BENEDEK Zsófia‡, BAKUCS Zoltán‡*1, Jan FAŁKOWSKI2 and FERTŐ Imre‡***3**

Intra-European Union trade of dairy products: insights from network analysis

In this paper, we employ a novel, network analysis based approach to gain new insights with respect to the changes in the structure of intra-European Union (EU) milk product trade between 2001 and 2012. Several network indices are computed to assess the relative importance of the countries from a number of perspectives. The results emphasise that the trade network has become denser, yet its overall centralisation slightly decreased during the period. While the impacts of the 2004 EU enlargement are clearly visible, the effects of the 2008 financial crisis are less evident. Integration of countries that joined the EU in 2004 or 2007 (the so-called New Member States, NMS) is only partial, and depends on the category of milk product considered. Although the number of NMS trade relations increased constantly between 2001 and 2012, the relative importance of most of them did not change. A significant exception is Poland, which became one of the most important exporting countries.

Keywords: EU-27, enlargement, dairy quota, export, weighted trade network, centrality

‡ MTA Közgazdaság- és Regionális Tudományi Kutatóközpont, Közgazdaság-tudományi Intézet, 1112 Budapest, Budaörsi út 45, Hungary. Corresponding author: zoltan.bakucs@krtk.mta.hu
* Budapesti Corvinus Egyetem, Budapest, Hungary.
** Uniwersytet Warszawski, Warszawa, Poland.
*** Kaposvári Egyetem, Kaposvár, Hungary.

Introduction

It is difficult to overestimate the importance of the dairy sector in the European Union (EU). Dairy products are the second most important source of animal protein; the yearly average per capita consumption in the EU is equivalent to approximately 300 kg milk (Westhoek *et al.*, 2011). Further, milk is the EU's number one single product sector in terms of value, accounting for 15 per cent of agricultural output in 2013 according to Eurostat data. In addition, not only are dairy products of many EU Member States competitive on global markets (Bojnec and Fertő, 2014), but the intra-EU milk trade is also very significant (EDA, 2014). In fact, over the period 2001-2012, some 90 per cent of all cow milk produced in Europe was commercialised and consumed within the EU.[4] More importantly however, these trade relations involve rich and complex network patterns. This calls for a network analysis (NA) approach to evaluate and understand the structure and dynamics of international relationships within the EU dairy sector. In this paper, we provide a first step in this wider area. Using NA, we study the dynamics of intra-EU milk trade in the period 2001-2012. By doing so, we are able to analyse the stability of the network across time and assess the extent to which it has been affected by two important events, the EU enlargement in 2004 and the global financial crisis starting in 2008. In particular, we aim to see whether the time series of the international relations exhibit any (rapid) shifts with different structures at the beginning and at the end of the period under study. This will allow us to draw conclusions on how the trading relations and the relative position of EU Member States – reflected in bilateral trade flows – changed over time.

Applications of NA in empirical economic research (e.g. Snyder and Kick, 1979, focusing on World-System/Dependency theories of differential economic growth between countries) or in mapping trade patterns (see, for instance, Nemeth and Smith, 1985 with respect to international relations, or Smith and White, 1992 for a quantitative analysis of trade) date back almost four decades. But it was the recent advances in computing power, empirical econometrics and new network methods that brought NA back into the limelight. Some more recent examples of the possibilities offered by NA include Büttner *et al.*, 2013 (trade network analysis of the pork supply chain in order to assess the spread of infectious diseases between holdings) or the methodological paper by Cranmer *et al.,* 2017 (assessment of NA as a statistical tool, concluding that models rooted in this approach can easily outperform traditional regression based models such as Logit or Probit). As regards economics of trade, Chaney (2014) uses French exporter data to analyse the network structure of international trade, while Arpino *et al*. (2017) apply impact analysis methods to show that neglecting network properties results in "considerably higher estimates of the effect of the GATT[5] on bilateral trade" (p.16). Perhaps more importantly, the authors conclude that a balanced sample based on cofounding variables – required for Propensity Score Matching – cannot be obtained unless network centrality measures are included in the analysis.

By using the NA approach in this particular context, our study contributes to the broader literature that adopts a similar perspective to discuss world trade patterns (e.g. Bhattacharya *et al.*, 2008; De Benedictis and Tajoli, 2011; Fagiolo *et al.*, 2013). Closest to our research is the paper of Gephart and Pace (2015). The authors apply similar techniques but focus on the structure and evolution of the global seafood trade network. Thus, to the best of our knowledge, agricultural commodity trade data, especially in an EU context, has not yet been analysed in this way. The main benefit of this approach is that the behaviour of the whole system (European milk trade) can be regarded (on a quantitative

[1] http://orcid.org/0000-0003-1071-6494
[2] http://orcid.org/0000-0001-6921-6342
[3] http://orcid.org/0000-0002-3742-5964
[4] These calculations use World Integrated Trade Solution data for HS0402 and HS0401 milk taken together. In addition, it is estimated that export outside the EU accounts for about 10 per cent of all cow milk produced in Europe (EDA, 2014).
[5] General Agreement on Tariffs and Trade – the predecessor of the World Trade Organization.

basis), while taking into account potential indirect effects that are usually given much smaller emphasis. The point is, bilateral trade relations are embedded in a broader network of relationships and the structure of this network is likely to affect the outcome of these relations. Thus, the application we propose may complement other empirical analyses of the intra-EU trade usually revolving around bilateral relations.

