA, Canada, and Ireland [22,23]; France [24]; the Czech Republic [25,26]; the EU [27,28]; and other countries [29–31]. These studies emphasize the fundamental role of feed costs, particularly wheat, as key determinants of production expenses and market prices. Additionally, variations in meat quality reflect

changes in consumer expectations and market segmentation driven by economic and lifestyle factors [32].

Similarly, recent studies from 2025 emphasize that consumers increasingly value animal welfare, natural production methods, and environmental sustainability, favoring meat products derived from alternative or circular farming systems that align with these ethical and ecological ideals [33,34].

Moreover, several studies have highlighted that food security is closely linked to the production of meat, including pork, and is influenced by factors such as grain production and food reserve strategies. In China, for example, the expansion of pork production has played a crucial role in improving nutritional security and dietary quality among the population [35].

According to Zhao [36], who analyzed data from the past two years provided by the National Bureau of Statistics of China, domestic pork prices exhibited fluctuations despite a steady increase in international prices. The COVID-19 pandemic had a significant impact on the market, rapidly reducing production capacity in 2020. Following the second wave of the pandemic, production returned to normal levels, but the demand declined, leading to an oversupply in the pork market. A further study focused on analyzing pork stock levels and corn prices to forecast price trends for 2022 [37].

Heber et al. [38] examined the influence of wheat prices and income levels on the EU pork market, emphasizing the impact on carcass quality and economic efficiency caused by raising pigs on small farms. Their study concluded that improper management of pig weight could lead to additional feed costs and a lower economic value of pork.

Regarding Romania, a review of the specialized literature highlights its strong traditions related to pig farming and trade [39]. According to research conducted by Bălan et al. [40], data from 2009 indicate that while the average prices of pork carcasses in Romania were lower than those in other EU Member States, their quality was comparable to that of more competitive countries. That year, the average lean meat percentage was 59.4%, and over 99% of carcasses were classified in the top-quality categories, E and U.

Analyzing the pork price fluctuations, a study by Pang et al. [41] highlighted key determinants such as epidemic shocks, supply and demand dynamics, and meat imports. To stabilize the market, the authors recommended that the relevant organizations undertake price monitoring using big data analysis, promote large-scale farms, and implement disease prevention and control measures. Additionally, research by Ma et al. [42] confirmed that negative media coverage regarding pig epidemics impacts pork price fluctuations both locally and through spillover effects in neighboring countries and regions.

Understanding the dynamics of pork carcass prices within the EU is essential due to their significant economic impact. The industry makes a notable contribution to the GDP of pork-producing countries, generates employment, and supports rural economies. Price fluctuations have a major effect on farmers and other stakeholders across the supply chain [43,44].

According to a study by Hamulczuk and Stańko [45], pig prices in Poland are primarily influenced by the balance between supply and demand, with farmers acting as price takers. Approximately 70% of the price variations were driven by external market conditions, while only 30% were attributed to domestic factors. Farmers' margins in the pork supply chain remained stable between 1997 and 2012, showing cyclical and seasonal fluctuations of around 37%. The decline in pork production in Poland after 2008 was mainly due to structural issues such as fragmented production, limited economies of scale, and high production costs, which negatively affected domestic demand and competitiveness against imports.

Xu et al. [46] highlights that the period from 2014 to 2023 was marked by major events such as the COVID-19 pandemic and geopolitical shifts, which had a significant impact on global trade, income levels, commodity prices, and various public perceptions [47].

Their study underscores that understanding these long-term trends is important for individuals, companies, and organizations, as it enables better anticipation of market developments and preparation for future challenges. Additionally, a study conducted by Steen et al. [48] demonstrated that the COVID-19 pandemic caused significant disruptions to supply chains, labor markets, and consumer behavior, leading to heightened price volatility in meat markets. Specifically, volatility in the prices of grains used as feed and the interdependencies between global and local agricultural markets played a key role in exacerbating these fluctuations. Furthermore, this study highlights an increase in the frequency of extreme weather events linked to climate change, such as droughts and floods, which negatively impact grain productivity and indirectly contribute to instability in agricultural markets.

