Spatial Integration of the Milk Market in Poland

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Abstract: The production of milk is an essential branch of agricultural production in Poland. There have been considerable changes in the milk market in Poland over the last 20 years (such as, e.g., the adjustment of the market to the EU requirements, which had an impact on the functioning of this market as well as its spatial integration. This research mainly aimed to assess the processes of spatial integration on the Polish milk market in the period 1999–2018. In order to process the material collected, the author applied the analysis of price differences, the analysis of correlation, the Johansen test of cointegration and the Granger causality test. As a result of the research conducted, it was found that there is a long-term balance between prices in various voivodeships in Poland. Moreover, the closer the voivodeships were to one another, the greater the co-variability of prices was between them. In addition, it was indicated which voivodeships were crucial from the point of view of the process of revealing and determining raw milk prices in Poland by two distinguished periods (1999–2008 and 2009–2018).

Keywords: milk market; spatial integration; Poland; milk; price

1. Introduction

The issue of spatial interrelations is subject matter that often draws the attention of economists studying markets, including agricultural markets [1]. Those interrelations are often analysed in regions, macro-regions and countries. Spatial integration of markets is one of the matters used to assess those interrelations.

The occurrence of spatial market integration is one of the basic conditions of maximizing the general welfare. In spatially integrated markets, signals are transferred between surplus and deficit regions, the effect of which is trade and production specialization. As a result of the exchange of goods, services or information, there is a mutual adjustment of demand, supply and prices, which leads to optimal allocation of resources, and indirectly also applies to the concept of sustainable development. The fundamental idea of sustainable farming is the merging of agricultural production with concern for the environment. This can be achieved by using available resources in such a way so as to satisfy farmers’ and consumers’ needs while preserving highly valued assets of the natural environment at the same time [2]. Farmers are often faced with the compromise between making a profit and exerting a negative impact on the natural environment, which determines the future of rural areas. In order to make informed decisions, farmers must rely on up-to-date information, theoretical and practical know-how providing the source of information about methods, tools and the manner of managing a sustainable farm [3]. In addition, farmers need to know about the functioning of the market, price stability and volatility, which depends on the processes of spatial market integration.

The issue of spatial integration of agricultural product markets seems to be a particularly important problem because agricultural products usually belong to those that spoil easily and the areas of their production and consumption are often separate [4]. Moreover, from the point of view of agriculture and the agricultural economy, delimitation in the field based only on the analysis of big administrative
entities such as whole countries may sometimes be rather artificial. Research into spatial integration of markets is important from both cognitive and utilitarian points of view. Defining markets properly may be useful, inter alia, for developing a policy towards a particular market, including competition policy, company strategy and in the processes of mergers and acquisitions on the market [5].

There are three methods of assessing spatial integration of agricultural markets distinguished in the literature and research. They include: A direct evaluation of the size of barriers to the exchange of goods between various domestic markets, developing opinions about integration of markets with the use of the analysis of the flow of goods and the analysis of price differences and price adjustment between markets [6]. Spatial integration of markets is determined in this article with the use of a third method, i.e., the application of the analysis based on prices. The analysis of price signals across space provides insights into the degree to which markets at different locations are integrated and into the ability of spatial arbitrage to buffer the price and welfare effects of local supply and demand shocks [7].

The article attempts to determine the spatial integration of the raw milk market, one of the key Polish agribusiness markets. The production of milk is an essential branch of agricultural production in the country and abroad. In 2018 Poland was the fourth biggest milk producer in the European Union (EU) and Polish farmers had an over 8% share in European milk production [8,9].

This article mainly aims to assess the processes of spatial integration in the Polish milk market. The key question in this context is whether there is a long-term balance between prices in different voivodeships (administrative units in Poland) and if so, in which voivodeships the prices have a dominant impact on the development of prices in other areas. In light of this, the hypothesis was verified that we are dealing with internal integration of milk markets in the domestic dimension. In addition, the article presents determinants of changes in spatial integration on the milk market in Poland. The structure of the study is as follows: Section 2 presents theoretical aspects of the evaluation of spatial integration of the market and comments on the research conducted into the milk market. Section 3 presents the research methodology and describes the methods applied as well as the characteristics of variables. Next, Section 4 presents the research findings by four aspects: The assessment of integration in the milk market in Poland in the context of price differences, the analysis of co-variability and price interrelations with the use of price cointegration, determines directions of interrelations and the main factors affecting changes on the milk market in Poland. The article ends with conclusions and a presentation of further research prospects.

2. Theoretical Background and Research Gap

The concept of spatial integration of markets is imprecise and multi-dimensional in nature. There are many definitions of spatially integrated markets, which take into account various aspects [1]. Roehner [10] interprets the concept of the level of market integration as an analysis of differences between prices in various locations. According to him, if relative differences in prices are big, one can recognise that those markets are poorly integrated, and when those differences are small, this confirms strong spatial integration of the markets. A similar approach to price integration of markets is typical of Engel and Rogers [11] as well as Goldberg and Verboven [12], who treat it more as a process of price alignment within the law of one price (LOP). Within this meaning, integration of markets progresses if price differences between various areas decrease. LOP is the main concept in accordance with which prices on two trade markets are usually levelled by arbitrage, of course apart from the cost of such arbitrage, which includes transport and other transaction costs [1,13]. Fackler and Goodwin [14] emphasise that the law of one price is only one of many conditions for efficient functioning of a market. However, the violation of LOP may mean inefficient functioning of markets [15].

