Determinants of Horizontal Milk Producer Price Integration

Zoltán Bakucs[a,b], Imre Fertő[a,b] , Zsófia Benedeka and Adrienn Molnár[a,c]

[a] Institute of Economics, Centre for Economic and Regional Studies, Hungarian Academy of Sciences

[b] Corvinus University of Budapest

[c] Ghent University, Faculty of Bioscience Engineering, Department of Agricultural Economics

E-mail: zoltan.bakucs@krtk.mta.hu

Abstract[1]

This paper analyses the efficiency of EU internal dairy markets between 2000 and 2014 from spatial price integration perspective, employing a cross-methodological approach in three steps. First, we analyse the spatial integration of raw milk markets, which is often used to test the efficiency of agricultural markets. National monthly raw milk price data are tested for integration and whether the Law of One Price (LOP) holds. Second, we assess integration results in a binary choice setting, employing gravity model variables. Finally, in order to partly overcome the often cited drawback of price transmission analysis (i.e. that by employing price variables (only), there is no connection with real trade flows), bidirectional network analysis models are designed using export variables. Country specific network centrality measures were contrasted with the frequency of LOP fulfilment. Results suggest that besides the milk volume traded, the position occupied in the trade network structure should be also considered when market integration is analysed.

Keywords: spatial price integration, internal milk market, trade, network analysis

JEL codes: F14, F15, Q11, Q17.

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1. Introduction

Market efficiency precludes competitiveness. Research on the spatial integration of agricultural markets is often used to test the efficiency of agricultural markets. Perfectly integrated markets are usually assumed to be efficient. On a spatially integrated market, the price of a product and price information should freely be transmitted between trading partners to attain an integrated and efficient market. Not surprisingly, one of the most important targets of the European Union's (EU) Common Agricultural Policy (CAP) is to facilitate the spatial integration of agricultural markets within the individual member states as well as at the whole EU level.

Spatial (and vertical) market integration papers are abundant: for instance, Mengel and Cramon-Taubadel, (2014) report 403 AgEcon Search papers using the 'price transmission' search term. The analysis of price transmission is an econometrician's playground. Without completeness, some of the ground-breaking methodologies such as threshold cointegration, smooth transition and some Markov switching models were developed and tested using this framework, (see e.g. Enders, 2010), most of these studies focus on single country-multi region cases (e.g. Brosig *et al.*, 2011) or country pairs (e.g. Bakucs *et al.*, 2015) or multi-country framework (e.g. Emmanouilides and Fousekis, 2015). Recently, the 2007-2008 and 2010-2011 price spikes generated a renewed interest in spatial price integration (e.g. Goetz and von Cramon-Taubadel, 2008; Esposti and Listorti, 2013).

Whilst assessing whether markets are integrated, or indeed whether the Law of One Price (i.e. whether 1% price change on one market induces 1% price change on the other) holds is itself an interesting research question; it is perhaps more intriguing to know which are the determinants of price transmission or market integration. Therefore, the focus of the paper is on horizontal integration; the natural second stage explanatory variable selection would include some kind of trade (volume, value) or trade share related indicators. Additionally, the physical distance between markets, transport infrastructure and border effects are also prospective regressors. However, the classical price transmission methodology was developed using only price data, thus it does not allow the inclusion of further covariates. More recent techniques may directly or indirectly account for non-price variable effects as well, but encounter data availability problems. As Stephens *et al.* (2012) rightly argue, 'lack of available complementary price, trade flow and transaction cost data has hampered the analysts' ability to test empirically whether or not trade flows are the main mechanisms behind spatial equilibrium patterns' (p. 454). There are however several possible solutions to the problem, joint analysis of market integration and its determinants.

The abundance of price transmission papers favours the use of meta-regression techniques in order to test second stage explanatory variables. This has been done for both vertical (e.g. Greb *et al.*, 2012; Bakucs *et al.*, 2015) and horizontal (Mengel and Cramon-Taubadel, 2014) price transmission. Besides often not directly comparable methodologies (partly possible to account for by the use of methodology-specific dummy variables) the publication bias might be a more serious issue when first stage data originates from published research. For example, Greb *et al.* (2012) find that cointegration occurs in 79% of all analysed commodity markets originating from published research, yet this ratio halves to 43% when the integration of similar commodity markets is directly assessed using FAO's GIEWS dataset.

A second possibility for incorporation of trade or trade costs indirectly are the application of non-linear threshold price transmission models which allow adjustment asymmetries (e.g. Enders and Siklos, 2001) or indirectly account for unobserved transaction costs and define regimes with varying adjustment and short-run parameters (e.g. Hansen and Seo, 2002). Perhaps the most intuitive of this model class is the Gonzalo and Pitarakis (2006) procedure, which is capable of directly defining price transmission regimes (including regime dependent long-run relationships) depending on an exogenous stationary variable (e.g. trade, market share, etc). Empirical examples applying the latter include Goetz and Cramon-Taubadel (2008) for German apple market or more recently, Bakucs *et al*. (2015) estimating trade volume dependent Slovenian and Hungarian wheat market integration models.

In this paper we employ a three-step approach to investigate the LOP in the European milk market. Dairy is the second source of animal protein; the yearly average consumption in the European Union (EU) is equivalent to approximately 300 kg milk (Westhoek *et al.*, 2011). Although dairy products of many EU member states are competitive on global markets (Bojnec and Fertő, 2014), intra-EU milk trade is also significant (EDA, 2014). Enlargement, policy reforms and trade liberalization are considered the most important drivers of the changes in the dairy sector; but the joint impact of these changes is rarely analysed, especially at the EU level (Bouamra-Mechemache *et al.*, 2008). In this paper we propose a new, systemic approach to analyse the changes in the previous decade from a market integration and efficiency perspective[2]. First, we estimate all possible long-run cointegrating models between (European milk) price pairs. Second, we apply discrete-choice models to assess the role of trade and possibly other variables affecting market integration can be uncovered. To the best of our knowledge, this approach has not been applied in empirical research. Third, we make an attempt to link our first stage results (the actual country pairs for which the LOP holds), with the position of independent price variable's country within the trade network. Network analysis, originally introduced in sociology is a powerful tool to visualise and analyse relationships and relative importance. The main benefit of this approach is that the behaviour of the whole system (European milk trade) can be regarded, on a quantitative basis; and also, indirect effects are to be analysed that are usually given much smaller emphasis. Thus, this application may complement other empirical analysis. Network approach is more commonly used in discussing world trade patterns, too (e.g. Garlaschelli and Loffredo, 2005; Barigozzi *et al.*, 2011; De Benedictis *et al.*, 2014). However, network analysis of agricultural trade data is very rare (a notable example is Ercsey-Ravasz *et al.*, 2012), and, to the best of our knowledge, research focusing on intra-EU trade have not been conducted. Thus, the main question here is whether there exist a testable correlation between the fulfilments of LOP amongst cointegrating countries and their position in the network.

