Price and Volatility Spillovers of the Producer Price of Milk between some EU Member States

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Abstract

The aim of this analysis is to compute the return and volatility spillovers of raw milk prices paid to producers in Germany, Hungary, Italy and Poland with the inclusion of world prices, in the time period between January 2003 and June 2017. This study poses the questions: what is the level of spillovers of the producer price of milk among these Member States? Has the level of spillovers increased over time? Based on the relevant literature, we assumed that agricultural price spillovers have increased over time in general and the price returns of Germany and Italy determined the price returns of Hungary and Poland. We calculated the Diebold-Yilmaz Spillover Index for the returns and for the absolute returns in order to measure return and volatility spillovers. We found that on average, 50% of the price forecast error variance came from spillovers. Germany had the highest contribution to the forecast error variance of the other markets, while Italy was mostly affected by the other Member States and world prices. At the same time, none of the Member States had a significant effect on the world prices. In the case of volatility, the overall spillover index is relatively low, at around 20%. Germany had the strongest influence on the prices of the Member States, while Italy had the lowest contribution, which can be explained by the relative stability of Italian raw milk prices compared to the other three markets. Over time, return and volatility spillovers showed a moderate increasing tendency which supports the hypothesis of increased price spillovers on the dairy market in recent years.

Key Words

raw milk; volatility; return spillovers; dairy sector; Diebold-Yilmaz Spillover Index

1 Introduction

The aim of the research is to compute the return and volatility spillovers of raw milk prices paid to milk producers in Germany, Hungary, Italy and Poland while controlling for world prices. Dairy and milk price volatility have increased since 2007 (BERGMANN et al.; 2015, EUROPEAN COMMISSION, 2017; MÜLLER et al., 2017). After 2007, the stability of raw milk prices decreased substantially compared to processed dairy product prices, which was usually characterised by higher instability before 2007 (IHLE et al., 2017). The effect of the increased volatility of the dairy market is manifold, although it is mostly associated with uncertainty. Uncertainty in prices creates uncertainty in stakeholders' incomes, which also hinders long-term investments. Moreover, it is not simply the high level of volatility which is a problem, as now volatility has a more unstable, new path; as a result, even "volatility is more volatile" (EUROPEAN COMMISSION, 2017). Despite the serious economic and social effects, the increase in price volatility is not well documented at the EU level according to BERGMANN et al. (2015) and CARVALHO et al. (2015). It is mainly grains which are the key factors in agriculture price related research, because they are major staple foods and important inputs in agricultural production chains, mainly for meat production (GILBERT and MORGAN, 2010). Research studies on milk prices are limited, partly due to the limited price information on the market (which means, for example, the lack of high-frequency and long time series data compared to other agricultural sectors). There is no developed futures market for milk and dairy products in the European Union, which contributes to the lack of information available. Perishable raw milk is not suited for futures trade, either (CARVALHO et al., 2015). Furthermore, the fat and protein content of raw milk produced in the Member States is heterogeneous, but futures trading requires high quantities of a standardized product to operate (EUROPEAN COMMISSION, 2010a, b), and homogeneity of the product is not automatically guaranteed (EUROPEAN COMMISSION, 2017).

Thus, research in this field has a great economic and social importance. This paper contributes to the few existing research studies in this area. According to our knowledge, none of the studies have used the Diebold-Yilmaz Spillover Index to measure the return and volatility spillovers in the dairy sector, so far. In this paper, we calculated the return and volatility spillovers in the dairy sector and showed the development of these spillovers over time. Milk producers are the most vulnerable actors in the dairy supply chain and the development of the dairy sector was hectic after 2007. Although market protections are assured by the EU, price negotiations and street demonstrations were still a common tool used to shed light on the insufficiencies of the producer segment. Spillovers on the market can cause unstable prices and social insecurity; thus it is necessary to understand their behaviour.

2 Agricultural Trade, Market and Price Volatility

This section gives an overview of the general nature of the dairy market in order to understand the recent evolution of milk prices. Aggregate demand for milk is rather price inelastic because milk is intended for human consumption and does not have many substitutes. Change in the aggregate demand results in strong price changes. While the aggregate demand is inelastic, this is not true for the product level, because different dairy products can compete with each other. Furthermore, change in the demand for different products is not the same (BOUAMRA-MECHEMACHE et al., 2008). Small changes in the supply and demand can cause great fluctuations in the producer price of dairy products, a situation which is intensified by the low volume of dairy production and the low number of exporters and importers involved in international trade (O'CONNOR et al., 2009). The trade share of global milk production is generally under 10% in milk equivalent (THIELE and RICHARTS, 2013). Agricultural trade determines the openness to international price volatility on the dairy market. Globally, the market situation of New Zealand (main exporter) and the USA (one of the main milk producers) strongly affects the international dairy market. Shocks originating from these nations run through every main milk producer market. In the EU, the German and Dutch markets are sensitive to international shocks due to their intensive role in trade with third countries (CARVALHO et al., 2015). On the demand side, the proportion of milk and dairy products in total human consumption will continue to grow due to increases in income and consumers from the middle classes (EUROPEAN COMMISSION, 2014). Consumption habits are shifting towards higher added value, which includes dairy products (TADESSE et al., 2014). Per capita cheese consumption increased by more than 15% in the EU in 2015 compared to 2000, but in the case of fresh dairy products, there was a 4% decline (IHLE et al., 2017). In spite of increasing cheese consumption, expanding sales are not expected in the EU due to the stagnating or declining number of consumers. It is also hard to increase per capita consumption, since the EU is a developed region where the growth potential of dairy consumptions depends on the number of consumers rather than on purchasing power and changing consumption habits (THIELE and RICHARTS, 2013). Foreign trade has become more important due to the export opportunities and poor domestic sales possibilities. As HUCHET-BOURDON (2011) remarks, the effect of price instability can be felt by farmers and consumers in different ways. The downward fluctuations of commodity prices are problematic for producers while upward fluctuations are only a concern for consumers. Furthermore, GILBERT and MORGAN (2010) point out that producers have the chance to reduce risk by using different tools, e.g., future and forward contracts or insurance. Another way to reduce price risk is the price models of dairies. A very comprehensive overview can be obtained about general price volatility and the possible solutions from the work of the ULYSSES project[1].

In the past decade, China has been a major player in the international dairy market, mostly due to its strong demand for animal protein. China is the largest importer of milk products (OECD/FAO, 2017), and Chinese imports account for about one tenth of global dairy imports. Compared to 2004, Chinese dairy imports had increased ten-fold by 2014 (IHLE et al., 2017). SHADBOLT and APPARAO (2016) note that the skimmed and whole milk powder imports of the country are especially significant. In general, the consumption of developed countries like China has increased, mostly due to population increases, growing incomes and changing diets (OECD/FAO, 2017). These factors, combined with the production constraints of the Chinese dairy sector, have boosted the trade between China and New Zealand (the main exporter of dairy products globally) in order to satisfy Chinese demand (SHADBOLT and APPARAO, 2016). According to SALOIS (2016), the dairy sector in China has been expanding rapidly in the past decade mostly due to its strong domestic demand and government support, but as ZHANG et al. (2017) remarks, the shortage of agricultural land and water availability in China limits the possibilities for supply expansion. Efforts have been

[1] http://www.fp7-ulysses.eu/

made by the Chinese government to strengthen the trust of Chinese consumers in domestic products, and protect and promote the dairy industry, as well. Still, due to food safety and quality issues, the long term dependence on imported dairy products is likely to remain in the future.