Methodology

Network analysis

In NA, nodes represent countries and links represent trade relationships. Binary links show the existence of partnerships. A directed graph (digraph) represents directional relations, where links have an origin (exporting country) and a destination (importing country). Furthermore, it is possible to add values (weights) to the links representing traded volumes, thus asymmetric relationships are acknowledged. A *weighted digraph* consists of three sets of information: a set of nodes $N=\{n_1, n_2, \ldots n_k\}$, set of links $L=\{l_1, l_2, \ldots l_L\}$ and set of values (weights) $W=\{w_1, w_2, \ldots w_L\}$. The link from n_i to n_j is not necessarily the same as the link from n_j to n_i (two distinct weights might exist).

Several indices are calculated to quantify the relative importance of the Member States from various perspectives. Some of them are dependent only on the local characteristics of the focal node, while others regard wider network features. The most local index, degree (D_i) gives the number of nodes connected directly to node *i*. For directed networks out-degree ($D_{out,i}$) corresponds to the number of links that originate from node *i* (Wasserman and Faust, 1994). For trade networks, out-degree represents the number of trade partners to which a given country exports 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 from which country *i* imports). However, degree is not a useful measure for weighted networks. There are two ways to give a meaningful generalisation. Firstly, the average of the values of all links connected to a node can be calculated (weighted degree, (D_i^w). Consequently, *weighted out-degree* ($D_{out,i}^w$) gives the average export volume per trade partner, while *weighted in-degree* ($D_{in,i}^w$) represents the average import volume per trade partner (based on Wasserman and Faust, 1994). Secondly, the *strength* of a node (S_i) can be calculated that describes the total volume of annual trade associated with a node (Bhattacharya *et al.*, 2008):

$$S_i = \sum_j w_{ij} \tag{1}$$

Out-strength ($S_{out,i}$) of a node summarises the weights of links that originate from node *i*, thus the overall export from country *i*. Similarly, *in-strength* ($S_{in,i}$) denotes the overall import to country *i*.

Betweenness centrality (BC_i) is used very often in social network analysis (Wasserman and Faust, 1994). It describes the extent to which a node lies on the shortest geodesic (i.e. with the minimum number of edges) paths between other nodes (Freeman, 1977):

$$BC_i = \frac{2 \times \sum_{j<k} g_{jk}(i)/g_{jk}}{(N-1)(N-2)} \tag{2}$$

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 equation 2 is needed, otherwise *BC* would increase with the number of pairs of nodes (network size). However, *BC* is defined for binary graphs, and also the stress on the shortest path in many cases seems to be a too strong assumption. These drawbacks are eliminated by the measure of flow betweenness centrality of Freeman *et al.* (1991):

$$fBC(n_i) = \sum_{j<k}^{p} \sum^{p} m_{jk}(n_i) \tag{3}$$

where m_{jk} is the amount of flow between node *j* and node *k* which passes through node *i* for any maximum flow. fBC_i is the sum of all m_{jk} where $i \neq j \neq k$ are distinct and $j<k$. The flow betweenness is thus the extent to which the maximum flow between all unordered pairs of points depends on node *i*.

Eigenvector centrality (EC_i) is based on the idea that an actor is more central if it is in relation with actors that are themselves central (Ruhnau, 2000). According to Bonacich (1972), the centrality $c(i)$ of node *i* is:

$$\lambda c(i) = \sum_{j=1}^{m} a_{ij} c(j) \tag{4}$$

$a_{ij}=1$ if nodes *i* and *j* are connected; and $a_{ij}=0$ if they are not. Density is a global network index that shows the number of actual links relative to the number of all possibilities that could potentially exist. Density is a useful measure of structural cohesion especially in case of the lack of subgroups. As density corresponds to different level of cohesion in networks of different size (Friedkin, 1981), the measure is meaningful in time series analysis, when network size (the number of nodes) remains constant.

Data

Aggregate bilateral export volume data (expressed in 100 kg), as reported by the exporting country in World Integrated Trade Solution (WITS), are used for two milk product groups. In the Harmonised System classification these are: HS0401: *Milk and cream, not concentrated nor containing added sugar or other sweetening matter*, and HS0402: *Milk and cream, concentrated or containing added sugar or other sweetening matter*, representing around 30 per cent of the (milk product) value traded intra EU. These are the most homogenous milk product categories, roughly be equivalent with raw (unprocessed) and processed fluid milk. The natural logarithms of volume data are used in the calculations. To address system dynamics, data range from 2001 to 2012; hence the effect of EU enlargements (2004 and 2007), 'soft landing' (the start of gradual milk quota removal in 2008) and the financial crisis (starting in 2008) can be considered. WITS data are analysed with Ucinet 6 software (Borgatti *et al.*, 2002).

Results

Figures 1a and 1b depict the intra-EU trade networks of HS0401 milk in 2001 and 2012 respectively, while Figures 1c and 1d display the same for HS0402 milk. The intra-EU trade of HS0401 milk intensified in terms of the number of trading partners per country in the last decade. Especially peripheral (less connected) countries diversified their trading relationships. The comparison of the HS0401 and HS0402 milk sectors reveals that the trade of HS0402 milk was much more intensive between 2001 and 2012 than that of HS0401 milk. This difference is especially remarkable in the beginning of the period. A more detailed analysis of general network indices is discussed below to support these visual observations.