This paper extends the spatial transmission analysis and subsequently common market competitiveness into revealing some of it underlying or hindering factors. Besides providing an overall general picture of the raw milk markets' price integration in the European Union, we also explain the degree of market integration using gravity model variables and milk trade network analysis. It is important to observe that none of the papers reviewed in this section focus on milk price integration. It is not obvious why this CAP regulated sector was neglected by empirical researchers. This paper intends to shed some light (and also raise some questions) onto one of the fundamentals of an economic union: price discovery and transmission information flow between spatially differentiated raw milk markets.

[2] Following Barrett (2001), Holst and von Cramon-Taubadel (2013) discuss the distinction between market efficiency as result of price equilibrium in geographically distinct regions, and market integration as result of physical trade flows. In practice however, most importantly because of the lack of comparable frequency trade data, these terms are often used interchangeably.

2. Spatial integration of EU raw milk markets

2.1 Law of One Price

Research on the spatial integration of agricultural markets is often used to test the efficiency of agricultural markets. Perfectly integrated markets are usually assumed to be efficient. For a detailed discussion on the methodological issues and generally the empirics of horizontal market integration see the excellent review paper of Listorti and Esposti (2012), here we discuss only some basic aspects. Tomek and Robinson (2003) define the two axioms of the international price differences theory, in its simplest way:

- The price difference in any two international markets involved in trade with each other equals the transfer (or transaction) costs.
- The price difference between any two international markets not involved in trade with each other is smaller than the transfer costs.

We consider two spatially different markets, where the price (*P*) of a given good on market 1 in time 't' is P_{1t} and on market 2 in time 't' is P_{2t} respectively. The two markets are considered integrated, if the price on market 1 equals the price on market 2 corrected with transportation and other handling costs, K_t:

$$P_{1t} = P_{2t} + K_t \qquad (1)$$

Trade between the two markets occurs only[3] if $|P_{1t} - P_{2t}| > K_t$. To put it other way, the arbitrage ensures that prices of the same good traded in spatially separate international markets equalize. Empirical literature usually tests the validity of the LOP by considering the following equation, with prices expressed in logarithms:

$$lnP_{1t} = ln\,\beta_0 + \beta_1\, lnP_{2t} + \varepsilon_t \qquad (2)$$

According to the "strong" version of LOP, prices of a given good on the spatially separated international markets are equal, and they move perfectly together in time. Using the coefficients of equation (2), the necessary conditions are $\beta_0 = 0$, and $\beta_1 = 1$. In practice, however, the strong version of LOP occurs only very rarely[4], therefore a "weak" version of LOP was also defined. The weak version of LOP states that only the price ratio is constant, the actual price level is different due to transportation and other handling or transfer costs. Using again the notation of

[3] There are however some examples of existing trade despite negative arbitrage, explained e.g. by the need of keeping trade channels open or maintaining market share.

[4] Throughout the empirical analysis we use the weak version of LOP. Constant free cointegrating relationships are rather restrictive assumption resulting (amongst other issues) to over rejection of $\beta 1 = 1$ nullhipothesis.

equation (2), the necessary restrictions are $\beta_0 \neq 0$ and $\beta_1 = 1$, i.e. 1% price change in market 2 results in a 1% change in market price 1.

2.2 Methodology and empirical strategy

Given the time series nature of milk price data, stationarity and integration properties within well specified Vector Autoregressive models are assessed first, applying the usual unit root tests for logged data and their first difference. Then pairwise Engle and Granger type cointegration tests are run, followed by the estimation of bivariate cointegrating regressions. The (weaker) LOP hypothesis is tested for cointegrating price pairs only, within a Fully Modified OLS (FMOLS) framework developed by Phillips and Hansen (1990), which employs a semiparametric correction to assure unbiasedness and to allow the use of standard Wald and Chi-square tests. Using a 5% significance level we code the result of Chi-square restriction $\beta_1 = 1$ (eq. 2) into a binary variable taking the value 1 if the LOP holds, and 0 otherwise. Throughout the estimations, to account for residual serial correlation, the Akaike criterion is used for lag length selection.

The Maximum Likelihood estimator of parametric discrete-choice models is consistent and asymptotically efficient only if distributional assumptions are valid. A number of semiparametric discrete-choice models were developed (see the paper of De Luca, 2008 for more details on this model class) to overcome estimator inconsistency in the presence of unknown error distributions. In this paper we apply the semiparametric binary choice model of Klein and Spady (1993) and the semi-nonparametric discrete-choice model of Gallant and Nychka (1987).

2.3. Trade network analysis

In the trade network model nodes represent countries; whereas links represent trade relationships. Binary links show the existence of partnerships. A directed graph, or *digraph*, represents directional relations, where links have an origin (exporting country) and a destination (importing country). Although it is possible to add values (weights) to the links representing traded volumes (thus asymmetric relationships can be acknowledged) for the sake of simplicity we regard only binary relationships in this paper, similarly to De Benedictis and Tajoli (2010, 2011), or Garlaschelli, D., and Loffredo (2005). The benefit of this approach is that only the presence of a relationship is regarded, so the results are robust to data reporting inconsistencies and inaccuracies.