According to Goodwin and Schroeder [16], we can speak about the integration of two markets when the change in prices on one market is fully reflected in the change in the level of prices on another market. Due to the fact that the level of prices in the economy is shaped based on the relation between supply and demand, the level of market integration may be also defined as a measure of to what extent the fluctuation of those two variables on a given market is transferred onto the remaining markets.
connected with one another [17,18]. Tomek and Robinson [19] define market integration as a situation in which two conditions are fulfilled. One of them is the fact that prices between two markets that trade differ from one another as to the level of transaction costs. The other condition concerns the fact of whether the prices can be lower or higher than transaction costs in case of markets between which there is no trade exchange.

Besides the law of one price, spatial arbitrage is a theoretical foundation of the considerations concerning the issue analysed. Indeed, the bases of trade exchange and mutual connection of prices on markets should be watched for in efficient performance of market spatial arbitrage [20]. The condition of market arbitrage means that, in case of a lack of trade barriers, the differences between prices in two locations should not exceed the costs of goods exchange between those locations [1]. Otherwise, the possibilities of obtaining higher than average profits encourage arbitrageurs to increase trade exchange, which results in the decrease in price differences below the costs of exchange. In the case of competitive markets, it may happen that in a short period the price differences will exceed the level of goods exchange costs. That is why it is assumed that LOP is a term appropriate for a long term because much research indicates the departure from the law of one price in a short period [21].

It is worth mentioning that spatial integration of separate markets does not mean that prices in particular areas are identical, even when the exchange costs are considered. Integration should be recognised as a process of levelling prices off as a result of the flow of goods and information. Nevertheless, it is assumed that integration is a necessary condition but not sufficient for the occurrence of allocation efficiency of a market and optimisation of overall economic welfare. Moreover, spatial integration of markets is connected with the transfer of supply surplus from surplus areas to areas with shortages [21].

There are many advantages accompanying the integration of markets. Its measurement may become a basic tool to understand the functioning of markets. In case markets are integrated, the situation on a given market will be reflected in a situation on the other ones. That is why the cognition of the level and strength of integration of particular markets is essential, inter alia, for economic policy and taking decisions by decision makers. With the use of the analysis of market integration, it is also possible to evaluate the speed of transmission, which makes it easier to forecast prices on particular markets [22,23].

The literature presents much information about research in the issue of relationships between spatially separated areas (markets). Spatial relations between prices on agricultural markets have also been interesting for years now and their analyses have been very popular recently. Earlier works are summarised and discussed in Fackler and Goodwin [14]. There is much research concerning mutual relations of agricultural product prices between countries or regions [24–26]. One can also find publications concerning the whole foodstuff market [27]. Among numerous publications in this field, one can also find research into causal relations on the milk and dairy products market. Research into raw milk markets is especially popular. Katrakilidis [28] studied cointegration and the Granger causality of raw milk in Germany, France, Belgium, Denmark and the Netherlands in the period 1980–2003. Bakucs et al. [29] analysed integration of milk markets in Poland and Hungary in the period 1997–2009. Jha et al. [30] dealt with integration of wholesale milk market in India in the period 1994–2009. Acosta et al. [31] conducted analyses of spatial transmission of milk prices from global markets to domestic markets. There is research linking the analysis of the market structure covering the aspect of transmission of prices exemplified by the milk market [32] or analysis of the integration of small milk producers [33]. Some authors strive to extend the scope of research and consider the whole milk sector [34–36]. There are also analyses of integration of selected dairy products [5,37,38].

In Poland, Rembeza et al. [39] studied prices in particular marketing channels by analysing long- and short-term relations between milk purchase prices and dairy product prices. They also presented relationships between milk purchase prices in Poland and purchase prices in Germany, France and the Netherlands in the period 1994–2005. Szajner [40] analysed the variability of prices on the Polish milk and dairy products market with the use of indicators of monthly raw milk purchase prices,
prices of dairy produce sold (sale price) and dairy product retail prices. Fałkowski [41] analysed price transmission and market power in a transition context from the Polish fluid milk sector. However, there was no research conducted into the relationships of milk purchase prices between voivodeships in Poland, which covers the aim of this work, i.e., the evaluation of spatial integration of the milk market. Such a much more detailed approach covering the period of 20 years will make it possible to conduct a thorough analysis of spatial dependencies. That is extremely important in such a great spatial differentiation of milk production as exists in Poland.

3. Research Design, Data and Methods

The research concerned the raw milk market. It was chosen purposefully because of: The significant position of the milk sector in the Polish agribusiness and in the EU [8,9], very low transport and storage related raw material vulnerability, everyday production and necessity of frequent milk supplies to processing plants [42], numerous transformations in the sector including, inter alia, changes in spatial concentration of production and important changes in the Common Agricultural Policy (CAP) concerning, inter alia, milk quotas. [43].

