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Can Family Farms Depend on Price Information? Testing Butter and Curd Price Integration in Poland

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Abstract: This study examines the integration of regional dairy markets in Poland, which is a major European dairy producing country. The analysis of prices is important, as many dairy farmers are members of dairy processing cooperatives, and their incomes are affected by the prices of two popular products: butter and curd. Moreover, the period of study included significant fluctuations in the world market and the termination of the milk quota system in the European Union (EU). The price records used in this study are from the two main milk-producing regions in the country: Northern and Central. The data were tested for stationarity and Granger causality before estimating a Vector Error Correction (VEC) model. Estimation results show that the removal of the milk quota lowered prices of butter and curd in the two regions. The relationships of the prices in both regions for butter markets were nearly perfect during the period January 2010–November 2017, but curd prices were found unintegrated. Impulse response analysis showed that the effect of shocks was mostly absorbed in a two-week period and prices returned to full equilibrium in about four to five weeks. This fast price adjustment indicates that both markets operate properly and no market participant can obtain gains above those offered at equilibrium.

Keywords: milk quota; dairy market integration; butter price; curd price; Vector Error Correction; price shock

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1. Introduction

The transition to a market-based economy in 1989 shocked the entire Polish economy, including agriculture. The termination of the centrally planned economy involved the removal of price controls [1]. Various subsidies to agriculture, which accounted for 27% of the state's budget in 1989, were eliminated [2]. After decades of guaranteed procurement prices, state farm managers and private dairy farmers faced market risk. The transition to a market economy at the micro level involving state farms and family farms was chaotic [1]. The World Bank [3] estimated that about 13 million Polish rural residents, or about one-third of the country's population, lived on family farms.

As government support dwindled, within two years, the state dairy farm sector rapidly liquidated their dairy herds. The total number of dairy cows in the country declined from 4,884,565 in 1989 to 3,991,000 in 1993 (an 18.3% decrease), and they continued to decline throughout the 1990s [4] as market forces re-allocated resources. The family dairy farms maintained relatively large cow herds, increasing family farm importance as milk suppliers. The termination of the state monopoly on international trade allowed imports of ultrapasturized milk [1] from Western Europe contributing to price pressure on dairy farmers.

Family farms proved resilient and adapted to the new competitive market conditions, but many farmers admitted that "marketing" was among their major problems [5]. Since

price data under the new conditions were scarce, price reporting and analysis became a priority in training, and it was implemented by the Polish-American Extension Project [1]. Price information and analysis was necessary for business planning as the market revealed regional differences in natural resource endowment affecting milk production. Regional extension centers pioneered price collection information about commodities traded at local open-air agricultural markets [6] using a uniform methodology [7]. The Polish-American Market Information and Standardization Program operated in the 1990s and played an important role in price data collection. [6]. Local media disseminated the daily price information on local and regional markets, including price of calves, heifers, and cows, orienting farmers to the current supply and demand conditions.

Dairy farmers were members of dairy processing cooperatives. Their revenues streamed from raw milk sales and a share in the annual distribution of co-op profits. The specificity of milk and dairy products required a different system of price information collection. Thus, the government created price-reporting regions. Having the dairy regions with different production characteristics, without reliable price information at a national level, one would expect different prices in each region due to the lack of market integration. Moreover, a lack of regional integration could distort dairy farmer investment decisions, causing losses. It is important to note that market integration of the regional price reporting system has never been tested, and its performance has not been evaluated. The current study tests whether the regional dairy markets generating prices to the publicly available database are integrated. The focus is on the price integration of two common dairy products applying weekly regional wholesale butter and curd prices.

The selection of butter and curd is deliberate because of their importance in the diet of rural and urban residents. For example, curd prices were one of the few food products that remained under government control in the early stage of the transition to the market economy in the 1990s. Curd is traditionally eaten in various dishes in Poland and a source of nutrients, including protein. It remained a key food for many as Poland applied economic "shock therapy", resulting in approximately 700% inflation between 1989 and 1991.

In anticipation of European Union (EU) accession, the dairy price reporting system was formalized and revised [8–10]. The system of milk and dairy product price reporting is currently managed by the Ministry of Agriculture and Rural Development (MA&RD). The degree to which regional markets are integrated could have been affected by several factors between 2004 and 2020. Joining the EU implied the implementation of a milk supply mechanism in the form of a quota system. The quota resulted in penalties for some dairy farmers for exceeding it, and its termination in April 2015 led to an increase in milk production, but the increases varied regionally.