Thus, our *digraphs* consist of two sets of information: a set of nodes $N=\{n_1, n_2, \ldots n_k\}$ and a set of links $L=\{l_1, l_2, \ldots l_L\}$. The most local index, degree (D_i) gives the number of nodes connected directly to node *i*. In case of directed networks out-degree ($D_{out,i}$) corresponds to the number of links that originate from node i (Wasserman and Faust, 1994). In case of trade networks out-degree represents the number of trade partners where a given country exports to its products (De Benedictis and Tajoli, 2011). Similarly, in-degree ($D_{in,i}$) gives the number of links terminating at node *i* (thus the number of partners is given where country *i* imports from). Betweenness centrality (BC_i) is a measure, which is very often used in social network analysis (Wasserman and Faust, 1994), and also, in trade analysis (De Benedictis and Tajoli, 2011; Ercsey-Ravasz *et al.*, 2012). It describes the extent to which a node lies on the shortest (geodesic) paths between others (Freeman, 1977), thus it is important in the transmission of flows:

$$BC_i = [2\times\Sigma_{j<k}\, g_{jk}(i)/g_{jk}]/(N-1)(N-2), \qquad (3)$$

where g_{jk} is the proportion of all geodesics linking node *j* and node *k* which pass through node *i*; $i \neq j \neq k$, *N* is the number of nodes in the network. Division in (3) is needed otherwise *BC* would increase with the number of pairs of nodes (network size).

3. Data

3.1. Producer raw milk price data

Monthly cow's raw milk price series from 2000 January until 2014 February were obtained from the European Commission's milk market observatory (http://ec.europa.eu/agriculture/milk-market-observatory/). Raw milk is a homogenous (and thus directly comparable) product that has not gone through any transformation except cooling. Following an initial data consistency analysis country specific prices, in case of 20 out of the possible 27 member states, were included in the analysis, namely (in descending milk production order): Germany, France, United Kingdom, Netherlands, Italy, Poland, Spain, Ireland, Denmark, Belgium, Austria, Sweden, Czech Republic, Finland, Portugal, Hungary, Lithuania, Romania, Slovakia and Latvia, together accounting for 97.9% of EU27 2013 cow's milk production in 2013 (see Figure 1.).

Figure 2 presents the individual country specific milk prices. (Descriptive statistics can be found in the Appendix 1, whilst the joint evolution of time series is depicted in Appendix 2.). Old Member States (OMS) have 170 observations, while New Member States less, ranging between

62 (Romania) and 146 observations (Czech Republic and Hungary). The 2007-2008 spikes followed by the 2012 price increase are clearly visible on graphs; however the inclusion of structural break dummy in test equations did not prove significant or did not alter results.

3.2. Data on determinants of market integration

Gravity model variables such as (logarithm) *distance* between trading partners' capitals, measured in kilometres, *border* dummy variable taking 1 for neighbouring trade partners, *common language* dummy variable and *export* quantity or volume are prime candidates for second stage explanatory variables. The Worldbank's Trade Cost Dataset however offers the bilateral trade costs for agriculture (http://data.worldbank.org/data-catalog/trade-costs-dataset), computed within an Inverse Gravity framework (for details visit the link above). This allows us to directly input presumably more precise bilateral trade costs variables than using distance, border, common language and similar trade cost measures. Besides the Worldbank's trade cost variable (t_{ij}), the following right hand side variables are used in discrete-choice models:

- *lnexport*: is a log of export value between countries in 1000 dollars (source: World Integrated Trade Solution, or WITS, http://wits.worldbank.org);
- *lnexportq*: is a log of export quantity between countries in tonnes (source: WITS);
- *OMS*: dummy, takes value 1 if both countries are old member states and zero otherwise;
- *NMS*: dummy, takes value 1 if both countries are new member states and zero otherwise;
- *NMSOMS*: dummy, takes value 1 if the reporter country is new member state and the partner country is old member states and zero otherwise;
- *Euro*: dummy, takes value 1 if both countries are members of Eurozone and zero otherwise.

We expect negative coefficient for trade cost variable, positive for export quantities and volumes and Euro dummies. The expected coefficient for old/new member state dummies and their interaction term is an open question at this point. In addition, for comparison purposes, a rather simplistic approximation of trade cost, the log distance between trading partners' capitals (*lndist*) is also used.

3.3. Trade network data

For trade network analysis aggregate bilateral export volume data are used for cow's raw milk, as reported by the exporting country in WITS in Harmonised System classification (unprocessed milk: 0408). Data range from 2003 to 2012; the average is used for mapping to describe the whole period. All non-zero values are converted to one, as the focus is on network topology in this paper.

4. Results and discussion

The pairwise cointegration test results are placed in Appendix 3. The large number of unit root tests with varying deterministic specifications is not included in this paper, yet available upon request. In our single equation estimation and testing framework, each country in a price pair is considered as a dependent and then as an independent variable. Thus, using the logarithm of the 20 member state prices depicted in Figure 2, a total of 380 price pairs[5] were tested for cointegration and 135 (35%) proved to be cointegrated. The weak LOP restriction (β_1 = 1) could not be rejected in 63 cases, that is 16.5% of all possible price pairs and 46% of cointegrating price pairs. Next, an *LOP* binary variable is created that contains 63 entries of unity for country pairs where the restriction holds, and 72 entries of zeros totalling 135 observations.

Table 1 presents the output of the semiparametric binary choice (SML) model of Klein and Spady (1993) and the semi-nonparametric discrete-choice model (SNP) of Gallant and Nychka (1987)[6] employing Worldbank's trade cost variable. Results using a simple proxy for trade cost, the log distance are presented in Table 2, estimated by SNP (SML estimations were far less significant). Note, the number of observations in the second stage decreased from 135 to 108, since not all cointegrating price pairs are actually involved in physical trade, thus the log of trade quantity or volume is not defined. With each procedure two models were estimated with export entering the as quantity and volume: M1, M2, M3, M4 (Table 1.) and M5, M6 Table 2.).

Results obtained reinforce each other. Table 2 has more significant variables, but at the cost of approximating bilateral trade costs with distance only. Our primary interest however is not the magnitude, but rather the sign of coefficients. According to our expectations, trade cost (or

[5] k(k-1), where k=20, the member of countries considered in this paper.