Putting the issue into a time perspective, this research focused mainly on the evaluation of changes that took place in the period 1999–2018. The choice of the period may be justified by two reasons: The new administrative division of Poland introduced in 1999 and the latest data available at the moment of developing the publication. The work uses unpublished mass statistical data (covering the period 1999–2004) and published ones (covering the period 2005–2018) concerning raw milk prices collected by Statistics Poland [44]. The variables in the analysis of spatial market integration were average monthly milk purchase prices in the following voivodeships: dolnośląskie (DOL), kujawsko-pomorskie (KP), lubelskie (LBL), lubuskie (LBU), łódzkie (LDZ), małopolskie (MLP), mazowieckie (MAZ), opolskie (OPO), podkarpackie (PKR), podlaskie (PDL), pomorskie (POM), śląskie (SL), świętokrzyskie (SW), warmińsko-mazurskie (WM), wielkopolskie (WLP) i zachodniopomorskie (ZPM). Basic monthly statistics of milk purchase prices are presented in Figure 1. Due to the big differentiation of prices over the whole period, it is divided into two sub-periods: 1999–2008 and 2009–2018. The division into two sub-periods was due to the significant changes that have occurred on the milk market in Poland and in the world: A significant increase in prices in 2007, followed by a decrease in prices related to the global crisis and liberalization of the milk market related to its opening to the impact of the EU and the global market. Thanks to that, it was possible to determine changes in the spatial integration of the milk market after Poland’s accession to the EU.

![Figure 1](image1.png)

**Figure 1.** Differentiation of monthly milk prices in voivodeships in the years (a) 1999–2008 (b) 2009–2018. Source: Own study based on Statistics Poland data [44].
In order to select the appropriate research methodology, first of all, the evaluation covered the issue of proper time sequences within the scope of their stationarity with the use of the Augmented Dickey–Fuller test (ADF) [45]. In order to process the research material collected, the analysis of price differences and price adjustment, the analysis of correlation, the Johansen cointegration test and the Granger causality test were applied. Drawing conclusions on market integration may indirectly consist in the analysis of price differences or the analysis of price relationships between different locations. High arbitrage costs are one of the reasons for price discrimination against goods between regions [6]. The higher the price differences, the less strongly the markets are integrated. That is why, if areas are more distant from one another (the transport costs are higher), it is more probable that the degree of their integration will be lower.

One of the simplest methods making it possible to determine the integration of markets examined is to analyse the correlation of prices [46]. There were many objections raised to the approach based on the analysis of correlation, which are both economic and statistical in nature. Despite a lot of criticism of the method, there is also a problem of the level of the coefficient of correlation, which should be recognised as sufficient to determine an integrated market. Stigler and Sherwin [47] indicate that there is no unique criterion for determining a uniform market and although the two time series are correlated, it is also necessary to analyse factors that are not connected with prices. At the same time, they suggest that if the correlation coefficient is at least 0.9, it should be recognised that both areas form one market. Audy and Erutku [48] criticise the analysis of correlation because of the problem connected with the occurrence of price movement convergence, the lack of a universal criterion when the correlation is big enough to determine that two areas form one market, the possibility of defining a market too narrowly in a situation when we consider only prices, which are independent in the short term and dependent in the long term, and the unavailability of data.

One of the most important objections is the immediate reaction of some prices to the changes in some other prices. Price adjustments are not immediate due to the time necessary to obtain information and agree on the conditions of a contract or the flow of a product. As a result, not taking into account the dynamics of phenomena may cause the increase in the probability of rejecting the hypothesis assuming the existence of market integration. With the lack of reaction in time, there are also statistical problems connected with auto-correlation of the random element, which results in the weakening of the force of significance tests [21]. Therefore, the successive linear models have more and more often started to take into account a dynamic nature of price adjustments and statistical features of the time series analysed. The models should include, inter alia, the analyses of cointegration and the Granger causality used in the publication.

In order to determine price cointegration on particular markets, the Johansen method was used. It covers the test of trace (the results of the test of maximum value would be similar). In the Johansen procedure, to study the level of cointegration, the rank of a matrix $\Pi$ is used, which equals the number of cointegration vectors. The test is interactive in nature and the values of the estimator of matrix $\Pi$ are in a decreasing sequence. At the first stage, $H_0$ assumes that $R = 0$, which means that there is no cointegration vector in the matrix. If it is rejected, the next one assumes that $R = 1$, i.e., that there is at least one such vector. In the next stages of the procedure, sequential pairs of hypotheses are tested until the moment an appropriate null hypothesis is rejected for the first time, which means a cointegration series. The Johansen test can be presented as in Model (1).

$$\lambda_{\text{trace}}(R) = -T \sum_{i=R+1}^{n} \ln(1 - \lambda_i),$$  \hspace{1cm} (1)$$

where $\lambda_i$ is the estimated eigenvalue, $T$ is the number of available observations, $R$ is the means tested series of cointegration and $n$ is the number of variables in a vector $Y$ [49].