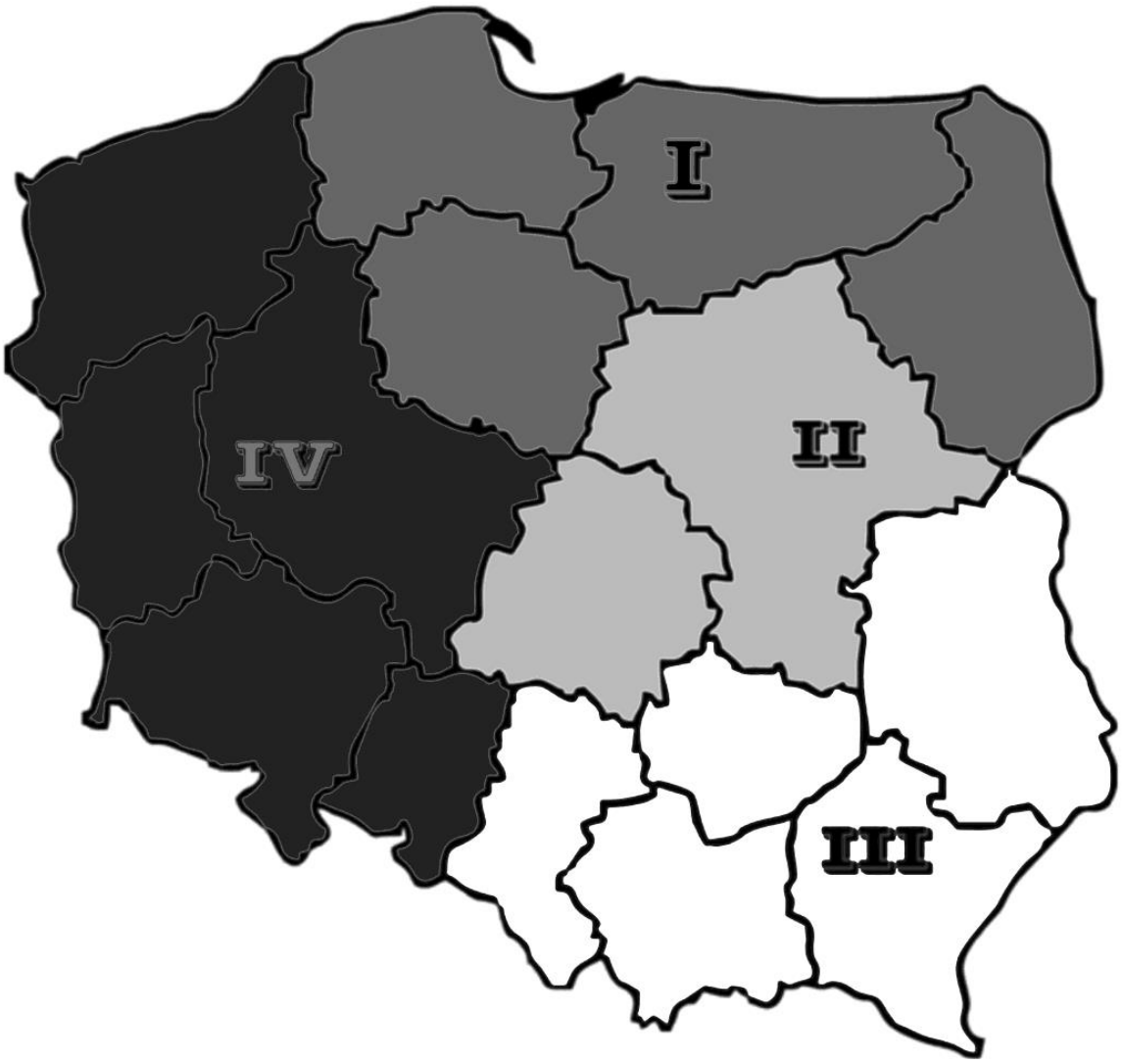
The objective of this study is to test market integration between two neighboring regions with large dairy sectors in Poland. The regions (see the description in Section 1.1) are as used in the price reporting system used by the MA&RD, previously not used in any of the empirical studies of dairy price series analysis in Poland. Previous studies focused primarily on the topic of price transmission across various market levels or the integration of selected dairy products in Poland and other countries and regions (see Section 3). Additional novelty of the current study involves the observation time horizon. All previous studies regarding the Polish dairy products used monthly observations, while this study uses weekly observations primarily to determine the speed of return to equilibrium. In contrast to previous studies, the product orientation of the current study is on the price of butter and curd as the high- and low-price products manufactured by the milk processing cooperatives. Dairy farmers, who are coop members, share in profits, and the lack of price integration could result in losses in sales revenues and affect the performance of the coop.

The remainder of this paper consists of the subsection describing the dairy price reporting system, the importance of butter and curd consumption in Poland, and a review of price integration studies. The Materials and Methods section includes data description

and the details about the modeling approach. In the next section, the estimation results are presented and discussed. The Conclusion section completes the paper.

1.1. Evolution of the Dairy Price Reporting System Serving Family Farms

The absence of price data and a well-organized gathering and processing system hampered transition to the market economy in Poland in the early 1990s. For the first time since World War II, Polish farmers faced a demand constraint for their products [6]. The need to prepare business plans for farmers, including dairy farmers, encouraged price data collection by the regional extension centers collaborating within the Polish-American Extension Project. The regional extension center in Minikowo was the first to collect and disseminate price information. Minikowo is located in the region later included in the Northern dairy price reporting system generating data applied in the current study (Figure 1). Areas in the Northern and Central regions are leading dairy-producing areas (see the detailed description in the following sections).



Legend: I—Northern region; II—Central region; III—Eastern region; IV—Western region.

Figure 1. Price reporting regions for butter and curd in Poland. Note: Northern and Central regions are the focus of the study. Source: Prepared by authors.

Gradually, the weekly price information gathering became a mandate applied, among others, to entities procuring and processing raw agricultural commodities, including

milk [8]. The regulation allowed public dissemination of the collected data, assured the data provider confidentiality, and specified quality control measures and penalties for improper use of the collected data. Poland's EU accession in 2004 affected regional dairy production in different ways [11,12]. Additional regulations regarding data collection were issued in 2007 [9]. The 2011 regulations established a weekly price reporting system [13] and permitted the publication of monthly and annual market and price information analysis. Several such reports are prepared and disseminated by the Institute of Agricultural Economics and Food Economy (Polish acronym IERiGŻ), which is a branch of the MA&RD Ministry of Agriculture and Rural Development. The most recently updated regulations concerning agricultural market data collection and identifying the responsible entities for timely submission of market data, including the data format, were issued in 2015 [10]. The currently operating Integrated Agricultural Market Information System compiles data collected by the MA&RD, regional extension centers, local commodity wholesale markets and auctions, and regional agricultural chambers, including milk prices [14]. The collected raw data are processed and published as bulletins by the Institute of Agricultural Economics and Food Economy of the MA&RD.

2. Butter and Curd Consumption

Butter and curd have contrasting characteristics. Butter is a high value storable product, while curd (also known as curd cheese, quark, tvarog, or farmers' cheese; Polish: twaróg) is a soft, white, highly perishable cheese. Butter is the most popular animal spread in Poland.