China has decreased its imports of whole milk powder (WMP), which has created a challenging market for the EU dairy sector (OECD/FAO, 2017). The outlook for the next few years depends critically on Chinese demand (SALOIS, 2016). ZHANG et al. (2017) states that the main supplier of Chinese demand is New Zealand (due to negotiations on the upgrading of the New Zealand-China Free Trade Agreement signed in 2008), thus the EU and the USA are facing strong competition in terms of dairy exports. However, the expansion in the supply of dairy products after the removal of milk quotas and the still ongoing, but accelerated free trade agreements between the EU and China support EU dairy exports (ZHANG et al., 2017). China will more than double its cheese imports by 2026, creating a favourable trade environment for the EU, the largest cheese exporter globally. Although most Chinese imports originate in New Zealand, the EU has been able to increase its dairy exports (butter and skim milk powder, SMP) to China. The role of China in the international dairy trade is uncertain and even small variations in its domestic production and consumption affect the international dairy market significantly (OECD/FAO, 2017).

3 Sectoral Regulations

The dairy market is historically one of the most regulated agricultural markets in the EU and its international trade has been distorted for decades (CARVALHO et al., 2015), although it has been significantly deregulated in recent years. Many countries have begun to deregulate their agricultural price and trade policies over the last 25 years. High income countries reduced assistance to farmers and decoupled some of that support from production in the late 1980s. Despite the deregulation of trade policies, the volume of internationally traded farm products has increased very slightly (ANDERSON, 2012). The Common Agricultural Policy (CAP) determines the milk price dynamics in the EU. Before the Luxembourg agreement in 2003, the aim was to maintain adequate and stable prices for particular commodities by market intervention tools. Since 2003, the focus has rather been on greater market integration including income support, although the reduction of market intervention tools and the abolition of milk quotas in 2015 has led to greater milk price volatility and lower prices (BERGMANN et al., 2015).

O'CONNOR et al. (2009) remark that dairy trade liberalization and deregulation has resulted in increasing price volatility since producer prices in the EU could adapt to world prices more efficiently. Since 2007, there has been a stronger interdependence between the EU dairy market and world market prices due to the reduced level of intervention prices and quantities and the growing demand for milk and dairy products globally. In addition, reduction of tariffs and suspension of export refunds have contributed substantially to the increasing interdependence between prices. From 2000 to 2006 the price range between the highest and lowest monthly price was between 5% and 10%, which increased to between 15% and 30% in the EU (IHLE et al., 2017). THIELE and RICHARTS (2013) show that the variance in world milk prices explains the variance of the value of EU market milk (which corresponds to raw milk prices) by 60% between 2000 and 2013. In a shorter period between 2006 and 2013, this relationship increased by up to 77%. European dairy farmers benefit from this increasing dependence on the world milk market. ANDERSON (2012) calculated the global short-run price transmission elasticities for different key foods (including milk with a coefficient of 0.51) between 1985 and 2010 across 82 countries. The estimates show that on average, half of the international price movements are transmitted to the domestic market in these countries.

The Common Agriculture Policy (CAP) allows Member States to form their own national sectoral policy. Differences in national policy implementation are important since small differences in agricultural and environmental regulations can have a great impact on the efficiency of dairy farms (JANSIK and IRZ, 2015). Access to raw milk in greater volumes is the focus of the sectoral strategic plans of the Member States and multinational companies' growth and acquisition strategy. Stronger competition for raw materials has increased the raw milk trade between Member States, which was boosted by the price difference between the old and new Member States. As prices became more integrated with each other, non-price factors gained greater importance in the trade (JANSIK and IRZ, 2015). Dairy processors prefer large-scale producers due to the high volume of milk produced with homogeneous nutritional content (JANSIK et al., 2014). Dairy processors are willing to detour hundreds of kilometres in procurement if necessary (JANSIK and IRZ, 2015). Dairy producers in the EU often do not know in advance how much they will receive in exchange for the milk delivered (EUROPEAN COMMISSION, 2010b); furthermore, milk producers often do not have the option to choose their dairy processor or transporter (EUROPEAN COMMISSION, 2010a). These facts were exacerbated by the low bargaining power of the milk producers in several Member States, which resulted in difficulties in adjusting supply to demand (EUROPEAN COMMISSION, 2010a) and in unplanned and unbalanced supply (EUROPEAN COMMISSION, 2010b). Farmers' bargaining power is very limited in some cases in the short term if producers disagree on pricing or the quality classification since milk is a perishable product (IHLE et al., 2017). Furthermore, the milk quota system operating for some 30 years and the high institutional prices have created an inelastic market. The market players were not motivated enough to give a proper response to the market signals due to their almost guaranteed market. This behaviour delayed the regime change, and did not support innovation and productivity increasing initiatives (EUROPEAN COMMISSION, 2010a). In 2008, exceptional weather events affected the EU dairy market, parallel to the implementation of the Health Check. Milk production decreased due to a drought in Oceania (EUROPEAN COMMISSION, 2010b) and the low level of butter and SMP stocks (WEBER et al., 2012). Export refunds of dairy products were set to zero in 2007 due to the higher producer price globally. This was the first time there had been a zero export refund in the case of every dairy product in the last 40 years (EUROPEAN COMMISSION, 2010b). BOUAMRA-MECHEMACHE et al. (2008) pointed out that the former milk quota system of the EU put further pressure on the market and contributed to the lower supply. However, as WEBER et al. (2012) notes, in 2007/08 the price spikes were rather due to insufficient global supply than the change in EU agricultural policy. The safety network was insufficient to protect the players on the market, thus market events had a more direct effect on domestic EU prices (WEBER et al., 2012). After the recovery of the supply, the evolving global economic and financial crisis occurred and contributed significantly to the increase in the price volatility (EUROPEAN COMMISSION, 2010b) and the decrease in consumer demand (WEBER et al., 2012). Partly because of these events, the so called Milk Package has been operating since October 3, 2012 in order to create a more market oriented dairy sector after the abolition of the milk quota. It is valid until June 30, 2020. The Milk Package aims to amend contractual relations, strengthen the producer and inter-branch organizations *(PO and IBO)*, regulate the supply of PDO/PGI cheese *(protected designation of origin - PDO, and protected geographical indications - PGI)*, increase market transparency and provide better information. All of these areas are critical points of the EU dairy sector (EUROPEAN COMMISSION, 2014). While these policy interventions aim to create a more competitive dairy sector, competition between regions of the EU, and between the EU and the international players is strong.