Testing the Granger causality is a method serving the analysis of cause and result relationships that take place within economic phenomena. In accordance with the above, a variable $x$ is the Granger
causes of a variable y in the case where the values of variable y may be predicted more thoroughly by taking into account the future value of variable x than without taking into account those values. The Granger causality is based on the following pair of models:

\[ Y_t = \beta_0 + \sum_{j=1}^{m} \beta_j Y_{t-j} + \sum_{k=1}^{n} \beta_k X_{t-k} + u_t, \]

\[ X_t = \beta_0 + \sum_{j=1}^{m} \beta_j X_{t-j} + \sum_{k=1}^{n} \beta_k Y_{t-k} + u_t, \]

where \( Y_t \) means the values of variable \( Y \), \( X_t \) means the values of variable \( X \), \( \beta \) means the model structural parameters, \( t \) is the time variable and \( u_t \) is the random element of the model. The null hypothesis in the Granger causality test says that all coefficients \( \beta_k \) equal zero, which means a lack of causality; on the other hand, an alternative hypothesis assumes that causality occurs [50].

4. Results and Discussion

4.1. Evaluation of Integration on the Milk Market in Poland in the Context of Price Differences

The first stage of the research was the evaluation of integration on the milk market in Poland in the context of price differences. The research was based on monthly purchase prices of raw milk by voivodeships. Small differences in monthly milk prices between voivodeships indicate strong spatial integration of regional milk markets in Poland (Figure 2). Average absolute deviations of monthly logarithms of prices in the period examined were below 2.3% of their level. Moreover, it should be noticed that there has been a decreasing trend since 2010. This may result, inter alia, from the increasing influence from the neighbouring countries while there are weakening internal relations resulting from Poland’s integration into the EU. In addition, the abandonment of regional milk quotas (in 2009) and their complete abolition (in 2015) might have had considerable influence on levelling prices off [44]. In the initial period after quotas ended, the price of milk decreased and then increased. Similar changes were observed in other EU countries. Even short-term fluctuations associated with economic crises did not significantly affect the milk market [51].

Figure 2. Average absolute deviations of monthly logarithms of raw milk procurement prices in voivodeships from the average prices in Poland in the years 1999–2018. Source: Own study based on Statistics Poland data [44].
In order to illustrate regional differences, the level of prices in voivodeships was evaluated (Figure 3). The maps presented confirm the concentric nature of the spatial distribution of milk prices with their high level in western and northern-eastern parts of Poland and a low level in southern Poland. Higher prices were recorded in voivodeships that are close to the border with Germany and in voivodeships where milk production dominates. On the other hand, lower prices occurred in voivodeships that are in the region giving up the production and procurement of milk.

**Figure 3.** Average purchase prices of milk in Poland (PLN / 100 l) by voivodeships in the years (a) 1999–2008, (b) 2009–2018 divided into four groups. Source: Own study based on Statistics Poland data [44].

It should be noticed that the distance between markets could be recognised as one of the more important factors determining price differences. In order to examine that, a more detailed analysis was conducted. Figure 4 presents the dependence between average absolute prices in voivodeships and the distance between them measured in kilometres. It can be observed that, with the increase of distance, the difference in milk prices between various voivodeships in Poland rises. Hamulczuk [21], who conducted research on the wheat market, came to similar conclusions about the importance of distance in the spatial integration of markets. Similar studies can be found on the example of the transmission of maize prices [7].

**Figure 4.** Average absolute price deviations and the distance between voivodeships in the years 1999–2018. Source: Own study based on Statistics Poland data [44].
4.2. Research into Correlation and Relationships of Prices

The research into correlation and relationships of prices on the raw milk market in Poland was started with the evaluation of the stationarity of time series of prices (logarithms and first increases in logarithms). The extended Dickey–Fuller test does not reject H0 on the integration of series of price levels at the at least first rate in every analysed case. There were no doubts that first differences in the series of price logarithms increases are stationary, either.

Examining the inter-changeability and transmission of prices, first of all linear correlation coefficients between series of increases in logarithms of prices were calculated (due to the fact that at the levels of variables all coefficients were close to 1, the lowest was 0.956, which resulted from non-stationarity of variables). Correlation coefficients were within the range of 0.39–0.83, which, as for the first increases, confirms rather strong inter-changeability of prices. The lowest coefficients of correlation with the remaining voivodeships were observed in the case of MLP and PKR voivodeships (the average in those voivodeships was 0.52). On the other hand, the highest coefficients were in the case of the central voivodeships (e.g., in WLK and KP the average was 0.69 and in MAZ it was 0.68).