The tradition of self-supply of butter and curd on Polish family farms has been strong and was encouraged by the government-controlled economy prior to 1989. A chronic shortage of foodstuffs in retail, including butter and less often curd, prior to 1989 meant that dairy farms were less likely to experience food insecurity. The initial period of transition (1989–1991) was characterized by accelerated inflation reducing real incomes across society as a whole, and the importance of self-supply remained high in rural households. For example, in 2003, self-supply in rural households continued to account for 58-87% of curd, whole milk, and cream, and in the period 2012–2014, the self-supply of curd and cream still accounted for 28–33% of rural household consumption of those products [15]. Dairy farms continue their butter and curd making, but over time, the supplies of dairy products in local retail outlets became stable, causing many households to stop making their own butter and curd. Young rural residents prefer that curd remain unchanged in its taste and form [16], and studies show a lack of variation in the sensory quality of curd from various dairy processing plants [17]. In recent years, per capita monthly curd consumption was 0.44 kg [18] and varied little across various types of households, although it appears to be more important for households with less income. The domestic demand for curd growth averaged 3% per year.

3. Review of Price Integration Studies in Poland

Milk and dairy product prices collected through the MA&RD unit permitted price analysis. The Institute of Agricultural Economics and Food Economy initiated a series of market analysis bulletins that include the milk and dairy product market and focus on the current market situation and short-term outlook. The published bulletins are intended for a wide audience including regional extension centers, farmer associations, dairy processors, bankers, government agencies, and members of parliament. A typical dairy farmer learns about the results of the analysis from the trade press or dairy coop and processor organizations. Studies applying advanced statistical techniques to domestic dairy product analysis are lacking.

Several studies of dairy prices in Poland applied data from foreign sources to examine the integration of the national average prices with prices in selected EU countries [19,20]. The external orientation of majority of these studies eliminated the use of the regional domestic price series because of data incompatibility with international databases. Such

studies provided knowledge for government agencies but were of limited use to family dairy farms.

Changes on the world milk market and its influence on the Polish milk market and its growth were investigated in [19]. Their study applied trend analysis and the FAO dairy price index data as well as the Italian Dairy Economic Consulting price data. The dairy price index was an aggregate index of world prices and was highly variable as were the prices of exported milk in the period 2000–2013. However, butter prices were found particularly volatile, and the fitted linear trend had an R2 value equal to 0.7011 [20]. The index of domestic milk procurement prices showed an increasing tendency, although it remained highly variable between 1999 and 2015. The prices of raw milk have followed EU prices since 2006, and the gap between prices in Poland and the EU-15 had narrowed by 2015. The narrowing of this gap was interpreted as an increasing cohesion of prices in Poland and other EU countries.

The degree of association between butter prices in Poland and 10 EU countries using monthly prices available from Milk Market Observatory and Italian Dairy Economic Consulting were examined in [20] for the period 2007–2016. The study applied time-series modeling and confirmed the integration of national butter prices in EU countries (out of 10 included in the analysis) and national average butter prices in Poland in the period 2012–2016. Roman provides evidence for the bi-directional causality of butter prices in Poland and Czechia, and Germany and France in the period 2007–2016.

Two studies applied unpublished data from the Main Statistical Office (Polish acronym GUS) and examined the asymmetry of milk prices. [21] used unpublished monthly butter prices at the national level to test the asymmetry of price interaction for the period January 1996 to August 2005, i.e., almost exclusively before EU accession and the imposition of a milk quota system. The test of national price integration focused on raw milk prices received by farmers, prices of processed milk at selected processing plants, and retail milk prices. Results showed that at the national level, prices received by farmers and charged by processing plants were integrated, but the prices of processing plants and retailers showed limited integration.

The issue of market price integration was revisited in [22] using unpublished monthly national milk price series for the period 2004–2014. Results showed the largest asymmetry between prices paid to farmers and processed milk sale prices received by dairy processing plants as well as the retail milk prices. [23] concluded that the price analysis should be continued and expanded, with emphasis on short-term analysis.

Monthly retail price of pasteurized milk and procurement prices as well as links between the former and other food prices for Poland and 27 EU member countries were analyzed in [23] (Table 1). Milk procurement prices were examined by [24]. The study examined the monthly prices reported by all 16 voivodships in Poland splitting the period 1999–2018 into two even length periods, 1999–2008 and 2009–2018. It was concluded that in the long term, prices were cointegrated across the regions. The dynamics of milk prices in Poland and EU countries was examined in [25] using monthly data (Table 1). The data series was split into two even periods. The authors concluded the milk market in Poland and the markets in the EU countries studied were integrated and emphasized an increased integration in the second subperiod.

The monthly SMP prices in Poland and other countries were analyzed in [26], splitting the analysis between two periods, 2000–2004 and 2005–2016 (Table 1). The analysis narrowed the geographical scope to Poland and other EU countries in the second period and provided evidence of price integration between Poland and several other EU countries with large dairy sectors, including neighboring Germany, but also the Netherlands and Ireland.

Table 1. Number of monthly observations in the studies of selected dairy products.

Period/Sub-Period	Number of Observations [a]	Product	Price Type and Source	Study
1996–August 2005	116	Milk	Procurement, retail; GUS	[21]
1996–2000	60			
2007–August 2005	56			
2000–2015	192	Butter, SMP, cheese [b]	CLAL	[19]
2000–2007	96			
2008–2015	96			
2004–2014	132	Milk	Procurement, processor sales price, retail	[22]
2007–2016	120	Butter	EU milk market observatory, CLAL	[20]
2007–2011	60			
2012–2016	60			
2004–2018 [c]	180	Milk	Procurement, retail; EU Milk Market Observatory	[23]
1999–2018	240	Milk	Procurement [d]	[24]
1999–2008	120			
2009–2018	120			
2005–2018	168	Milk	EU Milk Market Observatory	[25]
2005–2011	84			
2012–2018	84			
2006–2016	204	SMP	EU Milk Market Observatory, CLAL	[26]
2010–November 2017	410	Butter, curd	Wholesale; MA&RD	Current study

[a] All studies used monthly observations except the current study, which uses weekly observations. [b] Prices available at the CLAL website refer to dozens of different cheeses in various countries. It is not clear what specific cheese price series was selected for the analysis. [c] The time-series analysis using ARMA involved the weighted average milk price for the period 2007-2017. [d] Unpublished data for the period 1999–2004 and published data for the period 2005–2018 from www.stat.gov.pl.

