THE STRUCTURE OF THE UE INSURANCE MARKETS' CONNECTIONS NETWORK AFTER THE 2004 ENLARGEMENT IN THE CONTEXT OF SYSTEMIC RISK

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Abstract: *The enlargement of the European Union to new countries in 2004 launched mechanisms supporting the development of various social and economic areas as well as leveling the differences between the Community members in these areas. In the paper we focus on the insurance sector. Our main purpose is to analyze the structure of the network of connections between the insurance markets of old and new members of the European Union in the context of systemic risk (SR) after 2004. At the beginning we will briefly discuss the general problem of SR in the insurance sector in the context of macro-prudential policy. Then we will propose a new way to construct minimum spanning trees (MST. By examining selected MST topological indicators, we will analyze the interrelationships between countries through linkages between insurance companies, and thus the paths of transmission of possible financial problems that could spread. In particular, we will trace the place and role of the new enlargement countries in 2004 in MST.*

Key words: *systemic risk, insurance sector, minimum spanning trees, topological network indicators,*
JEL codes: *G01, G22, C10*

1. Introduction

In 2004 The European Union consisting of 15 countries such as[1] Austria (AT), Belgium (BE), Denmark (DK), Finland (FI), France (FR), Greece (GR), Spain (ES), the Netherlands (NL), Ireland (IE), Luxembourg (LU), Germany (DE), Portugal (PT) , Sweden (SE), Great Britain (UK) and Italy (IT) also referred to as the "Old Union" (Old EU) has been expanded to include countries Cyprus (CY), the Czech Republic (CZ), Estonia (EE), Lithuania[2] (LT), Latvia (LV), Malta (MT), Poland (PL), Slovakia (SK), Slovenia (SI) and Hungary (HU) (New EU). Then Bulgaria (BG), Romania (RO) and Croatia (HR) joined the EU. The United Kingdom is no longer a member of the Union from February 1st 2020. We want to answer the questions: what kind of connections exist between the members that can be inferred from the multivariate analysis of basic statistical data? What does the dynamics of interlinkages in the insurance sector look like over the past 15 years in the context of generating and spreading systemic risk (SR) in Europe?

We examine the dynamics of the structure of the network of linkages between insurance markets using the following selected topological network indicators: *Average Path Length* (APL), *Maximum Degree* (MaxDeg), *Parameters α of the vertices' degree distribution following asymptotically a power law*, *Diameter*, *Rich Club Coefficient* (RCC) and *Assortativity* which we obtain based on the determined Minimum Spanning Trees (MST) for each year studied. We construct MST based on the new measure of closeness between each pair of countries which is described by a function depending on the Mahalanobis distance, which takes into account the number of insurance companies, the market concentration indicator, gross and net premiums written, total assets, the insurance density ratio, the insurance penetration ratio, the life and non-life insurance share of the total insurance market.

The linkages in the insurance market depend not only on factors resulting from the principles and manner of its functioning. Economic and social conditions also have an impact on its structure. In each country, features such as the level of economic development of the country, the wealth of households, or the amount of insurance premiums collected are quite different. In addition, public awareness and insurance tradition is very important. By considering all these factors for European countries, we can obtain a very large set of information on the overall insurance structure in the EU.

[1] In the figures we use the abbreviations from the parentheses.
[2] Due to a lack of data, Lithuania has not been taken into account in the study.

The calculation is based on statistical data published by the European Insurance and Occupational Pensions Authority (EIOPA), the Schweizerische Rückversicherungs-Gesellschaft (Swiss Re) and the European Statistical Office (Eurostat). All calculations were made in the R program. The analytical part consists in analyzing the interlinkages between European Union countries in the context of SR in the insurance sector. While tracking SR we pay attention to specific periods on the timeline. The year 2005 is the first full year of membership of Poland and other 9 countries: Cyprus, the Czech Republic, Estonia, Lithuania, Latvia, Malta, Slovakia, Slovenia and Hungary in the European Union. Due to a lack of available data Lithuania had to be left out from the analysis. The year 2009 is a period of "struggle" against the effects of the global economic crisis that began in mid-2007. 2015 is the year in which EIOPA (2017) observed in several issues of its Financial Stability Reports the increasing penetration of unit and index-linked product in the market and warned on the potential implications for policy policy holders. In addition the European Systemic Risk Board notes such a shift of market risk to policyholders may cause issues for consumers, given that they are in a lesser position to manage and absorb market risk compared with large insurance agreement (ESRB, 2015). In addition, it is the last year in which Solvency II applies. In turn, 2018 provides the most current data for all variables used in the analysis.

The novelty of the present article consists in the combination of the development analysis of the insurance markets with the use of the usual global indicators to construct Minimum Spanning Trees in a new way. To do this we introduce a new closeness function using the Mahalonobis distance.

2. Systemic Risk in the insurance sector

In this section, we will briefly discuss the general problem of SR in the insurance sector in the context of macro-prudential policy. Some local insurance markets have already been included in the universal safety net of the entire European Union financial market as a result of imposing financial management rules on insurance companies, introducing regulations on capital requirements of entities operating on the market, introducing common principles of public and internal supervision, conducting strict procedures for the provision of financial services, extension of consumer safety guarantee. The European Banking Authority, the European Insurance and Occupational Pensions Authority (EIOPA), the European Securities and Markets Authority supervise the Union's financial security. The main goal of EIOPA is to ensure the implementation of legislation in the insurance sector so that financial stability is maintained, as well as an adequate protection of consumers of financial services. Financial crises have shown that Systemic Risk (SR) is one of the most important issues in a globalized economy. Financial market analysts, scientists and politicians have finally started a broad debate on how to identify SR, and on macro-prudential policy. For natural reasons, the insurance sector until the AIG crisis in 2008 was considered to be non-generating SR. However, as it turns out during in-depth research, this sector can also potentially create or increase systemic risk.