In the case of period analysis, a significant increase in the dependencies between milk prices in Poland must be noticed. In the period 1999–2008, the correlation coefficients were within the range of 0.24 to 0.85. The lowest coefficients with the remaining voivodeships were observed in the cases of MLP (the average was 0.47) and OPO (average: 0.48). On the other hand, the highest coefficients were in the case of the central voivodeships (MAZ—0.67, WLK—0.66 and KP—0.64). In the period 2009–2018, the correlation coefficients were within the range of 0.43–0.90. The lowest coefficients were in case of the voivodeships: LBU (0.55 on average) and PKR (an average of 0.57), and the highest in the voivodeships: KP (an average of 0.78), SL (an average of 0.76) and POM (an average of 0.75). Such a change in dependencies may result from the changes in the functioning of the milk market in Poland, logistic possibilities of long distance milk transportation, specialisation of regions involved in milk production and European integration. For example, Badiane and Shively [52] analysed the respective roles of spatial integration and transport costs in explaining maize price changes in Ghana. Using data from wholesale maize markets in Ghana their finding that reductions in local prices and local price variance following the introduction of economic reforms can be traced to both local and central market forces, but differences in the degree of market integration have important implications for long-run changes in transport costs and the evolution of prices in outlying markets.

Based on the analyses conducted, it is possible to formulate a conclusion that the closer voivodeships are to one another, the higher the inter-changeability of prices (Figure 5). The situation is similar to price differences presented in Figure 3. Thus, it can be stated that with the growth in the distance between voivodeships, there is an increase in price differences, which can result from costs of product exchange and, at the same time, the inter-changeability of prices weakens.

The analysis of the cointegration of pairs of variables with the use of the Johansen procedure is an extension of the analysis of the Pearson linear correlation. This is a proper approach because of the non-stationarity of the time series. The research was also conducted into logarithmic data. In order to draw conclusions on cointegration, models with a limited free word were applied. The occurrence of cointegration was tested within the Johansen procedure with the use of the trace test. It was assumed in the model that there is a delay based on the Akaike information criterion (AIC). Detailed findings containing the statistics of the trace test and value p are presented in Table 1.
Table 1. The results of the Johansen cointegration test (trace test) for logarithms of time series of monthly milk prices in Poland in the years 1999–2018.

| Woj. | H₀ | DOL | KP | LBL | LBU | LDZ | MLP | MAZ | OPO | PKR | PDL | POM | SL | SW | WM | WLP |
|------|----|-----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|----|----|-----|
| KP   | 0  | 25.22 | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   |
|      | 1  | 2.90  | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   |
| LBL  | 0  | 11.70 | 12.19 | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   |
|      | 1  | 3.50  | 0.71 | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   |
| LBU  | 0  | 15.58 | 13.86 | 16.38 | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   |
|      | 1  | 5.04  | 1.81 | 4.06 | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   |
| LDZ  | 0  | 23.40 | 23.84 | 18.71 | 23.47 | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   |
|      | 1  | 2.62  | 5.37 | 1.31 | 2.99 | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   |
| MLP  | 0  | 9.82  | 27.83 | 25.58 | 20.89 | 24.70 | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   |
|      | 1  | 0.87  | 1.35 | 2.20 | 2.13 | 0.66 | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   |
| MAZ  | 0  | 17.87 | 11.27 | 21.32 | 19.23 | 25.79 | 28.01 | -   | -   | -   | -   | -   | -   | -   | -   | -   |
|      | 1  | 3.46  | 2.61 | 1.78 | 3.29 | 4.04 | 1.54 | -   | -   | -   | -   | -   | -   | -   | -   | -   |
| OPO  | 0  | 25.96 | 35.66 | 23.85 | 25.17 | 34.27 | 16.85 | 32.82 | -   | -   | -   | -   | -   | -   | -   | -   |
|      | 1  | 3.39  | 4.47 | 4.34 | 4.71 | 3.94 | 0.58 | 4.03 | -   | -   | -   | -   | -   | -   | -   | -   |
| PKR  | 0  | 13.85 | 20.28 | 28.59 | 21.25 | 24.26 | 14.07 | 27.23 | 16.33 | -   | -   | -   | -   | -   | -   | -   |
|      | 1  | 2.41  | 1.99 | 2.79 | 2.71 | 1.52 | 1.76 | 2.87 | 1.66 | -   | -   | -   | -   | -   | -   | -   |

Woj.: Województwo (county); DOL: Dolnośląskie; KP: Kuyavian-Pomeranian; LBL: Lubuskie; LBU: Łódzkie; LDZ: Łódzkie; MLP: Małopolskie; MAZ: Mazowieckie; OPO: Opolskie; PKR: Podkarpackie; PDL: Podlaskie; POM: Pomorskie; SL: Śląskie; SW: Świętokrzyskie; WM: Warmińsko-Mazurskie; WLP: Wielkopolskie.
### Table 1. Cont.