In pig nutrition, wheat has a high energy value, serving as a rich source of starch. While its crude protein content is lower compared with other protein supplements, wheat provides significant amounts of essential amino acids because of its high level of inclusion in pig diets. Additionally, wheat by-products, such as bran and dried distiller grains, are increasingly used in pig nutrition, offering alternative sources of protein and energy.

Avelar et al. [49] and Rosenfelder et al. [50] emphasize that these wheat-derived protein and energy sources are essential, particularly when considering feed costs and the specific nutritional requirements of the animals, and contribute to optimizing growth performance while reducing production costs. Furthermore, Kim et al. [51] highlighted the importance of considering the wheat variety being cultivated, as its physical characteristics and digestible energy (DE) content can vary significantly.

Moreover, Dinu [52] argues that an undistorted competitive environment supports the proper functioning of the market economy, contributing to the more efficient satisfaction of consumer needs and fostering economic, technical, and scientific progress. Competition policy plays a key role in protecting consumer interests by promoting fair competition among economic agents, which translates into lower costs, greater diversity, improved quality of products and services, and maximized consumer satisfaction.

Spatial econometric techniques are used to empirically assess these dynamics and understand how competition and market efficiency evolve across regions and over time. The spatial model simultaneously analyzes both spatial and temporal effects, allowing for a more comprehensive understanding of processes that evolve over time and are shaped by spatial dynamics. It can also effectively handle heterogeneity by incorporating individual-specific effects, enabling it to account for unobserved differences across spatial units. This makes it particularly suitable for studies where regional characteristics vary significantly. Authors such as Kapoor [53], Baltagi et al. [54], or Lee and Yu [55] developed and generalized models that incorporated both spatial dependencies and errors alongside fixed or random effects, proposing a series of tests to select the appropriate model for potential predictions (e.g., the Hausman test). One of the most well-known models of this kind, frequently used in empirical studies, is that developed by Baltagi and Li [56] as part of a study on cigarette demand in 46 U.S. states from 1963 to 1992. It should be noted that due to the spatial coefficients included in the model, it is not used for predictions but solely to evaluate the relationship between the two variables of interest.

## 2. Materials and Methods

To investigate the factors influencing pork carcass prices in EU countries from 2014 to 2023, this study employed a spatial panel regression model. This method accounts for both temporal changes and spatial interdependencies among EU Member States (excluding the UK), providing a comprehensive analysis of how regional factors interact over time. Unlike conventional regression methods, the spatial panel framework explicitly

models spatial autocorrelation, acknowledging that price movements in one country may be influenced by neighboring markets through common policies or regional shocks [57,58]. By integrating the temporal dimension, the model allows for the identification of persistent trends and dynamic adjustments in pork markets. This makes spatial panel regression particularly suited for analyzing geographically distributed data where cross-country spillover effects and heterogeneous regional characteristics are expected to shape market outcomes.

### *2.1. Data*

To analyze the determinants of pork carcass prices across EU countries, it is important to identify the suitable variables that capture both the supply-side and demand-side influences. This selection was guided by the above literature review which emphasized the importance of costs, input prices, and consumer purchasing power. With this as a starting point, our aim was to provide a comprehensive understanding of the factors driving regional and temporal fluctuations in pork prices.

#### 2.1.1. Variables

Dependent Variable: Pork carcass prices.

Independent Variables: Wheat prices and annual net earnings.

For all three variables, there were missing values for certain countries or specific years. These were imputed either by using the most recent available values or by including the mean. For the dependent variable (the price of pork carcasses), the missing values pertained to Italy for the 2019–2023 period, where the last available value was used. For wheat prices, missing observations were identified for Ireland and Malta (for the entire period), Cyprus (2014–2019), and France (2017–2023). In the cases of Ireland and Malta, missing values were replaced with the overall mean, as these countries exhibited relatively stable price levels comparable to the EU average. For Cyprus and France, the first available observation was used to fill the gaps, since these omissions occurred at the beginning or the end of the series, and the available data suggested a consistent trend over time. Regarding the annual net income, missing data were recorded for Cyprus in 2015–2016 and imputed using the nearest available value, assuming a gradual evolution of income levels from year to year. These imputation methods were applied to preserve data consistency across countries and years while minimizing bias that could arise from unequal sample sizes.