The current study fills a gap in the existing literature by examining the integration of domestic regional markets for butter and curd in Poland, which generates price signals for decision making on family dairy farms. The concentration of dairy farms in the Central and Northern regions delineated by the price reporting system is of particular importance, especially since part of the Northern region includes some of the least developed areas of the EU, while parts of the Central region, outside the large urban centers, include rural areas where agriculture remains an essential sector of the local economy.

4. Materials and Methods

4.1. Data

Prices of butter and curd used in the analyses are recorded weekly in each voivodship, but the data collection service averages prices for each region (Figure 1) before making them publicly available. The Northern region encompasses the following voivodships: Podlaskie, Warmińsko-Mazurskie, Kujawsko-Pomorskie, and Pomorskie, while the Central region includes Mazowieckie and Łódzkie. Mazowieckie is the leading dairy producing voivodship in Poland, taking advantage of natural conditions (wide river valleys) and the largest domestic food market located in Poland's capital, Warsaw. Podlaskie is the second largest milk-producing voivodship, while Mazursko-Warmińskie also has a number of dairy farms and natural conditions favoring cow milk production. In addition to regional prices, the average price for the country as a whole is also calculated and recorded.

Price records applied in the current study are for wholesale prices and quoted per 100 kg for butter and curd. At retail, butter is usually sold in 250 g packets, although smaller packets have become available. Curd is sold in various size packets or containers at retail, typically ranging from 100 to 500 g with the 250 g packet being most common.

This study uses 410 weekly observations for the Northern and Central regions as well as Poland as a whole for the period from 3 January 2010 to 5 November 2017.

Fluctuations of butter prices between January 2010 and November 2011 were characterized by an initial short period of decline, a rapid recovery, and then a slow increasing tendency (Figure 2). Starting in December 2011, the price decreased and fluctuated, eventually peaking in January 2014. Prices of butter had been slowly decreasing from January through the middle of the summer in 2014 (Figure 2). The decline continued until May 2016, with a short recovery in late 2015. Between June 2016 and October 2017, there were two waves of butter price increases. The first started in June 2016 and peaked in January 2017. After a short hiatus, butter prices resumed their upward trend in April peaking in October 2017, when they began a rapid decline.

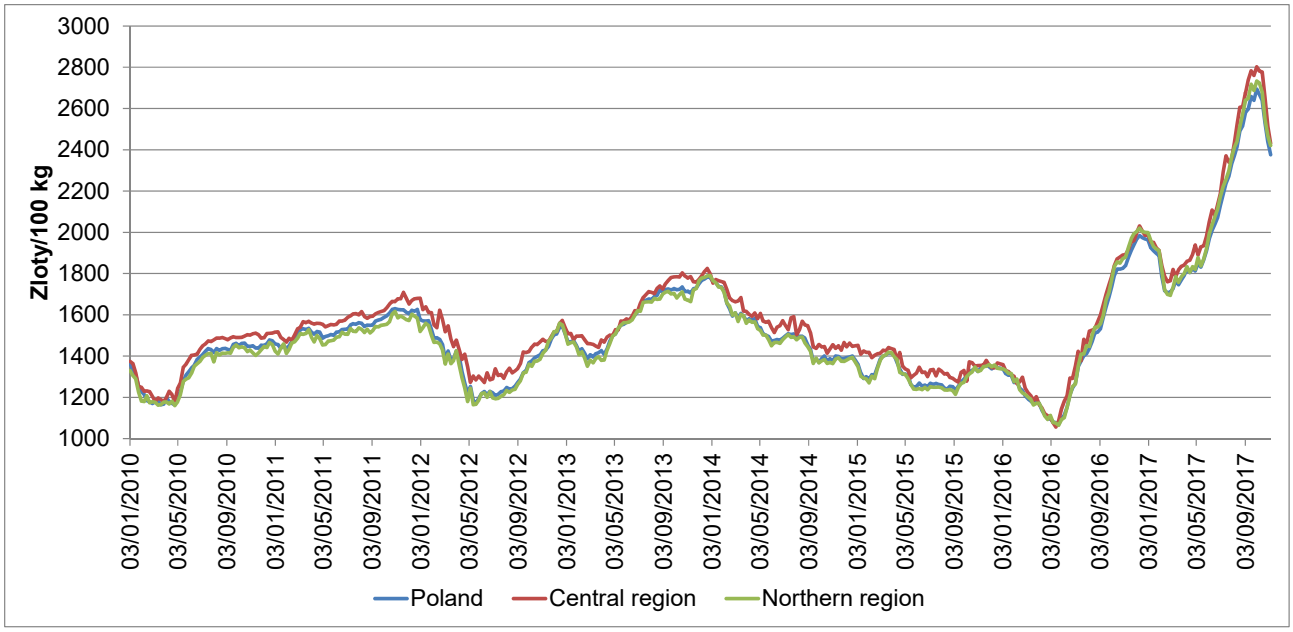


Figure 2. Weekly prices of butter in 100 kg blocks in the country and two regions, 3 January 2010 to 5 November 2017, in 2PLN.

Curd prices showed quite different behavior than butter prices during the period under consideration (Figure 3). Between January 2010 and January 2011, prices remained fairly stable. Northern region prices showed larger variability than prices in the Central region or nationally. All three price series behaved quite similarly from the end of 2013. For more than two years, from January 2014 to May 2016, the prices showed a decreasing tendency observed also in the case of butter prices. However, since May 2016, butter prices rapidly increased, but curd prices remained stable, showing sideway movements, with no clear increasing or decreasing tendency. The lack of any rise of prices reflects the perishable nature of the product, the stability of consumer preferences, and the largely unchanged consumption of curd and products using it as an ingredient. The difference in curd prices as compared to butter is associated with distinguishable price levels between the Central and Northern regions. The lower curd prices in the Northern region appear to have been quite stable, whereas curd prices in the Central region declined somewhat during the considered period. The gap between curd prices in the two regions was much wider at the beginning of the period than toward the end (Figure 3). The slow narrowing of the price gap may reflect the growing integration of markets over time.