| Woj. | H<sub>0</sub> | DOL   | KP    | LBL   | LBU   | LDZ   | MLP   | MAZ   | OPO   | PKR   | PDL   | POM   | SL    | SW    | WM    | WLP   |
|------|--------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| PDL  | 0            | 28.34 | 26.67 | 23.91 | 23.78 | 20.02 | 28.94 | 17.89 | 48.54 | 23.26 |       |       |       |       |       |       |
|      | 1            | 3.42  | 5.46  | 2.69  | 3.54  | 5.20  | 1.80  | 4.89  | 5.39  | 2.13  |       |       |       |       |       |       |
|      |              | 0.003 | 0.007 | 0.002 | 0.009 | 0.001 | 0.021 | 0.001 | 0.003 |       |       |       |       |       |       |       |
| POM  | 0            | 21.32 | 14.65 | 15.16 | 16.28 | 23.81 | 21.92 | 26.94 | 29.94 | 17.24 | 25.47 |       |       |       |       |       |
|      | 1            | 3.28  | 1.87  | 3.31  | 3.98  | 5.16  | 2.06  | 2.89  | 4.21  | 2.87  | 3.05  |       |       |       |       |       |
|      |              | 0.006 | 0.067 | 0.056 | 0.038 | 0.002 | 0.005 | 0.001 | 0.027 | 0.001 |       |       |       |       |       |       |
| SL   | 0            | 13.62 | 20.63 | 17.84 | 24.52 | 21.93 | 14.05 | 20.54 | 19.14 | 14.82 | 23.78 | 19.03 |       |       |       |       |
|      | 1            | 2.37  | 2.56  | 3.60  | 3.57  | 1.79  | 0.79  | 3.04  | 1.62  | 2.09  | 2.40  | 2.95  |       |       |       |       |
|      |              | 0.093 | 0.007 | 0.020 | 0.001 | 0.005 | 0.081 | 0.008 | 0.012 | 0.063 |       |       | 0.014 |       |       |       |
|      |              | 0.124 | 0.109 | 0.058 | 0.059 | 0.180 | 0.374 | 0.203 | 0.148 | 0.122 | 0.086 |       |       |       |       |       |
| SW   | 0            | 17.65 | 27.50 | 16.97 | 22.29 | 26.43 | 25.46 | 34.54 | 33.88 | 14.32 | 37.05 | 33.68 | 20.86 |       |       |       |
|      | 1            | 3.07  | 1.97  | 3.57  | 3.4   | 2.54  | 1.71  | 2.77  | 3.54  | 2.30  | 2.85  | 3.01  | 2.81  |       |       |       |
|      |              | 0.023 | 0.001 | 0.029 | 0.004 | 0.001 | 0.001 | 0.001 | 0.001 | 0.074 |       |       |       | <0.001 | <0.001 | <0.001 | <0.007 |
|      |              | 0.080 | 0.160 | 0.059 | 0.059 | 0.180 | 0.374 | 0.203 | 0.148 | 0.122 | 0.086 |       |       |       |       |       |
| WM   | 0            | 25.74 | 27.83 | 25.43 | 23.60 | 30.35 | 30.88 | 24.33 | 34.54 | 29.22 | 20.15 | 35.91 | 28.70 | 35.19 |       |       |
|      | 1            | 3.20  | 5.27  | 2.05  | 2.54  | 5.92  | 2.00  | 3.06  | 4.93  | 2.58  | 4.68  | 2.83  | 1.67  | 2.82  |       |       |
|      |              | 0.001 | 0.001 | 0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.009 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
|      |              | 0.074 | 0.021 | 0.112 | 0.111 | 0.015 | 0.157 | 0.080 | 0.026 | 0.108 | 0.030 | 0.093 | 0.020 | 0.093 |       |       |
| WLP  | 0            | 23.23 | 25.10 | 16.97 | 20.61 | 22.44 | 27.60 | 31.16 | 34.28 | 18.37 | 41.20 | 24.38 | 23.01 | 33.70 | 39.58 |       |
|      | 1            | 2.68  | 2.92  | 2.63  | 4.09  | 3.34  | 0.75  | 5.04  | 4.70  | 1.71  | 4.27  | 3.54  | 2.40  | 2.38  | 3.05  |       |
|      |              | 0.003 | 0.001 | 0.007 | 0.004 | 0.001 | 0.001 | 0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
|      |              | 0.101 | 0.088 | 0.105 | 0.043 | 0.068 | 0.39  | 0.025 | 0.030 | 0.191 | 0.039 | 0.060 | 0.122 | 0.123 | 0.081 |       |
| ZPM  | 0            | 30.15 | 27.61 | 16.46 | 22.54 | 28.37 | 29.17 | 18.58 | 35.23 | 23.44 | 24.57 | 40.69 | 27.30 | 30.86 | 23.03 | 35.89 |
|      | 1            | 4.33  | 5.21  | 1.66  | 3.28  | 5.50  | 2.47  | 4.11  | 5.62  | 2.46  | 5.11  | 3.60  | 3.42  | 3.21  | 5.80  | 3.64  |
|      |              | 0.001 | 0.035 | 0.004 | <0.001 | <0.001 | 0.016 | <0.001 | <0.001 | <0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
|      |              | 0.037 | 0.022 | 0.197 | 0.070 | 0.019 | 0.116 | 0.043 | 0.018 | 0.117 | 0.024 | 0.058 | 0.065 | 0.074 | 0.016 | 0.056 |       |