Table 1 details the network structure evolution through the changes of some general network statistics[6] and the average values of the network indices. Although for HS0401 milk the number of trading partners per country increased 1.6 times, the volume traded, showed by S_{out}, increased even

[6] Figures A1 and A2 provide some additional insights.

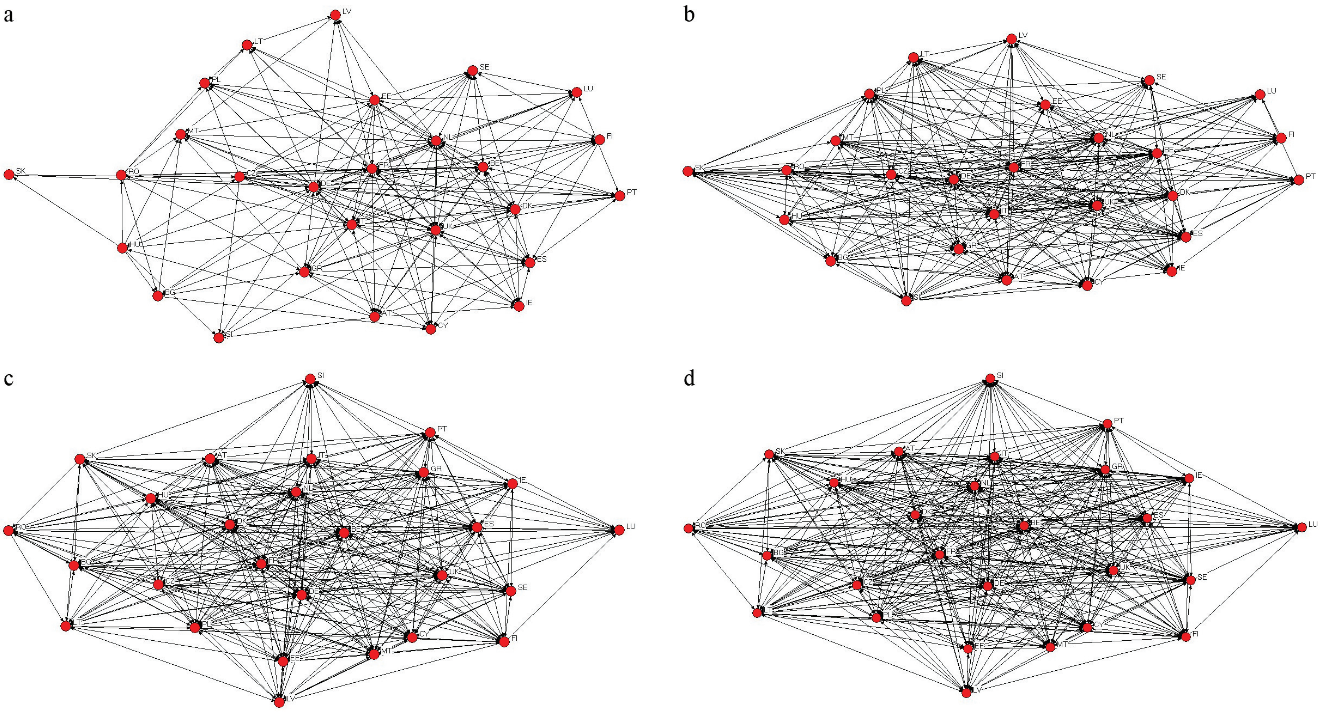

Figure 1: a: The intra-EU trade network of HS0401 milk in 2001; b: The intra-EU trade network of HS0401 milk in 2012; c: The intra-EU trade network of HS0402 milk in 2001; d: The intra-EU trade network of HS0402 milk in 2012. (All EU-27 Member States are included; weights are not shown).

The networks were dHS0401n with netdHS0401, Ucinet (Borgatti *et al.*, 2002)
Source: own compilation

Table 1: Trade network indices over time and their changes between the three-year (or two-year) periods.

	2001	2004	2007	2010	2012	Change				
						2004/2001	2007/2004	2010/2007	2012/2010	2012/2001
HS0401 milk										
No. of countries	27	27	27	27	27	1.00	1.00	1.00	1.00	1.00
No. of links	255	318	342	376	399	1.25	1.08	1.10	1.06	1.565
Density	0.363	0.453	0.487	0.536	0.568	1.25	1.08	1.10	1.06	1.565
D^w_{out} (average)	10.7	11.5	11.8	12	12	1.08	1.02	1.02	1.00	1.128
S_{out} (average)*	103.7	138.1	152.2	171.3	181.9	1.33	1.10	1.13	1.06	1.754
fBC (average)	25.8	23.5	24.6	24.5	24.4	0.91	1.05	1.00	1.00	0.946
EC (average)	0.172	0.181	0.182	0.183	0.185	1.05	1.00	1.01	1.01	1.071
HS0402 milk										
No. of countries	27	27	27	27	27	1.00	1.00	1.00	1.00	1.00
No. of links	484	504	568	574	589	1.04	1.12	1.01	1.02	1.217
Density	0.689	0.718	0.809	0.818	0.839	1.04	1.12	1.01	1.02	1.217
D^w_{out} (average)	12.6	12.7	13	13	13	1.01	1.02	1.00	1.00	1.031
S_{out} (average)*	233.1	262.3	283	288.3	293.7	1.12	1.08	1.02	1.02	1.26
fBC (average)	25.3	25.2	25	24.9	25	0.99	0.99	0.99	1.01	0.99
EC (average)	0.187	0.189	0.189	0.19	0.19	1.01	1.00	1.01	1.00	1.014