[6] SNP and SML procedures are implemented in STATA package, see De Luca (2008).

distance) negatively affects market integration, whilst increasing trade activity boosts integration when export volumes (and to a lesser extent, quantities) are considered.

Country group dummies are less significant than the core explanatory variables; however, when they are, irrespective of model specifications, they prove consistent with respect to the direction of their impact upon LOP. Thus, dummy variables are most significant in models M2, M5 and M6, the positive coefficient on the *euro* dummy emphasises that membership in the Eurozone results more profound milk market integration. With respect to dummy variable coefficients representing member state groups, integration is stronger if both exporter and importer countries are Old Member States (positive coefficient of *OMS*); weaker, if both countries are New Member States (*NMS* negative), posing interesting policy questions with respect of the successful post accession market integration of NSM. The positive coefficient of *NMSOMS* dummy (i.e. the reporting exporter country is a New Member State trading with an Old Member State) suggests stronger integration, perhaps possible to interpret as NMS are following OMS price signals. This seems plausible, since besides orienting towards the core of EU countries, except Poland, (6^{th} largest producer) other New Member States are generally smaller both when production and population is considered. Albeit focusing on the correction coefficient (speed of adjustment) and not on LOP, our results show strong similarities with the findings of Holst and von Cramon-Taubadel (2013) on the European pork market, i.e. faster transmission (stronger integration) between OMS, Eurozone members and if trade-costs are low (proxied by common border in the referred paper). However, some of our results contradict Holst and von Cramon-Taubadel (2013), namely that on milk market NMS perform worse on intra-regional markets compared to inter-regional ones (when one partner is OMS, the other is NMS).

By estimating the LOP restriction to all possible country pairs in the first stage, we implicitly assumed that price information might flow even without physical trade. Traditionally (horizontal) price transmission and market integration is considered trade driven. There is however evidence that error correction between price margins, and thus market equilibrium happens both with and without trade if distinct markets monitor each other's prices. Stephens *et al.* (2012) use tomato prices and actual trade-flow and trade-cost data to estimate a Hansen-type fully flexible error correction model (2003) allowing for separate trade and non-trade regimes. Although the authors expected that during no-trade periods prices are not adjusting towards the long-run equilibrium, empirical analysis proved cointegrated prices and adjustment in both regimes, implying multiple spatial equilibria (with and without actual trade flows). Similar conclusion, i.e. 'physical trade is not a necessary condition for price transmission' was reached by Holst and von Cramon-Taubadel (2013, p. 20.) with respect to horizontal integration of European pork markets. Although from a completely different perspective and methodology, it supports our finding of cointegration, i.e. equilibria for some country pairs not engaged in actual physical trade. More, in this paper we also found a fairly large number of country pairs where the LOP holds, without actual physical trade reinforcing the finding of possible market equilibria and integration with and without physical trade.

A key issue of our paper is the relatively low number of occurrence of pairwise cointegration on the milk market. Whilst Holst and von Cramon-Taubadel (2013) rejected the null of no cointegration[7] in 103 cases of the possible 105 (98%), our analysis resulted in a much lower rejection rate (35%). Does this finding point to lower degree of market integration of milk (defined here at its least restrictive form, co-movement of prices), compared to pork markets? It might as well just be so, when one considers the rather different way raw milk and pork markets are organised in space. Whilst transport of live pigs to slaughterhouses and processor plants from a given region occurs at given (larger) intervals and at lower unit costs, raw milk collection by processors is an (almost) daily business (depending on local cooling facilities) limiting spatially the radius processors can reach. Thus it is likely that prices are formed around milk collecting hubs, not necessarily within national borders. Consequently, national prices (at least within the EU) might not be fully representative for all of the given country's geographic regions. The availability of EU-wide regional prices would almost certainly change results.

Since network analysis is not the primary scope of this paper, below we only present the whole trade network (Figure 3a) and a subset of the network representing most important nodes (for better visibility) for the 2000 – 2012 trade averages (Figure 3b).

To assess whether there is any correlation between perfectly integrated country pairs and their relative position within the network, out-degree, in-degree and Betweenness Centrality measures are calculated for the 20 countries in the sample. Then an indicator for country prices is proposed when the countries enter the LOP equations as independent variables:

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[7] We are aware the referred paper employs a different approach, i.e. system cointegration with one cointegrationg vector versus our single equation approach considering each partner both as dependent and independent variable, yet the difference between frequency of no-cointegration rejection on pork and milk markets is striking.

I = (Number of non-rejection)/[(number of rejection) + (number of non-rejection)] or equivalently:

I= (Number of rejection)/(number the country price cointegrates as independent variable).

As an example, United Kingdom is an explanatory variable in cointegrating regressions in 11 cases, of these its coefficient is not significantly different from one 5 times. Thus I_{UK} = 0.454. The question we ask is whether there is any connection between country specific milk prices as independent variables with a unity coefficient, and the position of the given country within the network described by the network centrality indices (in-degree, out-degree and Betweenness Centrality). The Spearman rho correlation statistics of the centrality measures are presented in Table 3.

The significance of in-degree and Betweenness Centrality measures' correlation is close to 10%. Further conclusions would be too early to draw, yet it seems that the position taken in the trade network might have some influence upon horizontal integration. For example, the more important a country is in terms of flow transmission (the more likely it lies in between two other countries), the more probable that is takes part in cointegration. Also, the more partners a country has to import raw milk from, the more likely that this country cointegrates. It is not clear though why having certain exporting and importing partners result in so different outcomes. Network analysis with respect to trade analysis is a relatively new branch of research, thus further analysis is required to fully understand the exact role that the position in the trade network and its impact on market efficiency as such.