#### 2.1.2. Time Frame

This analysis spanned from 2014 to 2023, a period that included significant events such as Brexit, the COVID-19 pandemic, and geopolitical tensions affecting trade and commodity markets.

#### 2.1.3. Sources

- Pork carcass prices: Data on pork carcass prices (measured in euros per 100 kg) were sourced from the European Commission's Market Observatory.
- Wheat prices: Wheat price data (measured in euros per metric ton) were obtained from Eurostat.
- Annual income: Annual net earnings (measured in euros) were sourced from Eurostat.

### *2.2. Analysis*

#### 2.2.1. Spatial Panel Regression Model

The spatial panel regression model offers several advantages that make it a valuable tool for analyzing phenomena influenced by spatial and temporal factors. One of its key strengths is its ability to capture spatial dependencies and interactions between regions or entities, which traditional panel models often overlook. This feature is particularly

important when behavior in one area can influence neighboring areas. By accounting for spatial autocorrelation, the model provides more accurate and reliable parameter estimates, reducing bias and improving estimation accuracy.

This model includes fixed effects to control unobserved heterogeneity across countries and over time. It also incorporates a spatial lag variable to capture the influence of neighboring countries' pork prices on a given country's prices.

#### 2.2.2. Spatial Weight Matrix

A spatial weight matrix was constructed to define the relationships between countries. In the case of the present model, a matrix based on the inverse squared distance was constructed. Through preliminary analysis, this matrix proved to be more effective than the queen-type matrix.

#### 2.2.3. Key Model Equations

The spatial regression models are illustrated in the above equations [59]; in our case, concerning panel models. The first model is the spatial Durbin model (SDM), which conducts the most general spatial specification by including both spatially lagged dependent and independent variables. To determine whether the SDM could be simplified to either the spatial autoregressive model (SAR) or spatial error model (SEM), appropriate Wald and likelihood ratio (LR) tests were conducted. The results indicated that the SDM could not be reduced to either the SAR or SEM, confirming the presence of complex spatial dependencies involving both spatial lag and spatial error. Subsequently, the spatial autoregressive combined (SAC) model was estimated to account for these dual spatial processes simultaneously, incorporating both the spatial autoregressive and spatial error parameters. Model selection was guided by information criteria, specifically the Akaike information criterion (AIC) and the Bayesian information criterion (BIC), where lower values indicate superior model fit.

$$\text{SLX}: \ \boldsymbol{P} = \boldsymbol{X\beta} + \boldsymbol{WX}_y + \boldsymbol{\varepsilon} \tag{1}$$

$$\text{SEM}: \ \boldsymbol{P} = \boldsymbol{X\beta} + \mu, \mu = \boldsymbol{\lambda W}_\mu + \boldsymbol{\varepsilon} \tag{2}$$

$$\text{SAR}: \ \boldsymbol{P} = \boldsymbol{\rho WP} + \boldsymbol{X\beta} + \boldsymbol{\varepsilon} \tag{3}$$

$$\text{SDEM}: \ \boldsymbol{P} = \boldsymbol{X\beta} + \boldsymbol{WX}_y + \mu, \mu = \boldsymbol{\lambda W}_\mu + \boldsymbol{\varepsilon} \tag{4}$$

$$\text{SDM}: \ \boldsymbol{P} = \boldsymbol{\rho WP} + \boldsymbol{X\beta} + \boldsymbol{WX}_y + \boldsymbol{\varepsilon} \tag{5}$$

$$\text{SAC}: \ \boldsymbol{P} = \boldsymbol{\rho WP} + \boldsymbol{X\beta} + \mu, \mu = \boldsymbol{\lambda W}_\mu + \boldsymbol{\varepsilon} \tag{6}$$