Baseline: value in the first year of the period. (All EU-27 Member States included)
*: export, expressed as the natural logarithm of volumes
Source: own calculations

more. This EU-level pattern (also considering the rates of changes) might be explained by the enlargement process (providing a bigger market and more stable economic environment) supplemented by a gradual increase of 1 per cent per year in the milk quotas (initiated in 2008 to prepare a 'soft landing' in 2015 when the quotas expired).

A slight, 5.4 per cent decrease in *fBC* implies a decrease in the extent to which the network has been dominated by key countries. There are further notable changes: (a) the rate of change in the average EC was the highest before 2004, implying that connection to central nodes (important trading countries) was the most intensive before the 2004 enlargement, and (b) the change in the average EC was less than the change in density over the 2001-2012 period. In other words, the relative advantage (as an increase in the relative importance) that can be gained by connecting to a well-connected partner decreased.

However, a closer look at flow betweenness centrality – depicting separately the pre-2004 EU Member States (the so-called EU-15) and those that joined the EU in 2004 or 2007 (the so-called New Member States, NMS) – (Figures 2a and 2b), reveals that the decreasing differences of importance may be attributed to the decreasing importance of Germany among the EU-15. With the exclusion of Germany, it becomes clear that the other EU-15 Member States increased their importance (2.5 per cent of increase in *fBC*, compared to the 3.2 per cent decrease on average, when only NMS are studied).

In a similar fashion, Figure 3 depicting the ranks of EC emphasises the integration of NMS into the trade network. This is especially evident for HS0401 milk (Figure 3a), where all NMS except Estonia greatly increased their EC values between 2001 and 2012, emphasising an intensive relationship with the core (most prominently Slovakia, Slovenia, Lithuania and certainly Poland). Furthermore, according to the 2012 ranking of EC, a number of NMS rank higher (better integrated) than EU-15 Member States.

While for HS0401 milk changes were the greatest during the pre-enlargement period (2001-2004, see Table 1), the pattern is not that clear when HS0402 milk is considered: the number of partners (and consequently, density) changed the most between 2004 and 2007 (but not later). For the other measures the pattern resembles that of HS0401 milk. Owing to the originally more intensive relationships and higher volumes traded, changes were less pronounced for HS0402 milk than they were for HS0401 milk. In this case, the increase in the average out-strength (overall exports) goes together with the increasing number of partners (comparatively, the change in the export volume of HS0401 milk greatly exceeded the change in the number of partners).