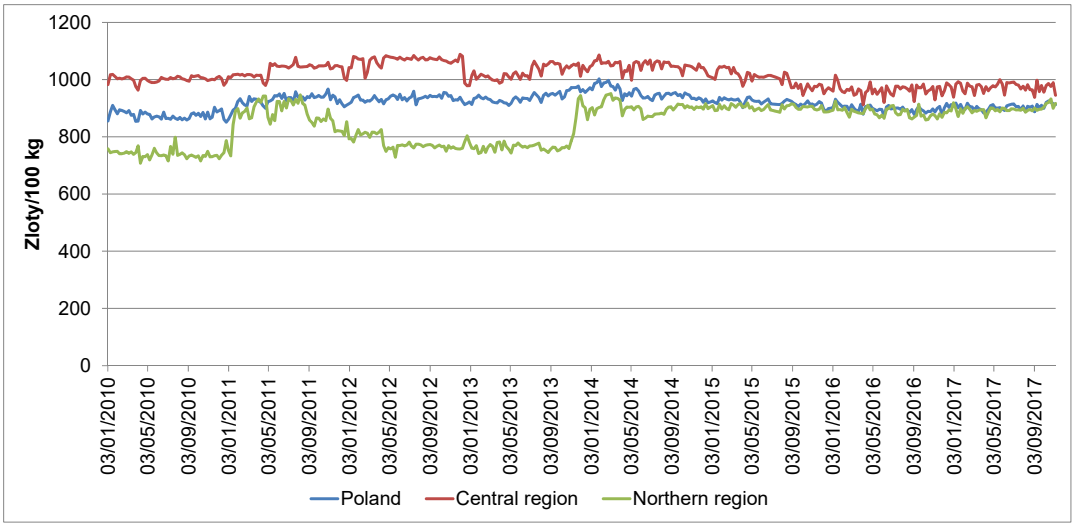


Figure 3. Weekly prices of curd per kg in the country and two regions, 3 January 2010 to 5 November 2017, in PLN.

4.2. Modeling Approach

The aim of this paper is to examine spatial integration of butter and curd prices in two neighboring regions, both with a large dairy sector, but one being a surplus region (Northern), while the other is a deficit region (Central). Price integration can be traced to the seminal work by Richardson [27], which described the relationship between prices of the same commodity between two markets as:

$$P1it = \beta 0\ P2it\ \beta 1\ Tit\ \beta 2, \quad (1)$$

where P1it and P2it are prices for butter (or curd) in time t in markets 1 and 2; Tit is transfer and transactions costs of butter (or curd) between the two regional markets. However, it is important to highlight that there has been significant progress on the modeling and testing of market integration [28–31]) as the area of time series models has developed significantly [32].

The price analysis began with the tests of individual price series to establish their stationarity [32]. This is important because an estimated model that ignores the presence of non-stationarity may lead to spurious results and erroneous interpretation.

This was followed by Granger causality tests that were applied to check the relationship between the time series (i.e., uni-direction causality or bi-direction causality). The causality tested in this study was between prices of butter or curd in Central and Northern regions. Note that given the proximity of both regions, it is expected that transportation costs should not be an obstacle in shipping either butter or curd from one region to the other, but testing is necessary to confirm this observation.

If non-stationarity is detected, the series entering into the regressions need to be further tested for cointegration. If cointegration is not rejected, then the price series can be modeled using a Vector Error Correction (VEC) model [32,33]. Finally, the dynamics of the VEC systems can be studied through impulse response simulations. This simulation is used to trace the effects of the shock over time [32,33]. In the context of price integration, if, for example, the Central region is integrated with the Northern region, then if the Central region experiences a shock, it should bring a response in the Northern region market. In the current study, tracing the effects also indicates the number of days it takes for the absorption of any shocks. Since there are multiple potential sources of a shock, especially given global fluctuations and internal competition within the EU, the focus is on the speed of shock absorption.

To account for the termination of the EU milk quota system, the applied specification includes a binary variable. The variable assumes the value of 1 for all observations falling

in the period after the milk quota system expired. Many Polish dairy farms were preparing themselves for the expansion of milk production long before the system was abolished [34], and they were even ready to pay fines for exceeding the allocated quota [35]. The study empirically tests the actual effect of quota termination on butter and curd prices in two regions.

5. Results and Discussion

The first step was to apply the unit root test to individual series to verify whether they were stationary [32,33]. Results of the augmented Dickey–Fuller (ADF) test showed that the two butter price series and two curd price series (Central and Northern region), tested in first differences, resulted in the rejection of the hypothesis that the series had unit roots. The test results for Central region butter and curd were 3.1906 (p = 0016) and −10.5435 (p = 0.0000), respectively. In the case of Northern region, the test for butter series was 4.2853 (p = 0.0045) and for the curd series was −9.0429 (p = 0.0000).

The application of the Granger causality tests yielded results suggesting bi-causality and implied that the series for butter from one region can be used in forecasting the behavior of prices in the other region (Table 2).

Table 2. Pairwise Granger causality test results for 40 lags of daily butter and curd prices in Poland.

Products	Number of Observations	F-Statistic	Probability
Butter			
Null Hypothesis:			
LogP12 does not Granger cause LogP11	370	2.6594	0.0000
LogP11 does not Granger cause LogP12		2.3771	0.0000
Curd			
Null Hypothesis:			
LogP22 does not Granger cause LogP21	370	0.5202	0.9930
LogP21 does not Granger cause LogP22		0.9925	0.4885

Notes: P11 = Central region butter prices; P12 = Northern region butter prices; P21 = Central region curd prices; P22 = Northern region butter prices; number of lags = 40.