5. Conclusions

In this paper we assessed the horizontal integration of raw milk markets in 20 EU member states accounting for roughly 98% of milk production in the EU for a period covering the past 13 years. Results suggest the cointegration of milk prices is less prominent than that of other agricultural sectors (e.g. pork or cereals). More, the pairwise LOP only holds in 16.5% of all possible cases, raising questions with respect to the efficiency of markets, and perhaps applicability of national price data. Second stage analysis emphasised the positive role trade plays in strengthening market integration, although results (in line with other recent papers) highlighted that physical trade in not a necessary precondition of integration and market equilibria. It appears that OMS and Eurozone member states are better integrated compared to NMS, yet there is some evidence for inter-regional relationships (OMS, NMS) accelerating integration. Finally, the first steps were taken to link price transmission to social network analysis. Albeit only at 12% level of significance, but the experiment shows correlation between the position of a milk market within the network as a whole, and its degree of integration. Whilst clearly more research is needed in this perspective, and surely the use of 12 year export averages to define the trade network is overly restrictive, we believe that there is potential to incorporate network analysis into price transmission studies.

Our paper however comes with a few caveats. First, we analysed the integration of milk markets and their determinants from a long-run perspective, i.e. for a period slightly longer than 13 years. Whilst appropriate for an overall picture and provides a sufficient number of observations, details such as changing pairwise trade patterns or temporary (co)integration of milk markets cannot be accounted for. Based on time series depicted on the Figure in Appendix 2, it is possible that an analysis of sub-periods similar to the work of Holst and von Cramon-Taubadel (2013) might have led to different conclusions (and other issues to handle, such as the arbitrary definition of sub-periods or excluding most NMS from early sub-periods due to lack of data). A further alternative in which we see some potential, is rolling cointegration and subsequent second stage analysis in a dynamic framework (some questions such as the arbitrary window length would however persist). Second, as hinted earlier, we are not convinced that national averages are appropriate for horizontal transmission (integration) analysis in the case of raw milk prices. Yet, to the best of our knowledge, regional price data is not available on sufficient quality and detail.

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Supporting information

Additional Supporting Information may be found in the online version of this paper:

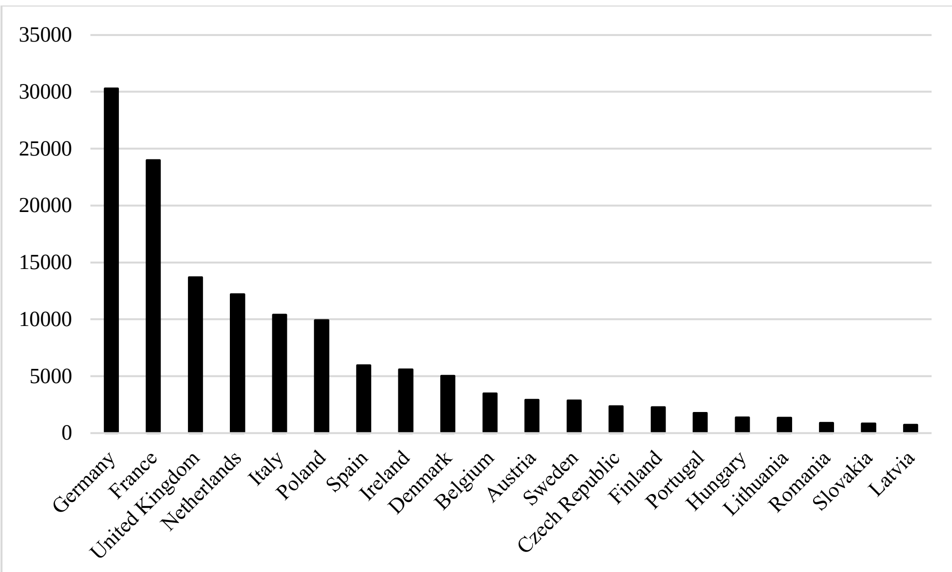
Appendix 1. Descriptive statistics of milk price data.

Appendix 2. Multiple graph of cow's raw milk price series.

Appendix 3. Cointegration (CI) and LOP probabilities

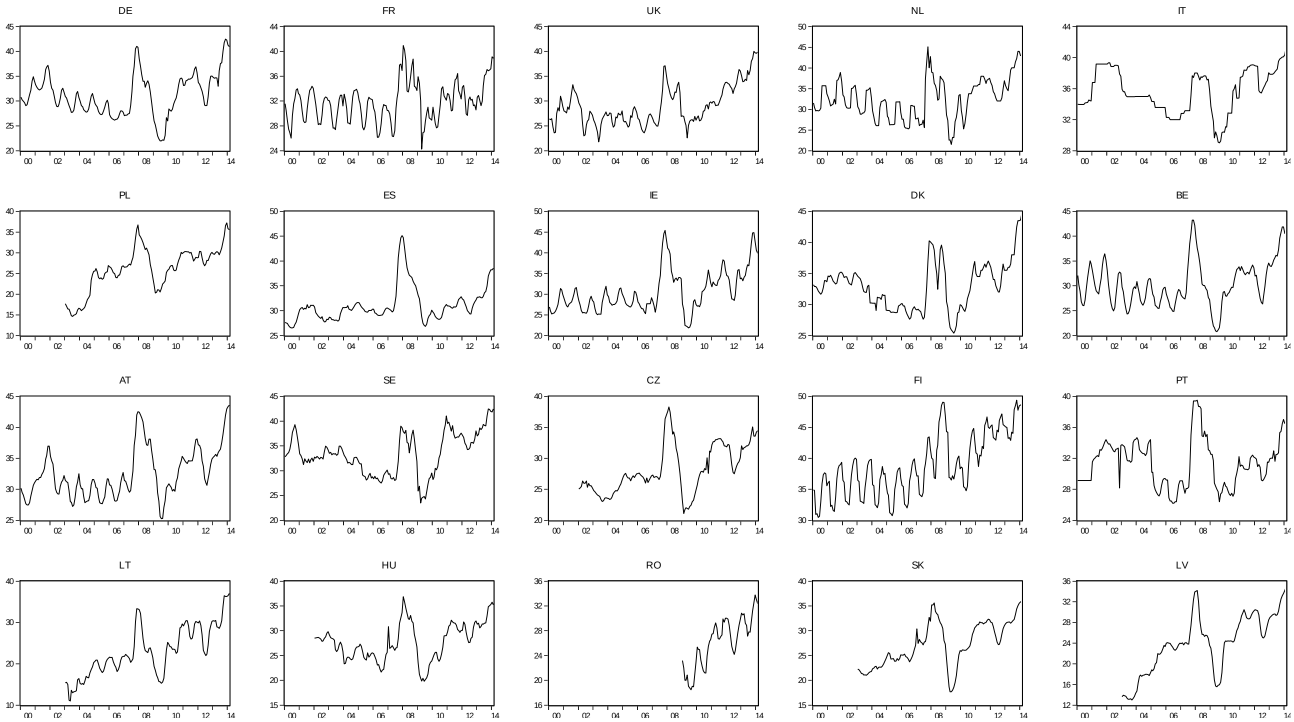
Tables and Figures

Figure 1: Raw milk production in 2013 (1000 tons)



Source: Own calculations, EUROSTAT data.