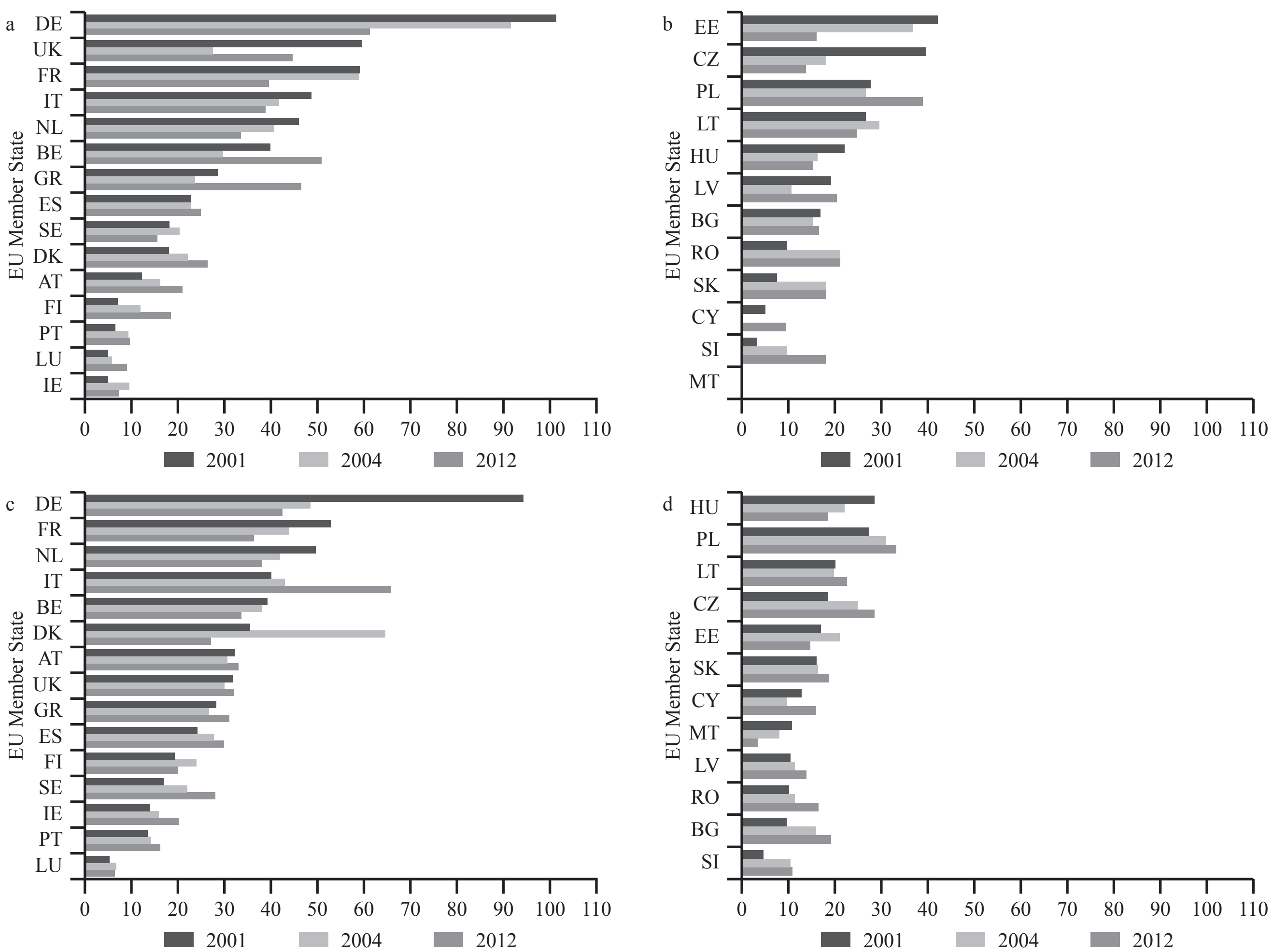

Figure 2: Flow betweenness centrality (a) EU-15 for HS0401 milk; (b) NMS for HS0401 milk; (c) EU-15 for HS0402 milk; (d) NMS for HS0402 milk.

Source: own calculations

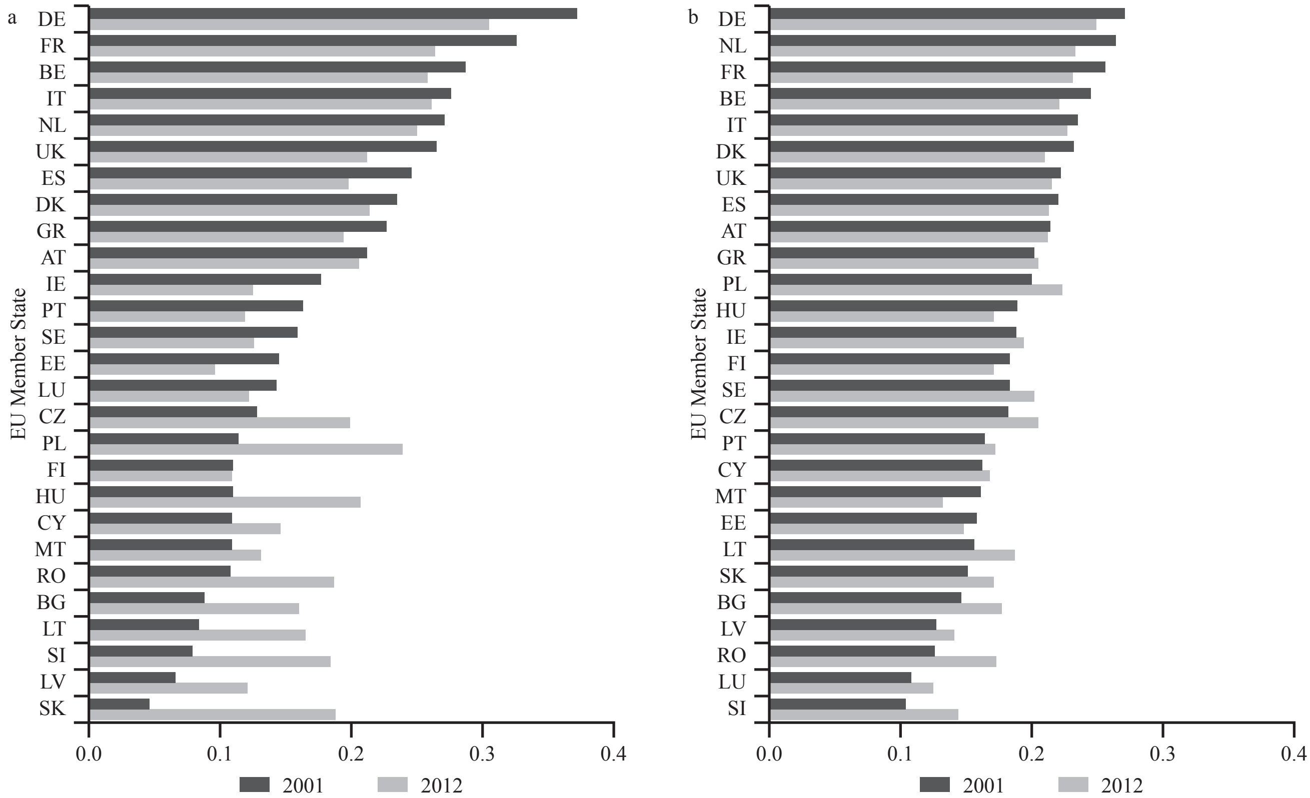

Figure 3: Ranks of Eigenvector Centrality. High *EC* shows intensive relationship with central nodes. a: HS0401 milk, b: HS0402 milk.
Source: own calculations

The performance (integration) of the NMS seems to be more complete for HS0402 milk. Figures 2c and 2d show the evolution of the *fBC* measure for the EU-15 and NMS respectively. Again, the decrease in the average *fBC* can be attributed mostly to the pattern observed for Germany. Its exclusion shows that the increase of *fBC* among the rest of the EU-15 Member States was 3.7 per cent on average, compared to the 16 per cent increase among the NMS. Thus, the trade network of HS0402 milk became less centralised in this period.