4 Institutional Backgrounds

4.1 Market Structure and Product Segmentation

This section focuses on the market structures of the dairy sector. Furthermore, it describes the relationship between the market structure and the development of raw milk prices, which can explain the clear difference between the four Member States analysed. Cooperatives and producer organizations (PO) are important factors in price development. Cooperatives are farmer owned and controlled organizations, thus they want to provide a favourable environment for the long-term investments of their members (MÜLLER et al., 2017). Furthermore, MÜLLER et al. (2017) found that a higher national proportion of cooperatives indicates a lower dairy price volatility on the market. Moving from zero cooperatives to a market fully controlled by cooperatives means for most of the analysed countries one standard deviation decrease. Furthermore, prices are more stable in countries with a relatively high number of dairies, thus competition may be able to ensure stabilization. Still, we have to add that diversified production structures are more efficient in achieving stable prices since the different product portfolios are less sensitive to excessive price movements and their demand is more stable leading to decreasing price fluctuations, as well. According to IHLE et al. (2017), the dairy processing industry in the EU has invested considerably in product differentiation over the past decade. Besides production methods, product attributes have also been linked to different locations.

The European Union has recognized the importance of these factors. POs, collective negotiations and contractual arrangements are parts of the provisions of the Milk Package. These instruments can distribute risk more equally between supply chain stakeholders, stabilise producers' incomes and obtain more bargaining power for diaries. Grouped by the type of contractual arrangements, in 2016 almost 70% of cows' milk was delivered to cooperatives in Germany and Italy, while in Poland the proportion was over 70% (collecting and processing). The remaining 30% belonged mostly to private processors. In Hungary, the share of cooperatives and private processors in 2016 was 40–60%, respectively (EUROPEAN COMMISSION, 2016). The lower milk price paid to the producers by dairies in Hungary can be attributed partly to the higher share of private processors in contractual relations, since private processors usually have more bargaining power on the market compared to producers. It is important to notice that cooperatives are farmer-owned entities, thus they already have a given level of bargaining power in price negotiations.

The structure of the dairy processing chain in the EU differs not only by Member States, but by regions within the different Member States, as well. In Italy and in Germany between 2006 and 2015 the number of enterprises decreased from 2103 to 1,528 and from 223 to 124, respectively. Between 2006 and 2016 the number of dairies decreased in Poland from 249 to 178, and increased in Hungary from 41 to 54. Hungary is the only member state in the EU where the number of enterprises has increased (IHLE et al., 2017). By analysing the market segmentations by product and by market share, there is a distinct difference between the old and the new Member States. The market shares (market value share) of the leading companies or groups in the German and Italian dairy market cover around 16% and 25% of the whole domestic market, respectively. This share is above 50% in Hungary and almost 40% in Poland (measured in sales shares). Thus, these companies may have a greater bargaining power in the domestic markets of Hungary and Poland, which in turn, may imply lower milk prices. Furthermore, Zanetti Spa in Italy is entirely specialized to produce and distribute Italian cheese and butter products with a relatively high share in the domestic market. In Germany, Hochland AG is specialized in cheese production, as well (Table 1).

Product segmentation also differs between Member States. The share of processed dairy products in processes such as cheese and butter production is much higher in volume in Germany and Italy (1.8 and 1.2 million tonnes of cheese and 507 and 95 thousand tonnes of butter, respectively in 2016). In Hungary and Poland, cheese production was 80 and 806 thousand tonnes, while butter production was 8 and 204 tonnes in 2016. Cows' milk collection was 32 and 11 million tonnes in Germany and Italy and 11 and 1.5 million tonnes in Poland and Hungary (EUROSTAT, 2018a, b, c). Market segmentation was similar in the analysed Member States, although the proportion of the demand for dairy products was very different in some cases. In 2017, the demand was the highest for the 'cheese' and 'milk and cream' categories (proportions based on the demand in US dollars). In Germany, cheese represented almost 50% of the total national demand while milk and cream made up an additional 18%. In Italy, the values for these categories were 61% and 14%. The shares were different in Hungary and Poland. The demand for cheese in Hungary was only 35% of total dairy product demand,

Table 1. Concentration of the dairy markets of Germany, Italy, Hungary and Poland (by market value share in the case of Germany and Italy, and by sales share in the case of Hungary and Poland, 2016)

Germany	%	Italy	%
Muller Group	4.9%	**Groupe Lactalis**	13.2%
Royal FrieslandCampina N.V.	4.7%	**Granarolo S.P.A.**	5.9%
Savencia SA	3.8%	**Mondelez International, Inc**	3.2%
Hochland AG	2.8%	**Zanetti Spa**	3.0%
Other	83.0%	**Other**	74.8%
Total	**100.0%**	**Total**	**100.0%**
Hungary	**%**	**Poland**	**%**
Bonafarm Group (SOLE-MiZo Zrt.)	18.18%	**Mlekovita**	12.16%
Alföldi Tej Kft.	15.42%	**Nestle S.A.**	10.99%
FrieslandCampina Hungária Zrt.	9.93%	**Mlekpol**	10.97%
Tolnatej Zrt.	9.36%	**Okręgowa Spółdzielnia Mleczarska W Łowiczu**	4.75%
Other	47.12%	**Other**	61.14%
Total	**100.0%**	**Total**	**100.0%**

Source: authors' own data collection based on the data from EMIS (2018a) and EMIS (2018b) almost exactly the same value as in Poland, while the demand for milk and cream represented 25%, the highest value among the analysed Member States. In Poland, the latter category made up 20% of demand, while the 'milk in powder' and the 'other' categories (which consisted of buttermilk, whey, casein and a few other, minor categories) represented an additional 13 and 15%, respectively. Furthermore, the proportion of demand for ice cream was almost 20% in Hungary. The shares based on the national demand values were significantly different. While the value of the national demand for dairy products was 28.4 and 28.0 billion US dollars in Germany and Italy, the same numbers were 7.5 and 1.2 billion US dollars in Poland and Hungary, respectively. These facts imply that in some Member States, market concentration may be much higher compared to other Member States. High added value products are significantly present in the Italian dairy market (mostly special types of cheese), while Germany has also produced a relatively high proportion of processed products, when compared to Hungary or Poland.