The series non-stationarity required subjecting the price series of butter and curd for Central and Northern regions to a test to determine whether they were cointegrated. The test involved different specifications considering the intercept and trend, and linear and quadratic functional forms. The applied test indicated cointegration in the case of all price series, expressed in logs, at the preselected 5% significance level [36] (Table 3).

Table 3. Engle–Granger cointegration test for butter and curd prices in Poland.

Butter					Curd				
Series	tau statistic	Probability	z statistic	Probability	Series	tau statistic	Probability	z statistic	Probability
LOG(P11)	−7.28	0.00	−106.39	0.00	LOG(P21)	−4.18	0.00	−38.51	0.00
LOG(P12)	−7.28	0.00	−106.50	0.00	LOG(P22)	−3.38	0.05	−22.49	0.03

* p-values from [37].

Consequently, the lagged prices (in first-differences) were included in the specified VEC equations. A binary variable indicating the phasing out of the EU milk quota system was also included starting in March 2015. The binary variable accounts for possible reaction of dairy producers to the anticipated termination of the quota that took place in September 2016 (Tables 4 and 5). However, the test results did not confirm the causality in the case of curd prices, suggesting the limited ability to explain curd price changes in one region using prices from the other region. The observed independent price behavior in each region poses a challenge in marketing curd, which has limited storability.

Results show a strong integration of butter and curd prices in the two. The price transmission is 0.98 in the case of butter prices between the two regions, when the perfect transmission is 1. This result confirms that both regions—the surplus-producing North and the Central, with its deficit—are highly integrated.

In the case of curd prices, the price transmission is −0.119, departing from the perfect transmission. Since the applied prices are regional and averaged from records collected from multiple locations, local price distortions could be larger, but they are unlikely to persist.

Abolition of the EU milk quota had opposite effects on butter and curd prices, causing the former to decrease and the latter to increase. Milk prices declined after the abolition of the quota system, and countries that exceeded the quota earlier [35] could further expand milk production. Poland increased its butter production by 13.5% in 2017 and by 19.7% in the period 2015–2019. The positive effect of the expiring quota system on curd prices in the two regions in Poland could have resulted from an increasing domestic demand (at a 3% annual growth rate).

Table 4. Cointegrating equation and Vector Error Correction (VEC) model for prices of curd in the Central region in Poland.

Cointegrating Equation	**Statistics**	
Log P21(−1)	1	
Log P22(−1)	−0.1196	
	−0.0583	
	(−2.0502)	
	−6.1359	
Intercept	−0.3911	
	(−15.6967)	
Vector error correction model	D(LogP21)	D(Log P22)
Error correction term	−0.2068	0.0706
	−0.0389	−0.0497
	(−5.31)	(1.42)
D(Log P21(−1))	−0.2726	−0.0134
	−0.0532	−0.0680
	(−5.12)	(−0.20)
D(Log P21(−2))	−0.1416	−0.0250
	−0.0495	−0.0632
	(−2.86)	(−0.40)
D(Log P22(−1))	−0.0737	−0.2341
	−0.0391	−0.0500
	(−1.88)	(−4.69)
D(Log P22(−2))	−0.0443	−0.0640
	−0.0400	−0.0502
	(−1.13)	(−1.28)
Dummy for QUOTA	−0.0149	0.0049
	−0.0031	−0.0039
	(−4.86)	(1.25)
R-squared	0.2052	0.0610
Adj. R-squared	0.1953	0.0493
F-statistic	20.7068	5.2100
Log likelihood	1077.5280	978.0174
Akaike AIC	−5.2655	−4.7765
Schwarz SC	−5.2064	−4.7200
Log likelihood[a]		2056.616
Akaike information criterion [a]		−10.03251
Schwarz criterion [a]		−9.8848

[a] Refer to the VEC model. Notes: P11 = Central region butter prices; P12 = Northern region butter prices; P21 = Central region curd prices; P22 = Northern region butter prices; D (.) stands for first differences. Number of observations = 407; standard errors under the coefficients, t-statistics in parentheses. D (.) stands for first differences.

To simulate the interaction of the series in the VEC system and understand their dynamics (e.g., persistence of a shock), impulse responses to one-standard deviation shocks generated from the VEC model were performed (Figures A1 and A2 in Appendix A). The response of butter prices in the Northern region is initially slightly different than in the Central region (Figure A1). Prices in the Northern region adjust within 10 days, but it takes about five days for butter prices in the Central region to respond to a Northern region price change to equilibrium. Prices in both regions return to near equilibrium in five weeks and reach equilibrium in no more than ten weeks.

Prices of curd behaved differently than prices of butter during the period under consideration. The adjustment of curd prices in one region in reaction to prices in the other region was almost unnoticeable (Figure A2). Eventually, however, after about the same 10-week period, curd prices returned to equilibrium in both regions. However, in a space of about one to two weeks following the shock, the prices in both regions behaved differently. Curd prices in the Northern region adjusted rapidly, and by the fourth week, the disturbances were diminished. The adjustment of curd prices in the Central region was longer.

Table 5. Cointegrating equation and Vector Error Correction (VEC) model for butter prices in the Central region in Poland.