SAC model with panel data:

$$P_{it} = \rho \sum_{j \neq i} W_{ij} P_{jt} + X_{it}\beta + \mu_{it}, \tag{7}$$

where

$P_{it}$ is the dependent variable for unit i at time t;

$\rho$ is the spatial autoregressive parameter, capturing the influence of spatial interactions;

$W_{ij}$ is the element of the spatial weight matrix W at position (i, j) representing the spatial relationship between units i and j;

$X_{it}$ is the vector of independent variables for unit i at time t;

$\beta$ is the vector of coefficients for the explanatory variables;

$\mu_{it}$ is the error term for unit i at time t.

Error term structure:

The error term in a SAC model typically has a spatial autoregressive structure:

$$\mu_{it} = \lambda \sum_{j \neq i} W_{ij} u_{jt} + \varepsilon_{it}, \quad (8)$$

where

$\lambda$ (lambda) is the spatial autocorrelation parameter for the error term;

$u_{jt}$ is the spatially correlated error term for unit j at time t;

$\varepsilon_{it}$ is the idiosyncratic error term (white noise, typically assumed to be independent and identically distributed).

#### 2.2.4. Interpretation

The SAC model with panel data incorporates both spatial dependence (through $\rho$ and WW) and temporal dependence in the error term (through $\lambda$ and the spatial lag in $u_{jt}$).

This model enables both direct spatial interactions (through the spatial lag $\rho$) and indirect spatial interactions (through the spatially correlated errors $\lambda$).

#### 2.2.5. Diagnostic Tests

Pesaran test: To decide whether spatial models are more suitable.

The Pesaran test was conducted to decide whether spatial models would be more appropriate, with the results illustrated in Table 1. Given the *p*-value, the null hypothesis was rejected. Thus, the Pesaran test shows that spatial models are more appropriate for this dataset compared with a classic regression model.

**Table 1.** Pesaran test.

| | |
|---|---|
| Pesaran's test of cross-sectional independence | 43.271 (*p*-value: 0.000) |
| Average absolute value of the off-diagonal elements | 0.762 |

### *2.3. Software and Tools*

This analysis was conducted using statistical software such as Geoda (v1.22) and STATA 18. By combining spatial and temporal dimensions, this analytical framework provides a robust understanding of the factors driving pork carcass prices in the EU.

## 3. Results

### *3.1. Impact of Wheat Prices on Pork Carcass Prices*

A significant positive correlation was found between the prices of wheat and pork carcasses, with an increase in wheat prices leading to an increase in pigmeat production costs. This in turn led to a further increase in pig carcass prices across the entirety of the territory (EU) analyzed, underlining the importance of production costs in determining the final price of pigmeat.

### *3.2. Influence of Annual Income Levels*

Higher annual income levels, especially in economically advanced EU Member States, led to higher demand, while in lower-income regions with less elastic demand, the dynamics were slightly different. This suggests differing consumption behavior between EU countries (Table 2).

**Table 2.** Main results.

| | Models | | | |
|---|---|---|---|---|
| **Coefficients** | **OLS** | **SDM Random Effects** | **SDM Fixed Effects** | **SAC** |
| Constant | 3.764584 *** | 1.522482 *** | - | - |
| Wheat price | 0.2714834 *** | 0.0486582 *** | 0.1879952 *** | 0.1724461 *** |
| Annual net earning | 0.057659 ** | 0.2994138 *** | 0.2975839 *** | 0.2745334 *** |
| W wheat price | - | −0.2400977 *** | −0.3388913 *** | - |
| W annual net earning | - | −0.608515 *** | −0.2354983 | - |
| Rho | - | 1.323524 *** | 1.340298 *** | 0.7792935 *** |
| Lambda | - | - | - | 1.119499 *** |
| | Information criterion | | | |
| Akaike | | −455.6632 | −602.8598 | −619.7234 |
| Bayesian | | −426.8758 | −581.2693 | −601.7313 |

Notes: ** valid for 95% probability, *** valid for 99% probability.