4.2 The Role of Futures Markets in the EU

Efficient futures markets can be a primary tool to overcome the adverse effect of price fluctuations. While in the US, futures market for dairy products are more consolidated, the EU and New Zealand have only entered this type of market in recent years. The role of futures markets has only recently grown in the EU (while in the US it has developed significantly), and they are much less used than in the cereal sector (EUROPEAN COMMISSION, 2017). BERGMANN et al. (2015) also suggest the use of efficient futures markets, but remark at the same time, that in the EU, only butter, SMP and whey futures are traded, thus derivative markets are still in an "embryonic" state with thin liquidity in the case of these contracts (BERGMANN et al., 2015). At the same time, despite the lack of liquidity futures prices can be used for business decisions. There are two stock exchanges in the EU offering alternatives for dairy products; the Euronext and the European Energy Exchange (EEX). Contracts are available for butter, SMP and standard whey powder. Globally, the Chicago Mercantile Exchange (CME) and the New Zealand Exchange (NZX) are very active in the dairy trade. Their contracts include the trade in milk (MKP), butter, butter oil (anhydrous milk fat), SMP and WMP in New Zealand, and Milk Class III, Class IV, butter, SMP, standard whey powder and cheddar cheese in the US. Thus, the difference can be seen in terms of the contract types and sizes and the maturities available (EUROPEAN COMMISSION, 2017). Besides the lack of developed futures markets in the EU compared to the USA, the lack of the use of dairy hedging tools is quite common in the EU (EUROPEAN COMMISSION, 2017). These factors are mostly related to the base risk associated with futures markets, the cost of trading and the lack of understanding the operation of futures. The EUROPEAN COMMISSION (2017) states that processors could operate more easily on the futures market, and thus provide more stable prices for the producers. Lack of knowledge and trust in such futures poses an obstacle to increasing the traded quantity; furthermore, technically skilled staff and training are also needed in order to operate efficiently on the futures market, while currently the level of knowledge is not present. There is a need for a collective approach to the use of futures markets due to the heterogeneous farm size and supply in the EU.

5 Material and Methods

We measured the return and volatility spillovers by the method used by DIEBOLD and YILMAZ (2009). In order to do this, we first used the augmented Dickey-Fuller Test to establish the order of integration of the time series (DICKEY and FULLER, 1979, 1981). We tested for the presence of cointegration by the method used by JOHANSEN (1988) and JOHANSEN (1991). In the next step, we built a vector autoregressive or a vector error correction model (VAR or VECM), depending on the result of the pre-tests in order to measure the return and volatility spillovers. A general VAR model explains the price changes today with its own past and with the past values of other variables. If there is long-run co-movement between the prices (so called cointegration), a VAR model can be transformed into a VEC model. The VEC model captures both the long- and the short-run movements of the prices. The DIEBOLD and YILMAZ (2009) index measures the spillover between variables by the use of the forecast error variance decomposition (VD). The forecast error is a given error series associated with a forecast. Since the VAR/VEC models explain the price changes with a given number of variables, the forecast error consists of the effect of these variables. However, the contribution of the given variables is different, according to their relative importance in the system formed by the set of variables. Basically, the indexes measure how much price or volatility effect spills over from a given variable to another. The index, also generalized by DIEBOLD and YILMAZ (2012), allows for directional spillovers, as well. In order to get orthogonal innovations, the Cholesky factorization is commonly used, but variance decomposition becomes dependent on the ordering of the variables. The generalized index is no longer dependent on the ordering of the variables due to the use of generalized forecast error variance decomposition (GVD) by PESARAN and SHIN (1998). Defined in this way, the N variable covariance stationary VAR, based on DIEBOLD and YILMAZ (2012), can be represented as:

$$x_t = \sum_{i=1}^{p} \Phi_i x_{t-i} + \varepsilon_t \tag{1}$$

Where x_t is the analyzed price vector at time t, Φ_i is the autoregressive parameter matrix for a given lag, p denotes the maximum lag in the model, and the independently and identically distributed error term is the vector $\varepsilon_t \sim (0, \Sigma)$. A VAR (or in the case of cointegration, a VEC) model is able to capture the rich dynamics of a set of time series, thus it is suitable for multivariate economic modelling. The variance of the forecast error can be broken down into its own variance share and a cross variance share, the so called spillover. The GVD H-step-ahead forecast error variance decomposition $\theta_{ij}^{g}(H)$ in the case of $H = 1,2$ ... can be defined as:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h \Sigma e_j\right)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)} \tag{2}$$

Where σ_{jj} is the standard deviation of the error term for the jth equation, Σ is the variance-covariance matrix of the error vector denoted by ε, while e_i is a simple selection vector which consists of one in the ith position and zeros everywhere else. The matrix A_h came from the moving average representation of the VAR model. The error of the forecast of a given variable consists of parts from its own dynamics and from the other variables. The above mentioned formulae calculate the variance of these errors and the percentages of “its own” and the “other” contributions.
The normalization is:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)} * 100 \tag{3}$$

The sum $\sum_{j=1}^{N} \tilde{\theta}_{ij}^{g}(H) = 1$ and $\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H) = N$.

- Defined in this way, the *total volatility spillover index* measures the total forecast error variance proportion of the returns and volatility that derives from spillovers.

$$S^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} * 100 \tag{4}$$

- The *directional spillover* measures the proportion of the forecast error variance of market *j* originating from innovations of market *i*, or the proportion transmitted to market *i* originating from market *j*. These spillovers can be measured between individual markets or between a given market and every other market.

$$S_{i*}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} * 100 \tag{5}$$

$$S_{*i}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{ji}^{g}(H)}{N} * 100 \tag{6}$$

- The Net volatility spillover is the amount of spillover from market i to all other markets j.

$$S_{i}^{g}(H) = S_{*i}^{g}(H) - S_{i*}^{g}(H) \tag{7}$$

- Finally, the *rolling window analysis* uses the same method, but the model is estimated based on a moving window of the same size. The size was set to 6 months since this was the period in which the rolling spillover did not change significantly with added periods.

The general and the directional spillover measurements can show how many of the return and volatility changes derived from spillovers on average within the system of the variables. Directional spillovers can reveal the spillover mechanism between the market players. Thus to some degree, the measurements can explain the overall relationships between the set of prices. The measurements offer additional information about the market, which, combined with existing and future research, can form a basis for decision making, since it can be calculated how price or volatility changes in one market affect price and volatility changes in another market. This information may help to improve the market forecasts and understand the dependencies between the set of markets. BRÜMMER et al. (2013) remark that underinvestment in agriculture increases food price volatility in general. Better market predictions play a crucial role in investment decisions, although it must be added that the causation is bi-directional, since increased price volatility may result in a lower level of investments in agriculture as well. As STIGLER (2011) remarks, a fundamental understanding of commodity prices is lacking, which creates an obvious gap between theory and empirical data. We choose to follow a data-driven methodology, where we relied on results provided by empirical data. For the return series, we used the first difference of the raw data. To estimate volatility, we used the absolute returns as an approximation. The analysed prices are nominal, monthly historical series of the MILK MARKET OBSERVATORY (2017) (MMO) and CLAL (2018) between January 2003 and June 2017 (T = 174) for Germany, Hungary, Italy, Poland and the World (Fonterra), denominated in euros. The analysed countries were selected according to different criteria.