Cointegrating Equation	**Statistics**	
Log P11(−1)	1	
Log P12(−1)	−0.9837	
	−0.0194	
	(−50.6791)	
Intercept	−0.1633	
	−0.1413	
	(−1.1561)	
Vector error correction model	D(Log P11)	D(Log P12)
Error correction term	−0.1113	0.1627
	−0.0430	−0.0420
	(−2.59)	(3.88)
D(Log P11(−1))	−0.1190	0.2168
	−0.0582	−0.0568
	(−2.05)	(3.82)
D(Log P11(−2))	−0.0701	0.1356
	−0.0534	−0.0522
	(−1.31)	(2.61)
D(Log P12(−1))	0.3743	0.1192
	−0.0591	−0.0576
	(6.34)	(2.07)
D(Log P12(−2))	0.2543	0.1476
	−0.0557	−0.0543
	(4.57)	(2.72)
Dummy for QUOTA	−0.0001	0.0044
	−0.0017	−0.0017
	(−0.06)	(2.67)
R-squared	0.2357	0.2343
Adj. R-squared	0.2262	0.2248
F-statistic	24.7363	24.5404
Log likelihood	1082.227	1092.201
Akaike AIC	−5.2886	−5.3376
Schwarz SC	−5.2295	−5.28
Log likelihood [a]		2211.664
Akaike information criterion [a]		−10.7944
Schwarz criterion [a]		−10.6467

[a] Refer to the VEC model. Notes: P11 = Central region butter prices; P12 = Northern region butter prices; P21 = Central region curd prices; P22 = Northern region butter prices; D (.) stands for first differences. Number of observations = 407; standard errors under the coefficients, t-statistics in parentheses.

Overall, the behavior of butter and curd prices in two regions was markedly different. Butter prices behaved differently only in the first week and returned to equilibrium within a four- to five-week period. The length of the period was insufficient for any market participant to take advantage of such short-term price distortions. The costs of cold storage and specialized temperature-controlled transportation would have offset any large butter purchases for future sales. The result is important, because butter is a high-value dairy product that generates substantial revenues to farmer-owned dairy processing cooperatives. The semi-perishable nature of butter allows for storage, and the product storability facilitates marketing decisions. Although the milk production seasonality has been less pronounced in recent decade in Poland, the largest volume is still produced in the late spring and early summer. The surge in supply is not matched by demand for dairy products, and the ability to store temporary butter surplus reduces the potential for price fluctuations due to domestic butter consumption.

In contrast to the butter price integration between two regions, the prices of curd seem not to have been integrated. The causes of the observed lack of spatial curd price integration could be related to the relatively low price of curd as compared to butter, cream, or ripened cheese. The risk of the loss of sensory quality of curd is another factor tempering price distortions. It appears that curd prices tend to be dictated by the regional supply and demand conditions due to its high perishability leaving a narrow marketing window for the dairy processing coop sales department. Curd prices in the Northern region returned to equilibrium particularly fast. The region's population density is the lowest in the country and as a result, the management of curd production is based on long-term records of sales volume.

The keen competition among dairy cooperatives in the marketing of butter and curd also safeguards the stability of prices across regions. The confirmed high degree of butter market integration suggests that dairy farmers are not more negatively affected by shocks that could be expected under competitive conditions on the butter market. It seems that when facing well-performing markets, the key to the success of dairy farms is in managing production costs. It could be that the dairy processors adjust curd production after allocating raw milk to production of other, relatively higher value products. The increasing share of supermarket chains changing the structure of the food retail sector and the long-term character of contracts on delivery of butter and curd with dairy processing cooperatives further limit taking advantage of price fluctuations. However, the role of the structural food retail changes in Poland are beyond the scope of the current study.

6. Conclusions

Dairy farmers depend on revenue from milk sales, but as members of dairy processing cooperatives, they also share in revenues from sales of two popular dairy products, butter and curd. Two top milk-producing areas are Mazowieckie and Podlaskie Voivodships, which are located in the Central and Northern dairy price reporting regions, respectively. Poor integration of the prices in the two regions could place dairy farmers at a disadvantage, may have led to revenue loss, and bring too much price variability. Additionally, the recent termination of the EU milk quota system could also contribute to price distortions. Therefore, the current study examined the cointegration of butter and curd prices between two regions using weekly average prices for the period January 2010 to November 2017.

Following the testing of the price series for stationarity, results show both products in the two regions to be strongly integrated. The price transmission is near 1 in the case of butter prices. The effect of abolishing the EU milk quota had a negative effect on butter and curd prices, causing them to decrease. The dynamic simulation of price reaction to an external shock suggests that the prices of butter and curd adjust within four weeks, although the path of adjustment varies and is smoother in the case of butter prices. The short period of butter price deviation from equilibrium and a very short period of prices behaving differently in both regions do not offer adequate opportunities for gains from

price changes. The relatively low curd price may be the detriment thwarting any attempts to benefit from price differences between two regions.

The results did not detect distortions in the series of butter and curd prices, and this is reassuring to dairy farmers, as this is indicative of well-performing dairy markets. Such results also imply that other dairy product prices are also well integrated between the two markets. Dairy farmers may experience price fluctuations, but the adjustments of local markets appear to be swift. The termination of the quota system and solid integration imply that butter prices reflect supply and demand conditions and should serve in guiding management decisions. Since many dairy farmers in the two regions have invested heavily in their operations in recent years, knowing that market prices accurately reflect underlying conditions encourages efforts to continue increasing efficiency. There is potential for efficiency gains from increasing the milk yield per cow. The size of herds is also relatively small, but recent regulations in agricultural land sales may limit expansion, as land purchase is restricted to the county of residence, while earlier laws placed a ceiling on the total agricultural land area owned by a single farmer. Still, some small farms will likely withdraw from production, and the average herd size will increase, justifying additional investment in milk production, which may result in more efficient operations and an increase in dairy exports. Over time, dairy farmers and regional markets will become further integrated with the international dairy product market, banning any new attempts to control supply.

The future research may focus on expanding the examined portfolio of dairy products, given the absence of relationship between curd prices in two regions. It is possible that the integration is related to the degree of storability of a product and its relative price level, i.e., higher priced products could be integrated, but lower price products behave differently. Additionally, the expansion of the geographical scope of the study to include all dairy price reporting regions could broaden the insights about the price behavior relevant to diary farmer decisions, dairy processing coops marketing plans, and dairy product sourcing be retailers.

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Data Availability Statement: Weekly data for the most recent year regarding butter and cottage cheese are available from the Ministry of Agriculture and Rural Development (MA&RD) at https://www.gov.pl/web/rolnictwo/rynek-mleka (accessed on on 21 February 2021). Other data are made upon request made to the MA&RD.