Source: Own study based on Statistics Poland data [44].
The conclusions of testing a cointegration of pairs of variables are as follows. In the model with a limited free word in the trace test, the null hypothesis with a zero cointegration vector was not rejected only for 12 pairs of variables at the level of significance \( p = 0.05 \). The null hypothesis with the maximum of one cointegration vector was rejected in the case of 27 pairs. The findings of the examination of the rank of cointegration variables in the case of those pairs indicated a complete rank of a matrix \( \Pi \) for the series analysed. Thus, it should be assumed that the VAR model built for increases is a proper form of the model to examine cointegration. For the remaining 81 pairs, it can be assumed that we deal with one integration vector in every pair of variables. Thanks to that mechanism, prices return to the state of balance each time after they have been thrown off that state. The results obtained confirm studies using the Engle–Granger cointegration test for the years 2009–2014 [53]. However, it should be noted that the integration of the milk market in Poland increases in relation to previous studies.

\[
Y = 0.731 - 0.000331X
\]

**Figure 5.** Pearson’s linear correlation coefficients between prices (logarithm increases) and distance between voivodeships in the years 1999–2018. Source: Own study based on Statistics Poland data [44].

### 4.3. Direction of Dependencies

The next step was an attempt to answer the question which voivodeships are crucial from the point of view of the process of revealing and determining raw milk prices in Poland. While it is not the most important issue from the point of view of spatial integration of regional milk markets in Poland, it allows for deepening the analysis considerably. The present work is limited to the Granger causality within logarithmic series of prices in particular voivodeships. Table 2 presents the direction of dependencies in the period 1999–2018; in most cases we deal with the so-called “bidirectional causality”.

| Voivodeship | LP | MAZ | LUB | LWS | LDZ | KMK | WLP | WMA | KLR |
|-------------|----|-----|-----|-----|-----|-----|-----|-----|-----|
| LP          | ↔  | ←   | ←   | ←   | ←   | ←   | ←   | ←   | ←   |
| MAZ         | →  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   |
| LUB         | →  | ←   | ←   | ←   | ←   | ←   | ←   | ←   | ←   |
| LWS         | →  | ←   | ←   | ←   | ←   | ←   | ←   | ←   | ←   |
| LDZ         | →  | ←   | ←   | ←   | ←   | ←   | ←   | ←   | ←   |
| KMK         | →  | ←   | ←   | ←   | ←   | ←   | ←   | ←   | ←   |
| WLP         | →  | ←   | ←   | ←   | ←   | ←   | ←   | ←   | ←   |
| WMA         | →  | ←   | ←   | ←   | ←   | ←   | ←   | ←   | ←   |
| KLR         | →  | ←   | ←   | ←   | ←   | ←   | ←   | ←   | ←   |

| Table 2. | Direction of dependencies based on Granger’s causality in the years 1999–2018. Source: Own study based on Statistics Poland data [44].
In the period 1999–2008, the Granger causality tests conducted indicated one-way dependency direction in 33 cases; in the remaining cases the causality is bidirectional. In the period 2009–2018, in 33 cases causality was also one-way in nature but the role of some voivodeships was different. Figure 6 presents the sum of test statistics F for particular voivodeships for H₀ in two sub-periods, i.e., in 1999–2008 and 2009–2018. The higher the total value of statistics F is, the more frequent and stronger the grounds for rejecting H₀ on the lack of influence of the previous price in a given voivodeship on the current prices in the remaining voivodeships.

### Table 2. Direction of dependence based on Granger’s causality in the years 1999–2018.

| Specification | Signals to          |
|---------------|---------------------|
|               | DOL | KP | LBL | LBU | LDZ | MLP | MAZ | OPO | PKR | PDL | POM | SL | SW | WM | WLP |
| KP            | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| LBL           | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| LBU           | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| LDZ           | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| MLP           | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| MAZ           | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| OPO           | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| PKR           | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| PDL           | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| POM           | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| SW            | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| WM            | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| WLP           | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |
| ZPM           | ↔   | ↔  | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔   | ↔  | ↔  | ↔  | ↔   |

Source: Own study based on Statistics Poland data [44].

**Figure 6.** Summary of Granger causality testing results between milk price series in Poland in (a) 1999–2008 and (b) 2009–2018 (sum of F test statistics). Source: Own study based on Statistics Poland data [44].
In light of the Granger causality test, it turns out that the most exogenous prices in the first sub-period were in the central voivodeships, i.e., MAZ, LDZ and WLP. The position of those voivodeships seems to be justified due to their considerable production of milk, including in the period, and their location closeness. Weak exogeneity of the voivodeships PKR, SL and OPO may also be justified by their small share in the production of milk resulting mainly from unfavourable conditions and big fragmentation of milk farms in the regions.

In the other sub-period, significant changes in the development of some voivodeships’ position should be noticed. The most exogenous prices were in KP, which could result from the fact that the Western European countries had a bigger influence on the milk prices in Poland. Moreover, in the period 2009–2018, the key voivodeships in the first period lost their strong influence on the development of prices in other regions. The causal relations with the LDZ and PDL voivodeships weakened most. The weakest exogeneity in the voivodeships in the south of Poland may result from the fact that, if 1999 and 2018 are compared, there was a big reduction in milk production in those voivodeships. In addition, both milk production and procurement in those voivodeships were at a similar level in the second period and did not exceed 400 million litres per voivodeship annually. [54]. This is also confirmed by the research of Wysokiński et al. According to them, a steady growth of the level of concentration of wholesale milk production in spatial terms was observed in Poland. The differences between production of milk in individual regions are expanding. In particular, production becomes concentrated in a couple of regions (MAZ, PDL, WLP and LOD), while southern and south-eastern Poland is pushed to the margin [55].