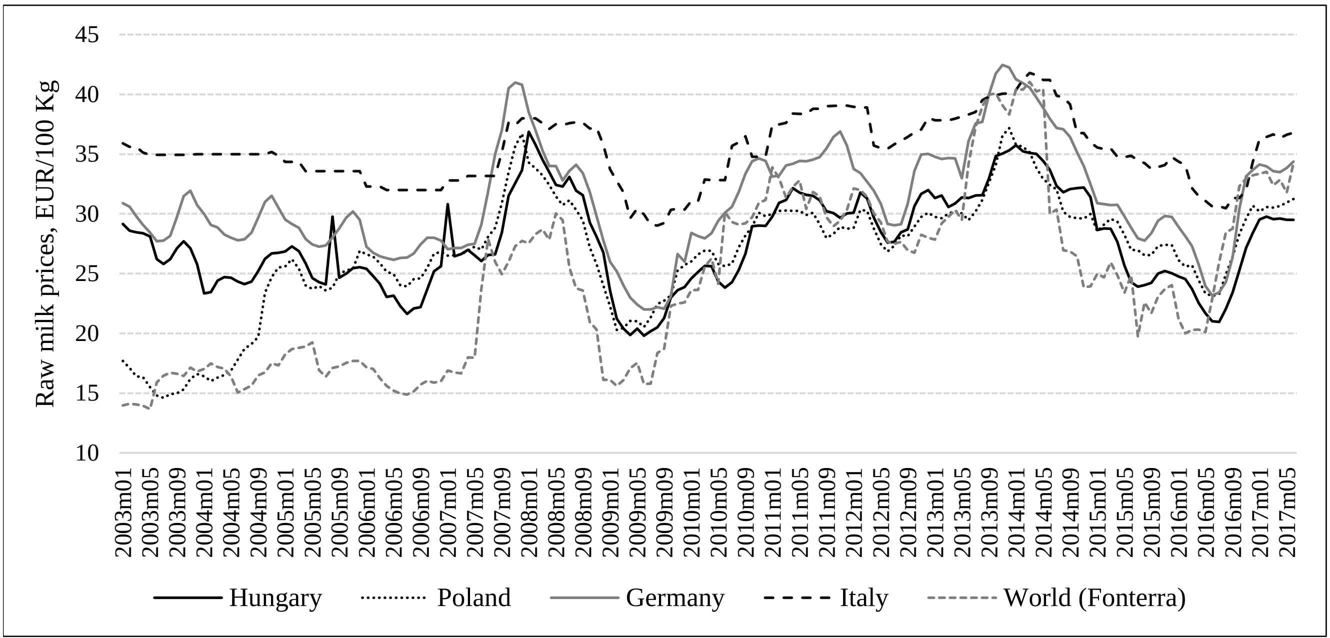
The aim was to examine the spillover mechanism. Hungary and Poland had a very similar economic background after the regime change in 1990; however, the dairy sectors of the two Member States developed very differently. For this reason, we analysed the development of the dairy sectors in these Member States. Germany seemed to be an obvious choice, since it has one of the most developed dairy sectors in Europe with a great impact on milk prices in the EU. While Italy has a crucial role in the dairy sector of the EU, it has a strong economic relationship with Hungary, as well. Furthermore, the producer price of milk is remarkably stable in Italy, which makes the relationship between Italy and the other Member States appealing in terms of the spillover mechanism. Still, the analysed group of countries can be extended in future research. The sample period was limited by the availability of data. Hungary had no data before January 2003, thus we adjusted the sample accordingly. Furthermore, before 2003/04, the dairy sectors of Poland and Hungary went through numerous changes to prepare for EU accession; thus our sample covers the price behaviour only in the new economic background after 2004. The last data point was the most frequent data point available at the time of the research. R Software was used for the calculations.

6 Results and Discussion

6.1 The Developments of Raw Milk Prices after 2003

Average milk prices have increased in the past decade in nominal terms. This trend is expected to continue in the future due to the growth of global economic activity (EUROPEAN COMMISSION, 2014). Due to the increasing price level the gap between the domestic prices of EU states and international prices has almost disappeared (WEBER et al., 2012). However, there are some noticeable developments in the raw milk prices of the four Member States analysed. Up until 2008, there was a seasonal pattern in the prices, which disappeared after 2008. This observation is in line with the conclusion of the EUROPEAN COMMISSION (2017) and IHLE et al. (2017), while BERGMANN et al. (2015) also noted that a seasonality pattern was clearly observable before 2003, but not so obvious after that period (especially after 2007). There is no general trend in the prices, but there are periods with constant increases and decreases. The development of Italian milk prices is clearly different from those of the other states; the milk price is much “smoother” without fluctuations as large as those in Germany, Hungary or Poland (Graph 1). The relatively more stable Italian milk prices compared to the other Member States were mostly due to a different product orientation (HANISCH et al., 2012). Furthermore, Italy was among the two Member States (with France) which adopted rules on the supply management for PDO/PGI *(Protected Designation of Origin/Protected Geographical Indication)* cheese. These regulations have a positive effect on price stabilization in Italy (EUROPEAN COMMISSION, 2016). On average, the dairy processors of Italy and Germany paid higher prices for produced milk than those in Hungary or Poland (Graph 1). The general price difference between the old and new Member States mainly originates from the different cost levels and the structure of production, since the proportion of higher value added products is higher in the old Member States, which gives a higher margin as well (HANISCH et al., 2012). Zanetti Spa in Italy and Hochland AG in Germany are good examples since these dairy companies entirely specialise in cheese production and sales with a relatively high domestic share (see Table 1). Some years after EU accession, prices in Poland and Hungary started to move together with the prices of Germany and Italy.

Graph 1. The development of raw milk prices in Germany, Hungary, Italy, Poland and the World (January 2003-June 2017)



Source: based on the data of the MILK MARKET OBSERVATORY (2017) and CLAL (2018)

BERGMANN et al. (2015) argue that price convergence after 2004 was mostly due to the CAP 2003 reforms and the focus on greater market integration within the EU dairy sector. Despite the greater level of integration, in Hungary, raw milk prices tended to fall after 2003 until 2006 due to the decreasing milk supports (Graph 1.). Before 2004, the Hungarian dairy processors received export refunds if they paid the reference price to the milk producers, keeping the prices artificially high (SZAJNER and VŐNEKI, 2014). There is no clear relationship in the EU between the production of dairy products with high added value and the price of purchased producer milk, so dairy processors producing more expensive products did not pay a higher price for raw milk (CHEVALIER et al., 2013). Nevertheless, a strong correlation between the proportion of high added value products and the price of raw milk should not be expected anyway. The milk price and the production structure of the dairies are strongly dependent on the region specific factors of Member States. Still, a higher level of added value would be preferable in the dairy sector of Hungary and Poland (and in some regions of Germany as well). The price increase after the EU accession was remarkable in Poland *(Graph 1)*. EU accession was a priority for milk producers in Poland and the dairy processors' position was that the improvements in their supplier base were implemented to get access to the EU market along with export licenses. Basically, the same thing happened in Hungary (DRIES et al., 2009). After EU accession, prices increased, but a big gap remained between the price in Poland and the EU average price (JANSIK et al., 2014). From the beginning of 2007, raw milk prices started to rise significantly until 2008, to be followed by a downturn. In this period, price movements were close to each other, and showed similar trends. The prices recovered in the next 2 years, but after 2014/15 they again hit rock bottom (Graph 1).