### *3.3. Spatial Dependencies*

The spatial lag term was significant, indicating that pork prices in one country were influenced by prices in neighboring countries. For instance, price changes in Poland had a measurable impact on prices in the Czech Republic, Slovakia, and Hungary.

The SAC model exhibited the lowest AIC and BIC scores among competing specifications, suggesting it provides the best explanatory power. Furthermore, the model demonstrated superior performance, with all coefficients being statistically significant. Thus, a 1% increase in the price of wheat leads to a 0.17% increase in the price of pork carcasses, while a 1% increase in consumers' average income results in a 0.27% increase in the price of pork carcasses. The spatial coefficients, rho and lambda, were also significant. As stated above, changes in one European country influence those in neighboring countries; an increase in the price of pork carcasses in one country will be reflected in a neighboring country, leading to one country being surrounded by others with similarly high prices.

The pig carcass prices for 2014 and 2023 are illustrated in Figure 1. It is evident that countries with high prices tend to be geographically clustered, which supports the spatial dependence assumption.

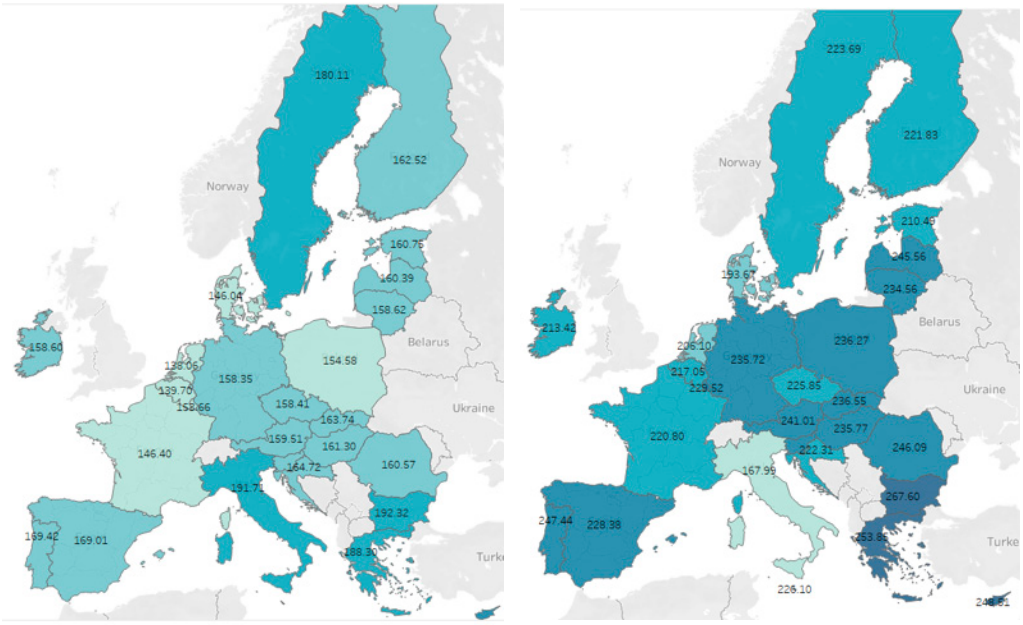


**Figure 1.** Pig carcass prices in 2014 vs. 2023.

In 2023, Bulgaria, together with Greece, Romania, and Cyprus, had the highest pork carcass prices in the EU. Bulgaria ranked first, with a price of EUR 267.6 per 100 kg, followed

by Greece (EUR 253.86), Romania (EUR 246.09), and Cyprus (EUR 248.51). Compare this to 2014, where Romania's price, EUR 160.57, was more in line with that of other EU countries. This significant increase compared with 2014 is in line with a general trend of rising prices in southeastern European countries. Italy is an exception due to its consumption of a different type of processed pork carcass, suggesting a fluctuation in the domestic market or a change in country-specific economic factors. Denmark, which had a relatively low price of EUR 146.04 in 2014, showed a slight increase in 2023 to EUR 193.67. Danish pork carcasses are cheaper than in other European countries due to the high efficiency and technological advancement of their industry; with large-scale farms, Denmark's producers benefit from low feed and health-related costs [60]. The government and research institutions also offer continuous innovations, keeping production costs low [61]. Central European countries also experienced considerable price increases, but with some regional variations. For example, prices in Poland rose from EUR 154.58 in 2014 to EUR 236.27 in 2023, and those in the Czech Republic jumped from EUR 158.41 to EUR 225.85. Prices in Slovakia and Lithuania saw significant increases, with prices reaching EUR 236.55 and EUR 234.56, respectively.