Figure 2: Raw milk prices in member states (EUR/100kg)



Source: own calculations.

Table 1: Determinants of LOP on the European milk market (trade cost variable)

	SNP		SML	
LOP	M1	M2	M3	M4
t_{ij}	-0.01***	-0.01***	-0.01	-0.01*
lnexport	0.07*		0.11*	
lnexportq		-0.01		0.18
oms	0.85	2.42***	0.82	1.95
nms	-0.68	-0.66	-0.15	-0.27
nmsoms	3.30***	3.31***	1.41**	1.91
euro	0.09	-0.61	1.06	0.70
Log likelihood	-58.93	-59.46	-61.08	-61.00
N	108	108	108	108

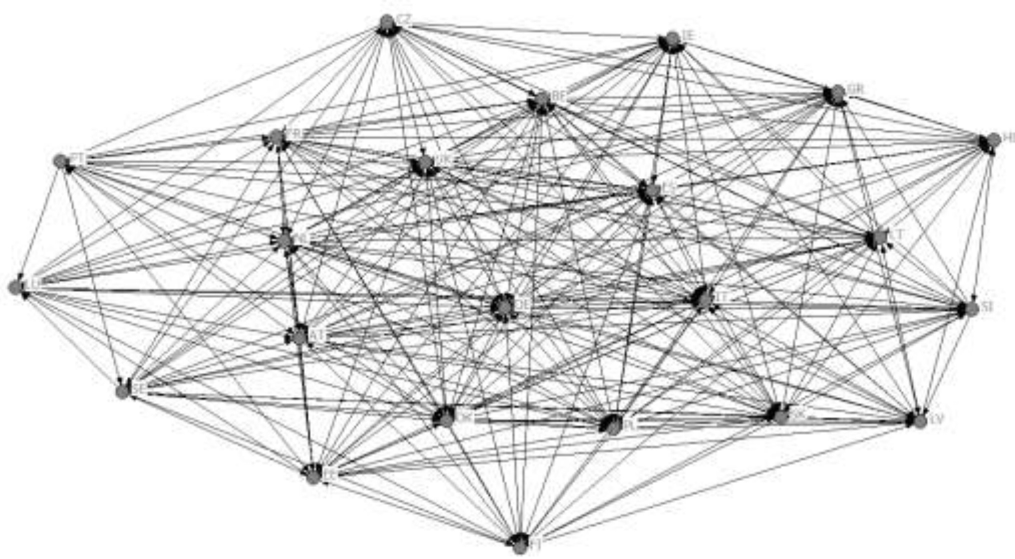
Source: own calculations

Table 2: Determinants of LOP on the European milk market (log distance variable)

	SNP	
LOP	M5	M6
lndist	-0.36***	-0.54***
lnexport	0.18***	
lnexportq		0.15***
oms	0.66	0.73
nms	-0.71	-0.96*
nmsoms	1.69*	1.20**
euro	0.99**	0.91*
Log likelihood	-60.23	-60.04
N	108	108

Source: own calculations

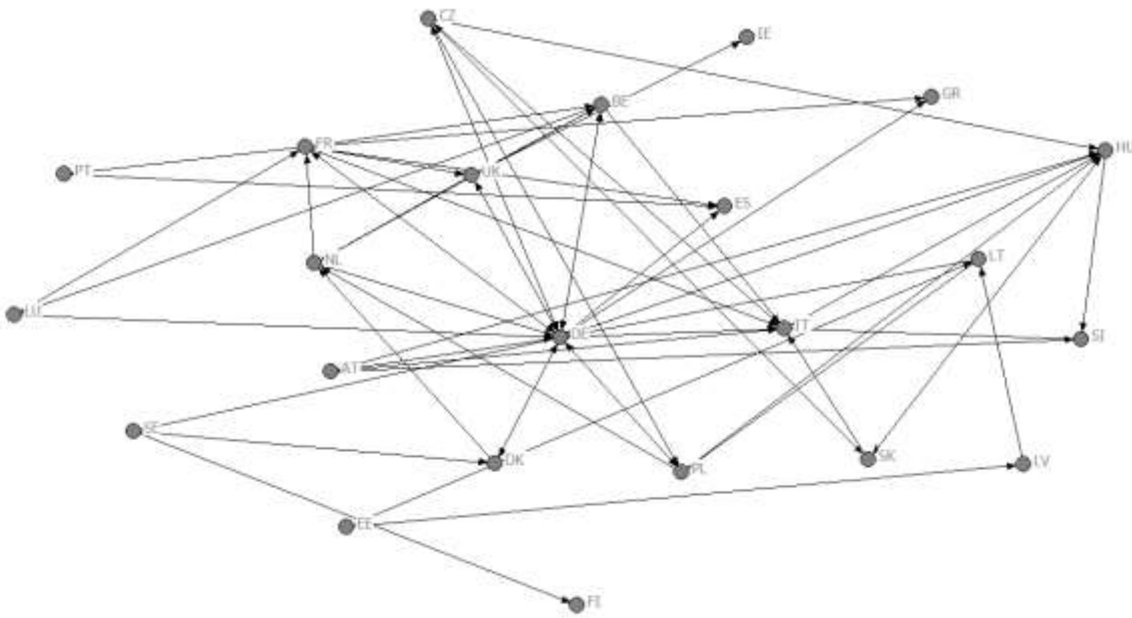
Figure 3a. Raw milk trade network[8]



Source: own calculations, data are derived from Worldbank's WITS database

[8] Ucinet 6.0 software (Borgatti *et al.*, 2002) was used for network analysis.