6.2 Unit Root and Cointegration Test Results

Our test strategy following DICKEY and FULLER (1981) and PFAFF (2008) was to test $\tau = 0$ in the first step, where τ is the parameter of the lagged value of the series in the ADF regression. Rejecting this null means that the series does not contain a unit root. If we could not reject this null, we went further and tested the ϕ_3 combined hypothesis, where ϕ_3: H_0: $\tau = 0$ and H_0: $\beta_1 = \beta_2 = \tau = 0$. Here β_1 is the drift and β_2 is the trend parameter. Non rejection of this hypothesis means the absence of linear trend while the series has a unit root. In the final step, we tested the ϕ_2 hypothesis, where H_0: $\tau = 0$ and H_0: $\beta_1 = \tau = 0$. Whenever we were able to reject the null, we stopped there. In the presence of the unit root, we tested the first difference of the series in order to achieve stationarity. The result of the ADF test shows that the series contain unit roots, but stationarity can be achieved after the first

Table 2. Results of the ADF test for raw milk prices

Member State	Type	Lag chosen by BIC	τ	ϕ_2	ϕ_3
Germany	none	1	-0.38		
Germany	drift	1	-3.25**	5.28**	
Germany	trend	1	-3.48**	4.06	6.09*
Germany	first difference	1	-5.47***		
Hungary	none	1	-0.19		
Hungary	drift	2	-2.81*	3.95*	
Hungary	trend	2	-2.94	2.88	4.32
Hungary	first difference	1	-7.05***		
Poland	none	1	0.18		
Poland	drift	1	-3.04**	4.84**	
Poland	trend	1	-3.24*	3.73	5.37
Poland	first difference	1	-6.27***		
Italy	none	1	-0.03		
Italy	drift	1	-2.13	2.29	
Italy	trend	2	-2.64	2.34	3.51
Italy	first difference	1	-6.70***		
World	none	1	0.28		
World	drift	2	-1.91	2.02	
World	trend	2	-2.65	2.47	3.51
World	first difference	1	-7.32***		

Critical values at the 1 percent level, for testing τ: -2.58, for testing ϕ_2: -3.46, 6.52 and for testing ϕ_3: -3.99, 6.22, 8.43. At the 5 percent level for testing τ: -1.95, for testing ϕ_2: -2.88, 4.63, for testing ϕ_3: -3.43, 4.75, 6.49. At the 10 percent level, for testing τ: -1.62, for testing ϕ_2: -2.57, 3.81 and for testing ϕ_3: -3.13, 4.07, 5.47. The ***, ** and * means significance at the 1, 5 and 10 percent levels respectively.
Source: authors' own calculation based on data from the MILK MARKET OBSERVATORY (2017) and CLAL (2018)

differencing. In some cases, in the presence of some deterministic variables, we were able to reject the null hypothesis of τ at the 5 percent level, but we did not have enough evidence to reject it at the 1 percent level. In these cases, we treated the variables as non-stationary, although at the 5 percent level, the null hypothesis could be rejected.[2] In the case of Germany, Hungary and Poland, the milk price contained a unit root around mean zero (however, in some cases, there is a significant drift parameter at the 5 percent level). In the case of Italy and world prices, none of the null hypotheses could be rejected even at the 10 percent level, so the two series also contain a unit root without drift and trend. The test showed that all of the series share the same characteristics. Finally, all of the first differences were stationary with relatively strong evidence against the null (Table 2). The Italian and the world milk price results supported the unit root hypothesis with the strongest evidence against the null. Since the other three series were more likely to contain outliers and the transition during the financial crisis in 2008 was more hectic in these cases (more prolonged increasing and decreasing periods), it is possible that these characteristics affected the power of the ADF test.

Non-stationarity, high persistence in the data and the kurtosis caused by extreme values are well-known characteristics of agricultural commodity prices (STIGLER, 2011). While the results for the two latter phenomena are not presented here, milk prices behaved in a similar manner.

Since all of the series are I (1), we examined the long run relationships by the cointegration test developed by JOHANSEN (1988) and JOHANSEN (1991). The AIC indicates 2 lags in the model. The maximum eigenvalue statistics (λ) indicates that there are three cointegrating relationships in the system. We decided to use a constant in the cointegration relationship, but omitting it did not alter the results. Based on the maximum eigenvalue statistics and the ordered eigenvalues, we decided to use three cointegration relationships (Table 3).

In the return VEC model and the volatility VAR model, we used a lag length of 2. We chose the forecast horizon in order not to cause changes with additional periods (and we have to keep it low due to the relatively small sample). The "contribution from" row

[2] The sample size is relatively small; thus we want strong evidence to be sure about the unit root problem. Furthermore, the visual inspection and the slow decay of the autocorrelation function (ACF) support the presence of the unit root.

means the share of forecast error variance of a Member State originating from innovation of the other markets, while the "contribution to" column means the contribution of a given country to every other country's price forecast error variance. This analysis refers to spillovers as 'shocks' since they originate from another price variable.

Table 3. Result of the Johansen method with no linear trend and constant in cointegration

H_0:	λ (K=2)	10 percent	5 percent	1 percent
r <= 4	6.88	7.52	9.24	12.97
r <= 3	12.03	13.75	15.67	20.20
r <= 2	26.46**	19.77	22.00	26.81
r <= 1	33.17**	25.56	28.14	33.24
r = 0	66.18***	31.66	34.40	39.97

The ordered eigenvalues are: 0.3194, 0.1754, 0.1426, 0.067, 0.039., -0.00…The ***, ** and * means significance at the 1, 5 and 10 percent level, respectively. The "K" denotes the lag number.
Source: authors' own calculation based on data from the MILK MARKET OBSERVATORY (2017) and CLAL (2018)