Some more general findings can also be drawn. The most important exporting countries of both HS0401 and HS0402 milk are Germany and France, in 2001 and also in 2012 (Figures A1-A2). For most indices (both product groups) the difference between the average index values of the EU-15 and NMS decreased in the studied period, which implies integration; though country ranks (relative importance) varied only to a minor extent. The exception seems to be the position of Poland which evolved to be the best performing NMS by 2012.

Discussion

In summary, milk trade intensified, especially for HS0401 milk. Differences in the average performance of the EU-15 and NMS decreased; though the relative importance of the countries did not change remarkably (with the exception of Poland). Centralisation of the dairy trade network at the EU level slightly decreased. Integration seems to be more complete for HS0402 milk; in the other product group the seeming decrease in differences can be attributed to the decline in the importance of Germany. In general, over the period 2001-2012, the 2004 enlargement caused bigger changes in the trade network structure than the financial crisis. Our results seem to indicate the following: denser connections between the EU-15 and NMS can be observed, as indicated by trends in *EC* for both groups of countries. Interestingly, this process is more clearly visible for transactions in HS0401 milk. This in turn is consistent with observations suggesting increasing internationalisation of the European dairy supply chain. We can conclude that the integration of NMS into the intra-European milk trade network was a successful process. The question with respect to the distribution of rents within these input-output linkages remains however an open one.

Indeed, while the centrality of NMS in the dairy trade network generally improved over the years, it is not that certain that it helped them to increase their share in the total value added. Note that the increase in unprocessed milk trade that we document is consistent with a growing process of international disintegration of production processes characterised by a noticeable expansion in input trade (Antras, 2016). It could be argued therefore that the changes in trade patterns which we observe result from the fact that countries vertically specialise in various stages of the production processes. In this context one may wonder whether NMS have started to specialise in producing raw materials (processed further abroad) which are typically associated with a relatively small value added. While this issue seems to be of high policy relevance it is relatively unexplored in the existing literature.

The picture emerging from this paper also suggests several other interesting directions for future research. Firstly, it may provide the reference for analysing the evolution of trade patterns in dairy sector following the milk quota removal. Given our focus, it is useful to note that the propagation of shocks (including those triggered by policy reforms) through trade networks might be an important driver of macroeconomic fluctuations. In this context, investigating to which extent the distribution of costs and benefits resulting from milk quota removal do or do not depend on the structure of the European milk trade network is an interesting (future) research topic. In other words, one may ask to what extent the overall impact of quota removal in a given country will be dependent on the outcomes observed in its trading partners. A further interesting research direction is to investigate factors responsible for network formation, e.g. whether exporting to/importing from a country *a* increases the chances of also trading with country *b* if countries *a* and *b* trade with each other, all else being equal.

A related and equally important question for our understanding of economics of trade is what specific mechanism is likely to transmit this impact. Does the evolution of trade networks follow the patterns of international workflow migration or is it rather an outcome of the presence of multinationals? Both these factors have been identified as exerting strong impacts on international trade. The EU enlargements that we cover in our analysis were marked by a sharp increase in migrant flows from NMS to the EU-15 as well as by huge investments made by EU-15-based companies in both the dairy sector and supermarkets in NMS. The relative importance of these and other factors in affecting the evolution of trade networks seems to be a fruitful area for future investigation.

Acknowledgments

Authors gratefully acknowledge support from the Hungarian Academy of Sciences and Polish Academy of Sciences through the bilateral research contract No. 2007414, entitled *Agrár-élelmiszeripari lánc meghatározó tényezői*.

References

Antras, P. (2016): Global Production: Firms, Contracts, and Trade Structure. Princeton NJ: Princeton University Press.

Arpino, B., De Benedictis, L. and Mattei, A. (2017): Implementing Propensity Score Matching with Network Data: The effect of GATT on bilateral trade. Journal of the Royal Statistical Society Series C **66** (3), 537–554. https://doi.org/10.1111/rssc.12173

Bhattacharya, K., Mukherjee, G., Saramäki, J., Kaski, K. and Manna, S.S. (2008): The international trade network: weighted network analysis and modelling. Journal of Statistical Mechanics: Theory and Experiment **2008**, P02002. https://doi.org/10.1088/1742-5468/2008/02/p02002

Bojnec, Š. and Fertő, I. (2014): Export competitiveness of dairy products on global markets: The case of the European Union countries. Journal of Dairy Science **97** (10), 6151-6163. https://doi.org/10.3168/jds.2013-7711

Bonacich, P. (1972): Factoring and weighting approaches to status scores and clique identification. The Journal of Mathematical Sociology **2** (1), 113-120. https://doi.org/10.1080/0022250X.1972.9989806

Borgatti, S.P., Everett, M.G. and Freeman, L.C. (2002): Ucinet for Windows: Software for social network analysis.