Figure 3b. Raw milk trade network (detail)



Source: own calculations, data are derived from Worldbank's WITS database

Table 3: Correlation between *I* and network centrality measures

	D_{out}	D_{in}	*BC*
Spearman rho	0.25	0.38	0.38
p value	0.32	0.12	0.13

Source: own calculations

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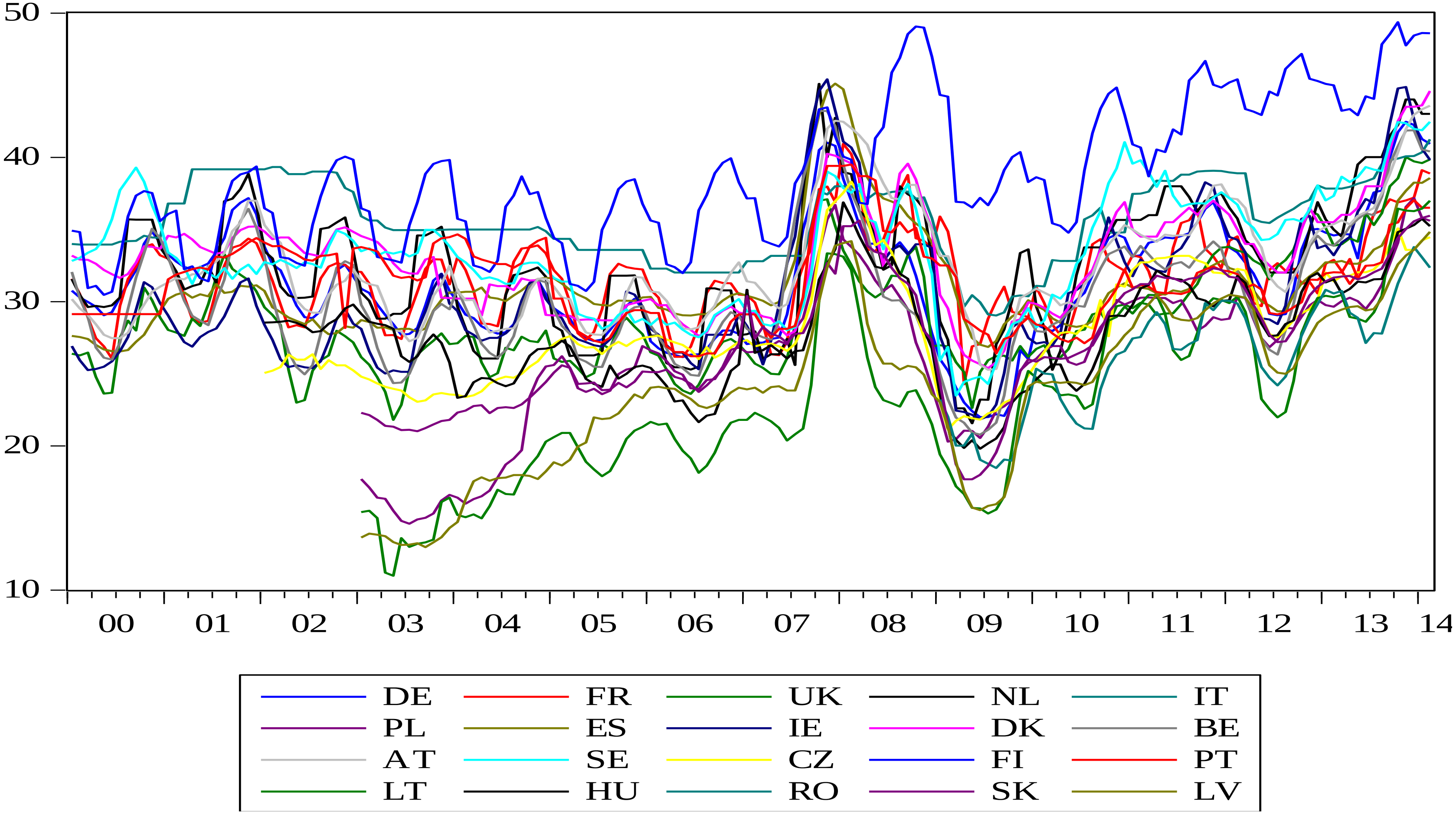
Appendix 1. Descriptive statistics of milk price data (EUR/100kg; data range from 2000 January until 2014 February)

	DE	FR	UK	NL	IT	PL	ES	IE	DK	BE	AT	SE	CZ	FI	PT	LT	HU	RO	SK	LV
Mean	31.27	31.77	28.95	32.54	35.63	26.04	31.12	30.57	32.94	30.35	32.51	33.36	28.13	38.81	31.36	23.04	27.71	26.17	27.17	23.89
Median	30.80	32.05	27.91	32.12	35.14	26.64	30.42	29.23	33.00	29.58	31.51	33.10	27.20	38.28	31.57	22.15	27.69	26.88	27.01	24.12
Maximum	42.46	40.93	40.01	45.09	41.24	37.17	45.10	45.40	44.59	43.20	43.58	42.47	38.30	49.37	39.50	37.00	36.87	33.78	35.95	34.84
Minimum	22.00	24.26	21.79	21.56	29.02	14.60	26.53	21.83	25.38	20.78	25.27	23.48	21.12	30.47	26.20	11.00	19.80	18.46	17.67	12.98
Std. Dev.	4.22	3.10	3.92	4.84	2.79	5.34	3.55	4.97	3.80	4.58	4.02	4.14	3.90	4.94	3.06	6.06	3.77	4.01	4.52	5.70
Skewness	0.33	0.36	0.82	0.19	-0.23	-0.42	1.89	0.98	0.52	0.61	0.81	0.01	0.50	0.34	0.49	0.29	0.10	-0.30	0.01	-0.24
Kurtosis	3.15	3.12	3.12	2.65	2.20	2.73	6.94	3.69	3.28	3.39	3.15	2.47	2.45	2.20	2.90	2.36	2.50	2.18	2.09	2.25
Jarque-Bera	3.30	3.73	19.17	1.86	6.03	4.35	211.64	30.72	8.37	11.66	18.86	1.98	7.95	7.92	6.86	4.19	1.74	2.65	4.66	4.46
Probability	0.19	0.16	0.00	0.39	0.05	0.11	0.00	0.00	0.02	0.00	0.00	0.37	0.02	0.02	0.03	0.12	0.42	0.27	0.10	0.11
No. of obs.	170	170	170	170	170	134	170	170	170	170	170	170	146	170	170	134	146	62	134	134