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Appendix A

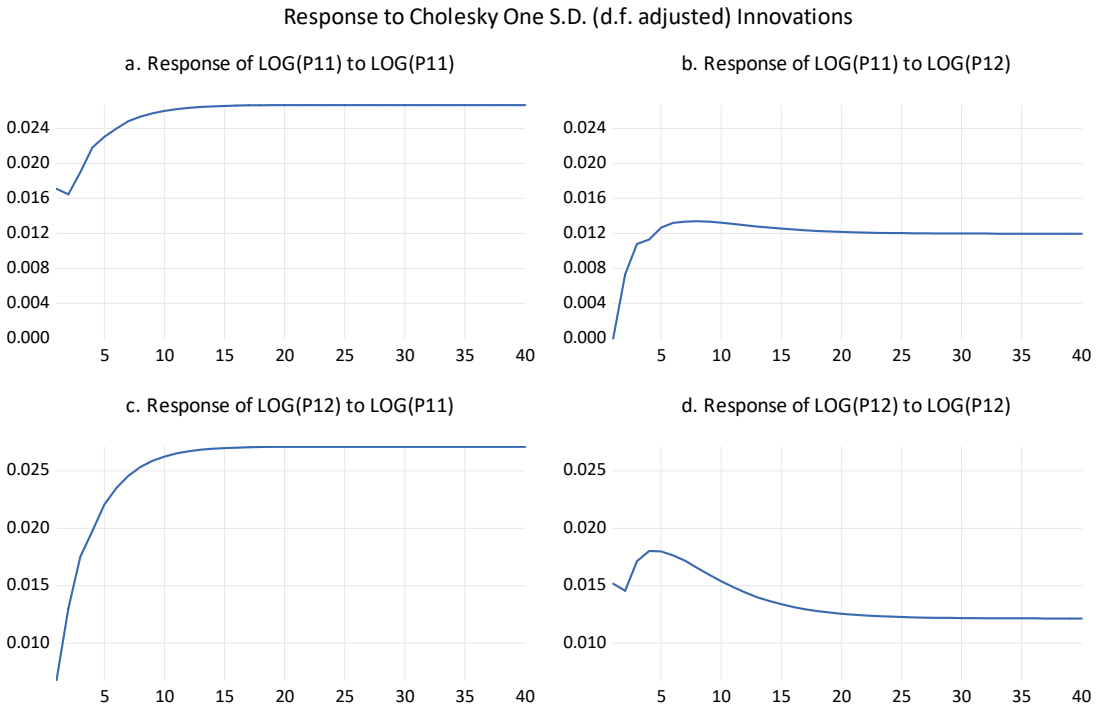

Figure A1. Impulse response estimates for butter in blocks prices in Central and Northern region, Poland, 5 January 2014 to 5 November 2017. (**a**) Response of butter prices in Central region to region's lagged butter prices. (**b**) Response of butter prices in Central region to lagged prices in Northern region. (**c**) Response of butter prices in Northern region to lagged prices in Central region. (**d**) Response of butter prices in Northern region to region's lagged prices

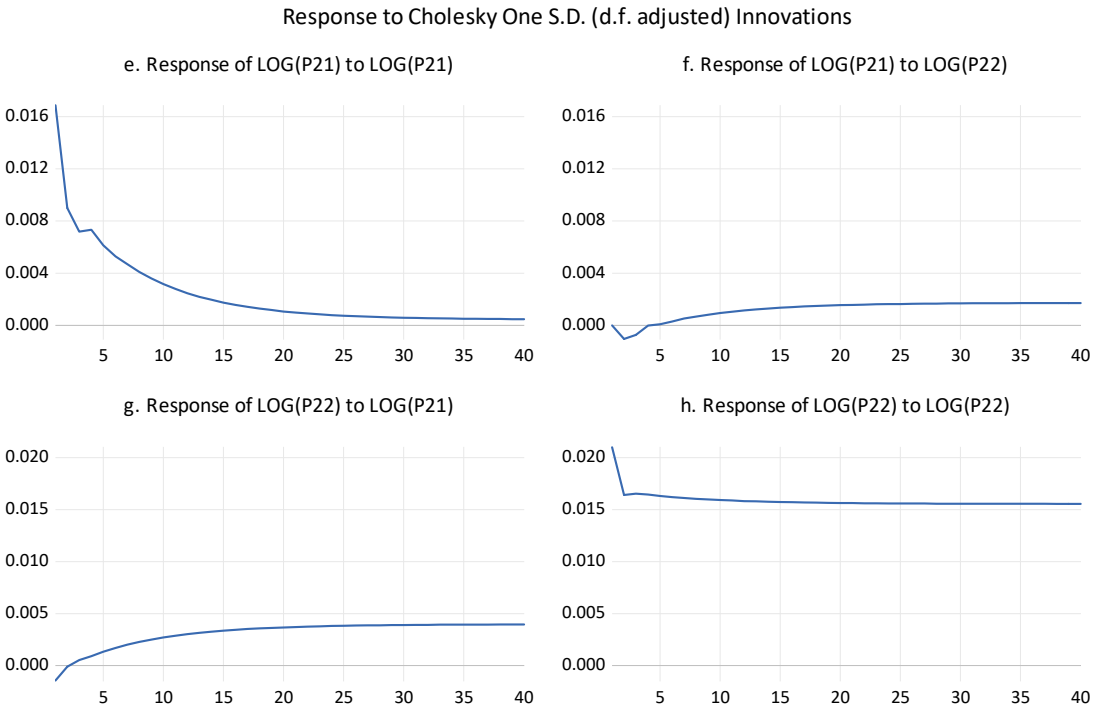

Figure A2. Impulse response estimates for curd prices in the Central and Northern regions, Poland, 5 January 2014–5 November 2017. (**e**) Response of curd prices in Central region to region's lagged prices. (**f**) Response of curd prices in Central region to lagged prices in Northern region. (**g**) Response of curd prices in Northern region to lagged prices in Central region. (**h**) Response of curd prices in Northern region to region's lagged prices.

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