6.3 The Return and Volatility Spillovers

The total spillover was around 50%, i.e. on average, half of the forecast error variance of the returns originating from spillovers from other markets. The most notable contribution was made by Germany (~102%) and world prices (~69%). The contributions of Hungary, Poland and Italy remained moderate, between 20 and 35%. The received spillover was the highest in the case of Italy and Hungary (73% and 63%), but the effects were more balanced, since Germany and Poland received half of their forecast error variance from spillovers. Furthermore, Member States hardly had any effect on world prices, where the "contribution from" value was less than 10% (and a considerable proportion of this effect can be attributed to the interaction with Germany). With the exception of world prices, Germany had a notable effect on the other Member States' forecast error variance, while it received spillovers mostly from world prices. The proportion of "own variance" was around 50% in the case of Germany and Poland, since they received fewer spillovers from other markets, while the remarkably high proportion of "own variance" (above 90%) in world prices showed possibly exogenous behaviour. Hungary, Poland and Italy did not transmit a significant amount of spillovers to other markets, while they received it mostly from Germany or from the extra–EU market. The net spillover is effectively the sum of the spillovers transmitted to, and those received from, every other market. Thus it shows whether a given market is more likely to transmit or receive price spillovers from all other markets. In this case, the net spillovers were 52.4, -30.82, -29.84, -50.95 and 59.21 for Germany, Hungary, Poland, Italy and the World respectively (Table 4). On the practical side, the results showed that even though Italy is a major player in the dairy sector, it was also a net receiver of spillovers. Furthermore, even if we control for the effects of world prices, Germany still remains a net transmitter of shocks, thus besides the international price effects, Germany is a major price determining Member State for Hungary, Poland and Italy. The significant contribution of Germany on the transmitter side can be attributed to its tight trade relations with the international market. Thus, part of the international spillover effect is transmitted by Germany, while some of the effect originates directly from the world market. The spillover index is above 30% for Hungary, which is mostly the sum of the transmitted spillovers to Germany and Italy. Hungary is a major importer of German processed dairy products, while the majority of Italian bulk milk imports originate from Hungary. Thus, changes in the Hungarian dairy trade can transmit spillovers to other markets. On the receiving side, the differences are moderate, indicating received spillovers affect the Member States equally, albeit they come from different sources depending on the given player. Germany received price spillovers mostly from the international market, while Hungary received them mostly from Germany, as did Poland. In the case of Italy, the received spillovers are the sum of the amounts originating from Germany, Hungary and the world market.

Generally, the volatility spillovers are much lower than those in the case of returns. The overall spillover index is around 20%, showing that on average, around 20% of the forecast error variance of the volatility came from spillovers. Germany had the highest contribution to the other markets' forecast error variance (between 2 and 15%). Poland also made a notable contribution, but at the same time it received the same amount of spillovers from the other markets as well. Around 17% of the volatility forecast error variance of Hungary originated from innovations, while its contribution to the other markets' forecast error variance was around the same. Italy had the lowest contribution to the other markets (~9%). The forecast error variance of the absolute returns can be explained mostly by the proportion of "own variance" (between

Table 4. The Diebold-Yilmaz Spillover Index for the monthly raw milk prices (%)

	Germany	Hungary	Poland	Italy	World	Contribution FROM
Germany	*50.30*	12.17	7.20	9.49	20.28	**49.14**
Hungary	34.03	*36.50*	9.10	9.17	11.20	**63.50**
Poland	26.80	2.81	*49.94*	2.60	17.81	**50.02**
Italy	35.09	16.49	2.04	*26.94*	19.45	**73.07**
World	5.62	1.21	1.84	0.86	*90.48*	**9.53**
Contribution TO	**101.54**	**32.68**	**20.18**	**22.12**	**68.74**	**Total Spillover: 49.16**

The forecast horizon was set to 6 months. The elements of the table in italics show the proportion of "own variance".
Source: authors' own calculation based on data from the MILK MARKET OBSERVATORY (2017) and CLAL (2018)

70 and 95%), and the transmitted or received spillovers were lower compared to the return spillovers. The world price contributed to the other markets' price volatility, but at the same time it received the lowest amount of volatility spillovers. This behaviour indicates that world prices had a substantial effect on the development of the volatility in the Member States, but not vice versa. Net spillovers were 9.96, 2.07, -3.04, -18.85 and 9.86 for Germany, Hungary, Poland, Italy and the World, respectively. On the practical side, the German and the world prices had the same effect in terms of net spillovers, while the remaining Member States were mostly net volatility spillover receivers (especially Italy). This again shows the major role of Germany in the EU dairy sector (Table 5).

We calculated the rolling window version of the spillover index in order to detect changes in the pattern of the spillover, since a constant spillover over time is not a realistic assumption. We used a 100 month rolling window with a 6-month forecast step. The return and the volatility index vary between a tight interval, around 55-70% for the former, and 20-30% in the case of the latter. The trend of the return and the volatility spillovers has been increasing, according to the results. The latter has been increasing since 2013, which supports the assumption of a higher volatility spillover level in recent years. This growth can be due to the fact that agricultural markets are increasingly deregulated and the decision makers in the EU aim to lower the support and the regulation levels of the dairy market (Graph 2).

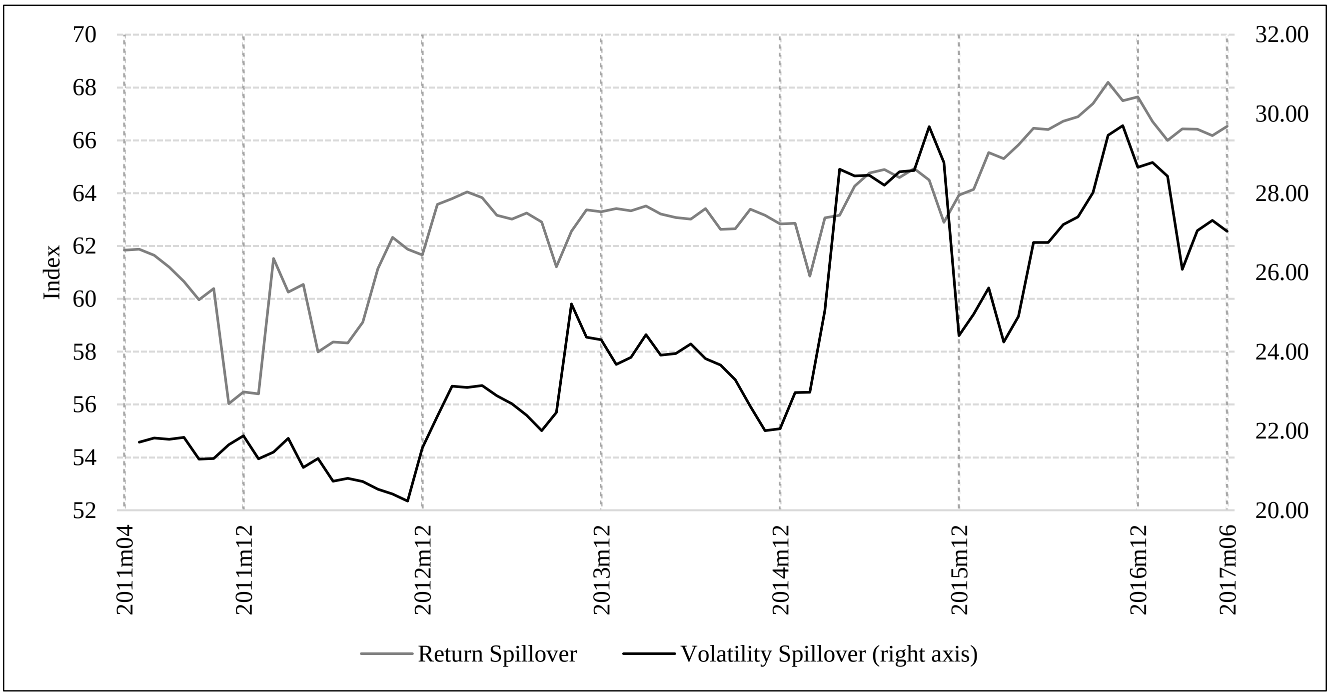
The models implemented showed no signs of autocorrelation and ARCH effect in the residuals. Furthermore, the residuals were close to the normal distribution. While residuals were not normally distributed, in most cases due to fat tails, the model is very robust against these deviations. We did a robustness check with the effective exchange rate of the euro and the US dollar and euro exchange rate. The inclusion of the exchange rate did not change the estimated parameters, so we did not include it in the final model.