Source: own calculations

Appendix 2. Multiple graph of cow's raw milk price series (EUR/100 kg)



Source: Own calculations

Appendix 3. Cointegration (CI) and LOP probabilities

Dependent variable	Independent variable	p (no CI)	p (LOP)
AT	BE	0.02	0.02
AT	FI	0.00	0.00
AT	HU	0.01	0.04
AT	IE	0.03	0.01
AT	LT	0.00	0.00
AT	LV	0.02	0.00
AT	PL	0.03	0.00
AT	RO	0.03	0.00
AT	SK	0.00	0.00
AT	UK	0.01	0.00
BE	AT	0.00	0.17
BE	CZ	0.00	0.27
BE	DE	0.00	0.78
BE	DK	0.01	0.22
BE	FI	0.00	0.01
BE	FR	0.01	0.05
BE	HU	0.00	0.26
BE	IT	0.02	0.85
BE	LT	0.06	0.00
BE	LV	0.00	0.00
BE	NL	0.02	0.00
BE	PL	0.04	0.00
BE	UK	0.00	0.07
CZ	AT	0.00	0.16
CZ	BE	0.02	0.20
CZ	FI	0.00	0.00
CZ	IE	0.00	0.03
CZ	LT	0.06	0.00
CZ	LV	0.02	0.00
CZ	PL	0.03	0.00

Dependent variable	Independent variable	p (no CI)	p (LOP)
CZ	SK	0.00	0.00
CZ	UK	0.01	0.00
DE	BE	0.00	0.02
DE	DK	0.00	0.56
DE	FI	0.00	0.02
DE	FR	0.05	0.02
DE	HU	0.00	0.68
DE	IT	0.00	0.01
DE	RO	0.05	0.28
DE	SE	0.00	0.60
DE	SK	0.00	0.06
DE	UK	0.00	0.00
DK	BE	0.01	0.05
DK	DE	0.00	0.01
DK	FI	0.01	0.02
DK	HU	0.01	0.04
DK	IT	0.00	0.31
ES	FI	0.00	0.00
ES	IE	0.03	0.00
FI	IE	0.02	0.89
FI	LT	0.03	0.00
FR	BE	0.02	0.00
FR	FI	0.01	0.00
FR	LT	0.05	0.00
FR	PL	0.05	0.00
HU	BE	0.00	0.18
HU	DE	0.00	0.32
HU	DK	0.01	0.20
HU	FI	0.00	0.01
HU	IT	0.00	0.01
HU	RO	0.00	0.48
HU	SE	0.06	0.51

Dependent variable	Independent variable	p (no CI)	p (LOP)
HU	UK	0.04	0.00
IE	AT	0.03	0.56
IE	CZ	0.00	0.50
IE	DK	0.01	0.54
IE	ES	0.00	0.61
IE	FI	0.00	0.34
IE	HU	0.00	0.96
IE	LT	0.02	0.00
IE	LV	0.04	0.00
IE	RO	0.00	0.39
IE	SE	0.01	0.14
IE	SK	0.04	0.01
IE	UK	0.02	0.26
IT	BE	0.06	0.00
IT	DE	0.01	0.00
IT	DK	0.01	0.01
IT	HU	0.03	0.00
IT	RO	0.01	0.00
LT	AT	0.02	0.00
LT	FI	0.00	0.01
LT	LV	0.00	0.84
LT	NL	0.02	0.07
LT	SE	0.04	0.99
LT	SK	0.05	0.00
LT	UK	0.03	0.00
LV	BE	0.02	0.02
LV	CZ	0.03	0.00
LV	FI	0.01	0.61
LV	LT	0.00	0.65
LV	NL	0.04	0.69
LV	RO	0.05	0.00
LV	SK	0.02	0.00

Dependent variable	Independent variable	p (no CI)	p (LOP)
LV	UK	0.04	0.05
NL	FI	0.01	0.22
NL	RO	0.02	0.10
NL	SE	0.05	0.24
NL	UK	0.02	0.33
PL	FI	0.00	0.94
PL	FR	0.03	0.36
PL	NL	0.01	0.12
PT	DK	0.05	0.09
PT	FI	0.03	0.00
PT	IT	0.05	0.94
PT	LT	0.03	0.00
PT	LV	0.01	0.00
PT	PL	0.01	0.00
PT	SK	0.04	0.00
RO	AT	0.01	0.08
RO	CZ	0.04	0.81
RO	DE	0.04	0.06
RO	DK	0.00	0.20
RO	HU	0.00	0.00
RO	IE	0.00	0.15
RO	IT	0.00	0.00
RO	LV	0.02	0.00
RO	PL	0.04	0.55
RO	SE	0.00	0.21
RO	SK	0.02	0.02
RO	UK	0.04	0.69
SE	AT	0.05	0.03
SE	DE	0.01	0.93
SE	IT	0.03	0.53
SE	NL	0.00	0.00
SE	RO	0.01	0.64

Dependent variable	Independent variable	p (no CI)	p (LOP)
SK	AT	0.00	0.25
SK	CZ	0.00	0.01
SK	DE	0.01	0.97
SK	FI	0.01	0.00
SK	LT	0.04	0.00
SK	LV	0.01	0.00
SK	RO	0.00	0.71
SK	UK	0.02	0.51
UK	FI	0.02	0.35

Note: only price-pairs cointegrating at 5% are shown. Deterministic specification: constant intercept restricted to cointegration space. Null hypothesis 1: no cointegration; null hypotheses 2: LOP holds, respectively.

Source: own calculations.