Figure 2 presents the growth index of pig carcass prices from 2014 to 2023, highlighting that the largest increases occurred in Latvia, Lithuania, and Slovakia.

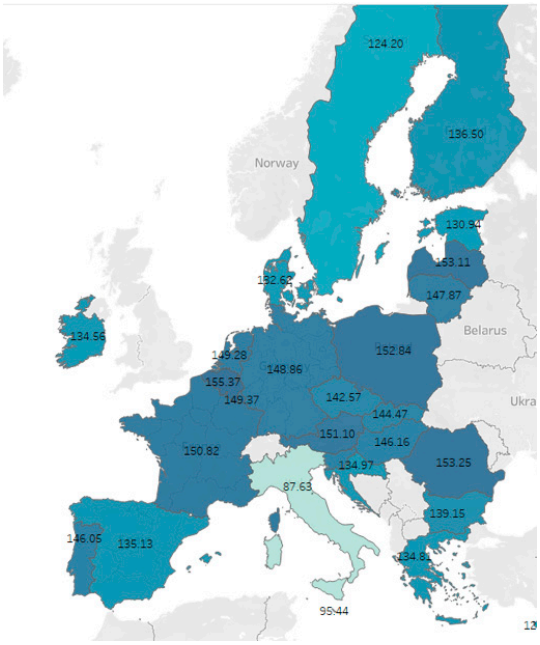


**Figure 2. The** 2023/2014 growth index of pig carcass prices.

In the figure, darker shades indicate stronger growth, while lighter shades indicate weaker growth or relative price stability. Western and Central European countries, such as France, Austria, Belgium, and Germany, experienced the highest increases in pork carcass prices. This may reflect the combined effects of rising production costs, supply adjustments, and higher demand.

A cluster of Central and Eastern European countries, including Poland or Hungary, showed moderate price growth. This may reflect advanced market integration with Western Europe or evolving consumer demand patterns.

The lowest growth indices were shown for Italy and Croatia, suggesting that pork carcass prices remained relatively stable or even decreased. These may be linked to lower domestic demand or policy factors.

In Northern Europe, countries like Sweden or Finland experienced below-EU-average growth. This may reflect smaller domestic markets and lower consumption levels.

## 4. Discussion

Our findings indicate that wheat prices, income levels, and spatial interdependence are key determinants of pork carcass prices in the EU. The observed positive correlation between wheat and pork prices reflects the role of input costs in livestock production, as wheat constitutes a major component of pig feed. This result shows strong support for Hypothesis 1, aligning with prior research showing that pork prices are particularly sensitive to feeding cost fluctuations compared with other meat types [62–66]. However, while wheat price increases generally translate into higher production costs, the magnitude of their impact can be moderated by factors such as transportation costs, government policies, and the degree of market integration, highlighting the complexity of cost pass-through mechanisms [67–69]. This suggests that simple correlations between feed prices and pork prices may over- or understate the actual market responses if these contextual factors are not considered.

Furthermore, income levels also emerged as a significant driver of pork prices, reflecting the interplay between consumer demand and purchasing power and confirming Hypothesis 2. Higher-income households tend to seek higher-quality or premium pork products, exhibiting lower price sensitivity and greater responsiveness to non-price attributes such as traceability or production methods [70–76]. This finding underscores that price determination is not solely a function of production costs; it is also shaped by demand-side heterogeneity across regions. In particular, the variation in consumption behavior between higher- and lower-income EU regions suggests that policymaker shocks may have asymmetric effects across the EU.