Büttner, K., Krieter, J., Traulsen, A. and Traulsen, I. (2013): Static network analysis of a pork supply chain in Northern Germany – Characterisation of the potential spread of infectious diseases via animal movements, Preventive Veterinary Medicine **110** (3-4), 418-428. https://doi.org/10.1016/j.prevetmed.2013.01.008

Chaney, T. (2014): The network structure of international trade. The American Economic Review **104** (11), 3600-3634. https://doi.org/10.1257/aer.104.11.3600

Cranmer, S.J., Leifeld, P., McClurg, S.D. and Rolfe, M. (2017): Navigating the Range of Statistical Tools for Inferential Network Analysis. American Journal of Political Science **61** (1), 237-251. https://doi.org/10.1111/ajps.12263

De Benedictis, L. and Tajoli, L. (2011): The world trade network. World Economy **34** (8), 1417-1454. https://doi.org/10.1111/j.1467-9701.2011.01360.x

EDA (2014): Economic Report 2014. Brussel: European Dairy Association.

Fagiolo, G., Squartini, T. and Garlaschelli, D. (2013): Null models of economic networks: the case of the world trade web. Journal of Economic Interaction and Coordination **8** (1), 75-107. https://doi.org/10.1007/s11403-012-0104-7

Freeman, L.C. (1977): A set of measures of centrality based up on betweenness. Sociometry **40**, 35-41. https://doi.org/10.2307/3033543

Freeman, L.C., Borgatti, S.P. and White, D.R. (1991): Centrality in valued graphs: A measure of betweenness based on network flow. Social Networks **13** (2), 141-154. https://doi.org/10.1016/0378-8733(91)90017-N

Friedkin, N.E. (1981): The development of structure in random networks: an analysis of the effects of increasing network density on five measures of structure. Social Networks **3** (1), 41-52. https://doi.org/10.1016/0378-8733(81)90004-6

Gephart, J.A. and Pace, M.L. (2015): Structure and evolution of the global seafood trade network, Environmental Research Letters **10**, 125014. https://doi.org/10.1088/1748-9326/10/12/125014

Nemeth, R.J. and Smith, D.A. (1985): International trade and world-system structure: A multiple network analysis. Review (Fernand Braudel Center) **8** (4), 517-560.

Ruhnau, B. (2000): Eigenvector-centrality – a node-centrality? Social Networks **22** (4), 357-365. https://doi.org/10.1016/S0378-8733(00)00031-9

Smith, D.A. and White, D.R. (1992): Structure and dynamics of the global economy: Network analysis of international trade 1965-1980. Social Forces **70** (4), 857-893. https://doi.org/10.2307/2580193

Snyder, D. and Kick, E.L. (1979): Structural position in the world system and economic growth, 1955-1970: A multiple-network analysis of transnational interactions. American Journal of Sociology **84** (5), 1096-1126. https://doi.org/10.1086/226902

Wasserman, S. and Faust, K. (1994): Social network analysis: Methods and applications. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511815478

Westhoek, H., Rood, G., Van den Berg, M., Janse, J., Nijdam, D., Reudink, M. and Stehfest, E. (2011): The Protein Puzzle: The consumption and production of meat, dairy and fish in the European Union. European Journal of Food Research & Review **1** (3), 124-144.