Table 5. The Diebold-Yilmaz Spillover Index for the absolute monthly returns (volatility) of raw milk prices (%)

	Germany	Hungary	Poland	Italy	World	Contribution FROM
Germany	*81.01*	4.32	9.77	1.22	3.68	**18.99**
Hungary	4.19	*83.18*	7.07	4.47	1.09	**16.82**
Poland	12.67	8.09	*71.29*	1.83	6.12	**28.71**
Italy	9.72	4.45	8.15	*72.45*	5.24	**27.56**
World	2.37	2.03	0.68	1.19	*93.74*	**6.27**
Contribution TO	**28.95**	**18.89**	**25.67**	**8.71**	**16.13**	**Total Spillover: 19.66**

The forecast horizon was set to 6 months. The italics show the proportion of "own variance".
Source: own calculation based on the data of the MILK MARKET OBSERVATORY (2017) and CLAL (2018)

Graph 2. The overall price and volatility (right axis) spillover plot of raw milk prices (%)



Source: authors' own calculation based on data from the MILK MARKET OBSERVATORY (2017) and CLAL (2018)

6.4 Linking the Results to Project ULYSSES Results

In this section we link our results to the general results regarding price volatility identified by the project ULYSSES. BRÜMMER et al. (2013) collected findings from many different research studies on price volatility. The general finding is that some of the drivers were identified by several studies while others are still the subject of ongoing debates (for example financialisation and speculation, or the role of biofuels). The identified drivers were mostly crude oil price changes, the role of stocks, exchange rate effects, demand side shocks and weather shocks on the supply side. Furthermore, methodological choices might affect the outcome of the debate. These potential drivers are more related to studies on grain price volatility and so they are not included in our study. However, they might have important roles in dairy price volatility research as opposed to farm-gate price research. ARTAVIA et al. (2014) analysed the effect of macroeconomic variables on price volatility, also including WMP. Macroeconomic variables have a greater effect on world market prices, thus their effect can be negligible on domestic prices. The strongest medium-term driver of uncertainty in WMP prices was uncertainty around GDP (which means uncertainty on the demand side), while crude oil prices, exchange rate effects, CPI and GDPD were almost equal and not particularly high among the commodities. Our result showed that most of the uncertainty came from international price movements, while exchange rate movements had no effect on farm-gate milk prices. As in the case of the WMP, demand uncertainty is a relevant problem in the dairy sector. Crude oil prices were not included in our framework, since international milk prices are more affected by the energy market and we checked for these price movements. It can be seen that some of the drivers of price volatility are similar to the general findings, but the domestic results can differ from these. However, the grain market and the oilseeds market were severely affected by different macroeconomic variables. Since feed costs constitute a high proportion of the total production cost it is worthwhile to study the pass-through effect of these macroeconomic variables along the dairy chain more intensively, although these kinds of analysis might require cross-sectional or panel methods.

7 Conclusions

In the agricultural context, globalization can be seen in the stronger co-movements and integration of prices indicating a higher level of spillover between prices or between the price volatility. The dairy sector was one of the most regulated agricultural sectors in the

EU with strong market protection and agricultural support. In the past few years (since 2003) the aim of EU decision makers has been to reach a more competitive market by loosening regulation and lowering the support level of the sector. Stronger integration means common reaction to shocks and a higher level of spillover between the price series.

Our findings showed that among Germany, Italy, Hungary and Poland, on average 50% of the forecast error variance of prices came from spillovers. At the same time, 20% of the variance originated from spillovers between the group of Member States. The international price movements had a strong effect on the raw milk prices of the Member States, while at the same time, they were exogenous to the EU dairy market. Thus, world prices had a relatively strong effect on EU raw milk prices but not vice versa. The spillover mechanism was complex between the Member States, but Germany seemed to dominate the market with the highest contribution to the other market's development. Furthermore, even though Italy is a major milk producer in the EU, its contribution was limited to the market development of the Member States. Apparently, the Hungarian dairy sector is affected mostly by Germany and Italy, while the Polish dairy sector is strongly affected by world price movements, as well. The possible explanation for the spillover effects is the trade relations between these Member States. In addition, Germany acts as a general transmitter of spillovers due to its intensive trade with the international market. Furthermore, our results support the hypothesis that return and volatility spillovers have become more common in recent years, since the return and volatility spillover index has been increasing since 2013. A higher level of integration and a more intensive trade in dairy products may increase the level of spillovers in the future, where a higher level of spillovers can be problematic for the Member States with no well-functioning safety net against price fluctuations. The sector should distribute market shocks using price risk management tools. Moreover, in some regions of the Member States analysed, increased competitiveness would be beneficial as well, because at a high production cost no safety tool can protect the farms concerned against a market crisis.

Milk producers have been exposed to a higher level of risk and uncertainty in recent years. While Germany seems to dominate the market, other Member States, such as Hungary, should focus on the spillovers originating from Germany. While Italian dairy companies have managed to pay the highest and most stable prices to their producers, the high level of producer price and volatility spillovers may pose a concern in the future. Furthermore, all of the Member States analysed should focus on the development of producer groups and cooperatives, since these market organizations can provide an efficient way to protect milk producers from excessive price movements. While some of the Member States already provide possibilities for these market tools, a high level of regional disparities can still be observed. Still, producer groups and cooperatives are only one side of the coin. On the other side, better industry strategies and a greater proportion of high added value products may provide more efficient protection for producers. The role of the futures market is likely to increase substantially in the future as an efficient tool to fight against increased risk. The increased role of the futures market will require better skills in terms of education and information processing in the future. Producer organisations and cooperatives should focus on the work of futures market experts in order to operate more efficiently and offer long term assistance to their members in this area. While futures markets require skilled experts to operate efficiently, POs and cooperatives may take on this role and operate these risk management tools for the benefits of their members. Results indicate that the volatility drivers of farm-gate milk prices are more limited than those of world market prices. Since world market prices usually influence domestic prices, the correct determination of causality using the pass-through time between these prices may help to establish an early warning system designed for the market concerned (which exists in different forms and for different markets).

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