Crucially, our results reveal a substantial spatial dependence effect, whereby pork prices in one country are influenced not only by domestic factors, but also by prices and input costs in neighboring countries. For instance, price changes in Poland significantly affect markets in the Czech Republic, Slovakia, and Hungary, consistent with evidence of spatial spillovers in agricultural markets [28,77–80]. The incorporation of spatial lag terms in the econometric model captures this interconnectedness, illustrating that traditional non-spatial models may underestimate cross-border market integration and misrepresent regional price dynamics [77–79]. This emphasizes the importance of considering spatial effects in both empirical research and policy design, particularly in highly integrated markets such as the EU pork sector, and confirms Hypothesis 3.

All of our findings highlight the interplay of supply costs, demand heterogeneity, and spatial integration when determining pork carcass prices. They also suggest that policy measures or market interventions targeting one region may have wider, sometimes unintended consequences across neighboring countries. This reinforces the need for coordinated cross-border approaches in agricultural policy and market monitoring.

## 5. Conclusions

Pork is a key component of European diets, making it important to determine the factors influencing carcass prices; thus, this study provides useful relevant background information in the EU between 2014 and 2023, with a focus on changes in wheat prices (an important source of pig feed), income levels, and spatial dependencies between EU Member States.

Econometric analysis has shown that there is a significant positive correlation between the prices of wheat and pig carcasses. An increase in wheat prices led to an increase in pigmeat production costs, which in turn led to a further increase in the pig carcass prices across the entirety of the territory (the EU) analyzed. This result underlines the importance of production costs, in particular feed, in determining the final price of pigmeat. In addition, it was shown that higher annual income levels, especially in richer regions of the EU, lead

to higher demand, and hence higher prices, while in lower-income regions, where demand is less elastic, the dynamics are slightly different, suggesting that consumption behavior differs between EU countries.

Another important finding is the identification of a spatial dependence effect between pig carcass prices across EU countries: price movements in one market are not determined solely by domestic supply and demand conditions but also by developments in neighboring countries. Such interconnections suggest the presence of price spillover effects, whereby shocks in one market are transmitted to surrounding regions. For example, in the case of the Czech Republic, Slovakia, and Hungary, a measurable impact was observed following the change in Polish pig carcass prices. This demonstrates the high degree of integration of the EU pigmeat market fostered by the free movement of goods and harmonized trade regulations. The existence of such spatial interdependence underscores the importance of coordinated policy approaches and cross-border market monitoring, as isolated national measures may have unintended consequences on neighboring markets.

However, several limitations of this study should be acknowledged. First, while missing or inconsistent data were addressed through imputation techniques, the quality of these estimates may vary across countries and years, potentially introducing minor bias into the results. Second, although the SAC model provides strong explanatory power by capturing both spatial and error dependencies, it is primarily designed for inference rather than prediction, limiting its ability to generate reliable forecasts or simulate future market behavior under changing conditions.

In conclusion, the results presented in this study can aid both policymakers and those involved in the production and marketing of processed pork, as it is important to consider the relationships between the wheat prices, income, and prices of pork carcasses as well as spatial dependencies between European markets.

In terms of future research directions, it would be valuable to broaden the analytical framework to include additional economic and structural variables that may further influence the pork price dynamics. For instance, energy costs play a crucial role in agricultural production. Moreover, given recent fluctuations in food prices across the EU, future studies should investigate changes in consumer behavior in response to price volatility. Examining these behavioral and macroeconomic dimensions would provide a more comprehensive understanding of the market and help policymakers design effective strategies to stabilize the pork sector.

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## Abbreviations

The following abbreviations are used in this manuscript:

| | |
|---|---|
| EU | EU |
| LR | Wald and likelihood ratio |
| SLX | Spatial Lag of X |
| SEM | Spatial error model |
| SAR | Spatial autoregressive |
| SDEM | Spatial Durbin error model |
| SDM | Spatial Durbin model |
| SAC | Spatial autoregressive combined |

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