Annex

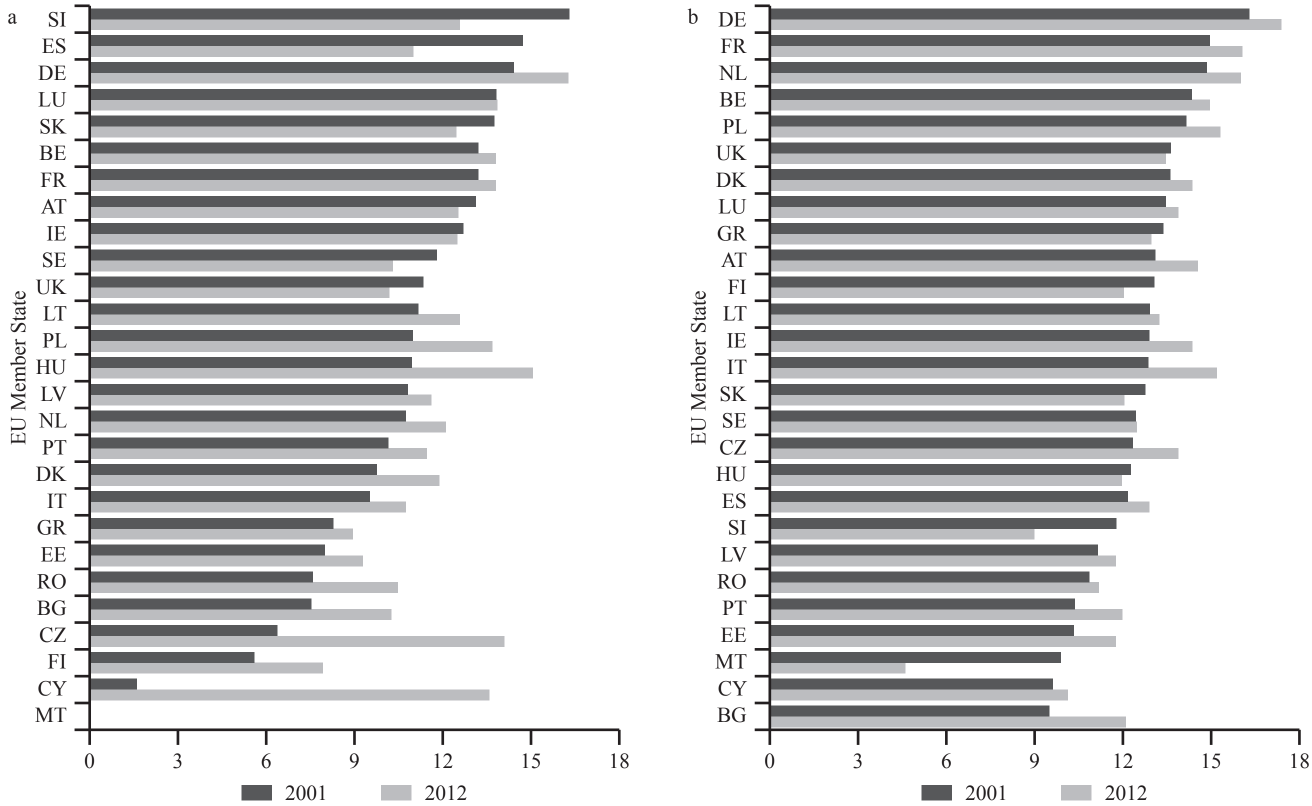

Figure A1: Ranks of weighted out-degree (the average export volume per partner). a: HS0401 milk, b: HS0402 milk.

Source: own calculations

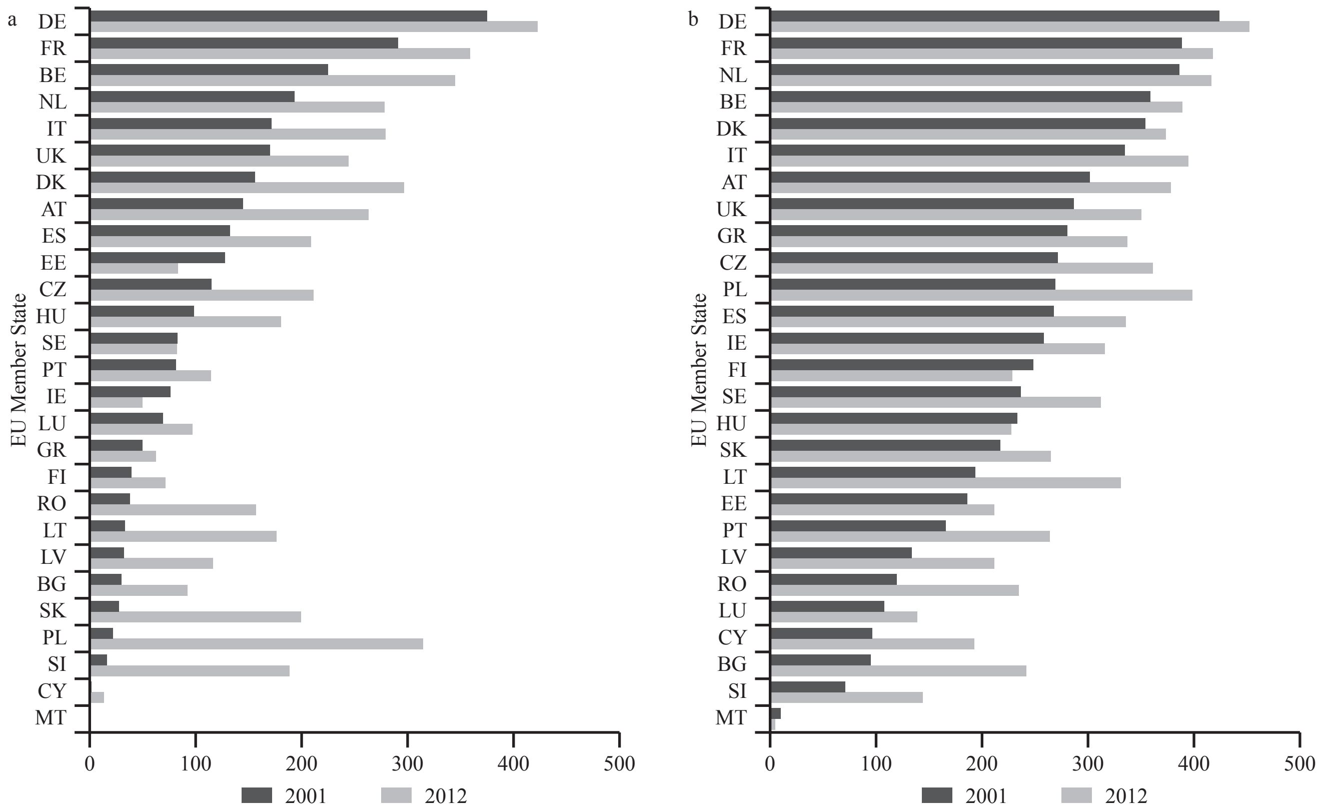

Figure A2: Ranks of out-strength (overall export volume). a: HS0401 milk, b: HS0402 milk.

Source: own calculations