4.4. Determinants of Changes in Spatial Integration on the Milk Market in Poland

This study confirmed that the main factor determining the strength of spatial integration on the milk market is the distance between separate locations. However, the increase in the degree of spatial integration of the milk market in Poland has its source in economic transformation, European integration, adaptations to EU standards and milk production quotas.

In the analyses period, in Poland integration processes were associated with a strong concentration of milk production, the elimination of the smallest farms, investments to improve the competitiveness of dairy farms and processing enterprises and farmers’ associations in producer organizations. Since Poland’s accession to the EU, milk production has increased by 20%. At that time, there was a strong specialization of north-eastern and central voivodeships (PDL, MAZ, KP, WLP, WM), which increased their milk production by an average of 50% (in PDL province it was even 75%) [54]. This is a result of growth in the number of cows and, above all, an increase in the average milk productivity. Efficiency depends on the quality of feed and equipment used. Therefore, the importance of international trade in Poland increases, especially as milk prices in the EU differ widely. An important factor in the spatial concentration of milk production were changes related to milk quotas. The elimination of milk quotas has changed the farming conditions in Poland and across the EU. Farms with more cows are in the best position [51]. Bórawski et al. investigated the impact of the removal of quotas on the production of milk on farms in Poland and the EU [8]. The number of dairy holdings in Poland has decreased, but it is still high. In the years 1999–2016, the number of farms with dairy cows decreased by almost 80%. Despite the increase in the concentration of cow breeding on Polish farms, there is still a large distance from Western European countries [56]. Therefore, further consolidation of dairy will continue, which will continue to affect the spatial integration of the milk market in Poland.

An important element of the market is producer organizations (POs). Cooperation in POs may be justified by the advantages of the economies of scale and the willingness to minimize transaction costs accompanying the processes of producing and selling dairy products. Furthermore, it is worthwhile mentioning that a side effect of the producer groups’ existence might be the links between producers, processors and commercial agents; these links could be important for the efficient functioning of the market, resulting in market and price stabilization [57]. Like other European Union countries, Poland has also provided support from public funds for the setup and operation of producers’ organizations.
The fact that such measures have been consistently included in agricultural policy measures indicates that cooperation among farmers in Poland, although very much desired, is still insufficient [58]. In 2019, in Poland there were 78 POs of milk, which associated 1.5 thousand members. As many as 80% of POs were registered in two voivodeships (WLP and MAZ) [59].

The rise of milk prices in Poland is faster than the EU-average. Changes in milk prices depend on conditions in European and world markets—consumer preferences. Milk prices are also determined by the level of costs incurred. Milk production in Poland is a labour-intensive and capital-intensive activity. It should be expected that milk prices can change significantly in a short period of time. Therefore, the progression of spatial integration in the milk market in Poland is expected to continue.

5. Conclusions

The main research issue undertaken in this publication is the evaluation of spatial integration processes on the Polish milk market. The basis for the implementation of the main task was the conduction of an analysis with the use of various quantitative methods in a dynamic approach in order to indicate changes. The fulfilment of the task, including the empirical research carried out, made it possible to verify the question and hypothesis asked in the course of work and to formulate final conclusions. Based on the findings of the research into price differences, price cointegration and the Granger causality, it should be recognised that there is a long-term balance between prices in various voivodeships in Poland. Moreover, the research conducted made it possible to formulate the following conclusions:

- There are strong conditions, based on economic theory, that confirm grounds for determining spatial market integration;
- it should be noticed that drawing conclusions on the issue of spatial price integration may to a great extent depend on the nature of the statistical data used in empirical research (the time scope of the analysis, source of data, data frequency or their spatial aggregation);
- there is no single best method of evaluation of spatial market integration; all methods have some limitations; that is why it is best to use a few alternative methods;
- the distance between markets may be recognised as one of the most important factors determining price differences;
- the processes of market integration are also influenced by other factors concerning the situation in the world or instruments of agricultural policy towards a given market, e.g., the abolition of milk quotas, the progressing specialization of milk production in the regions, the consolidation of production and the integration of farmers.

The issue of spatial integration of the milk market is an interesting and complex research subject. That is why this publication does not exhaust the issue, although a few research methods were used in it. The considerations presented, both the theoretical and empirical ones, may inspire to undertake further research into the field. Further research directions may be connected with the evaluation of spatial integration of other milk product markets and may be a continuation of the research into spatial aspects of the milk market with the use of other methods. Considerable changes in the development of the influence of various voivodeships confirm grounds for examining the relationships of Polish milk purchase prices with the prices in other countries in order to determine potential EU and global directions of influence.

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