According to the IMF (2016), the insurance contribution to systemic risk increased as a result of increased joint exposures of the sector and the rest of the economy. It remains, however, below the banks' contribution. The goal of academic research is to search for good predictive methods that support macro-prudential supervision. A key requirement for effective regulation and supervision is the authority's ability to collect and analyze insurance market data. Collected data should, according to IAIS, IMF, NAIC provide the opportunity to assess insurance activity and risk based on indicators in the categories of profitability and income generation, adequacy of capital / provisions and leverage, liquidity, underwriting performance and risks, investment performance, risks and reinsurance performance and risks. In the paper *Analytical tools for the insurance market and macro-prudential surveillance*, the authors of Kwon and Wolfrom discuss analytical tools used by supervisory authorities for market and macro-prudential purposes in 24 OECD countries and outside OECD. The indicators described assess the insurance sector among other in the context of validity, competition, scope of activity and insurance market risk and SR. In the paper (Kwon & Wolfrom, 2016) they presented information on monitoring indicators related to interconnections and changes in asset allocation. These are two areas that can potentially create SR. The level of interconnectedness in the insurance sector and between the insurance sector and other parts of the financial system indicates the potential for stress in the insurance sector transferred to other parts of the financial system. Significant changes in the allocation of assets throughout the insurance sector may be a signal of increased risk taking. OECD describes how in 24 selected countries are subjected to Insurance Market Risk analysis with periodic reviews of market risk, key indicators of market risk, indicators related to interconnectedness, indicators related to changes in asset allocation and indicators used in stress testing. Therefore, a common analytical tool used in many countries is to perform periodic reviews of specific types of risk for the functioning of insurance markets. In Europe, insurance regulators also contribute to financial stability by publishing reports prepared by EIOPA every two years. European Insurance and Occupational Pensions Authority (2017) is a document that initiated the publication of a series of documents on systemic risk in the insurance sector. By supporting macro-prudential policy in insurance, it contributes to the debate on the specific nature of insurance activity in the context of SR. This document aims to identify and analyze SR sources in the insurance sector.

International Association of Insurance Supervisors (IAIS) whose mission is to promote effective and globally consistent supervision of the insurance industry in order to develop and maintain fair, safe and stable insurance markets for the benefit and protection of policyholders and to contribute to global financial stability, brings together insurance supervision authorities from over 130 countries and a number of international entities (including OECD, World Bank, International Monetary Fund). In July 2013, nine insurance institutions were identified as *Global systemically important insurers* (G-SIIs) Allianz SE, AIG, Assicurazioni Generali, Aviva, Axa S.A., MetLife, Ping An Insurance Company of China, Prudential Financial, Inc., Prudential plc. – institutions of particular importance for global financial stability, which due to their size, market power and a wide range of global connections, in the event of bankruptcy (or financial problems) may result in a significant disruption of the global financial system and negative global economic consequences. Criteria for determining systemically important insurance institutions (EIOPA, 2017) are Size 5%, Global activity 5%, Interconnectedness 40%, Asset liquidation 45%, Substitutability 5%. Given that one of the largest weights is assigned to Interconnectedness, we use MST indicators and networks between countries to analyze the possibilities of generating and spreading SR.

3. Construction of Minimum Spanning Trees (MST)

We propose a new way of constructing MST. Based on the data, we determine eight basic global measures of insurance sector markets Gross Written Premium - Life Insurance, Gross Written Premium – P&C Insurance, Gross Written Premium - Health Insurance, Total assets, Investment portfolio on domestic market – Total, Market share of the top 5 insurance groups – Life, Market share of the top 5 insurance groups - P&C, Number of companies on total market.

For fixed eight-dimensional vectors describing a given country, we consider the Mahalanobis distance, which is the distance between two points in a multidimensional space that differentiates the contribution of individual component coordinates of points and uses the correlations between them. It is defined as $d_m(x,y) = \sqrt{(x-y)^T C^{-1}(x-y)}$, where $x = [x_1, \dots, x_n], y = [y_1, \dots, y_n]$ are vectors from $\mathbb{R}^n$ and C is a symmetric, positive definite matrix. This distance is commonly called the Euclidean weighted distance, where C^{-1} is the weight matrix.

Next we determine the weights for the MST using a closeness function of the form $f(x,y) = 2(1 - \frac{d}{1+d})$, where $d = d_m(x,y)$ is the Mahalanobis distance. Further, using the Kruskal's algorithm we construct MST for each year from the analyzed period 2004-2018.

4. Topological indicators MST

In this part we examine selected MST topological indicators. We will analyze the interlinkages between countries through relationships between insurance companies, and thus the paths of transmission of possible financial problems that could spread. We will focus on the following indicators, there were used in Denkowska & Wanat (2020):

- *Average Path Length* – APL. This indicator is defined as the average number of steps along the shortest paths for all possible pairs of network nodes. It measures the effectiveness of information flow or mass transport in a given network. APL is one of the strongest measures of network topology, along with its grouping factor and degree distribution. It distinguishes an easy-to-go network from a more complex and inefficient one. The smaller the average path length, the easier the flow of information. Of course, we are talking about average, so the network itself can have several very distant nodes and many adjacent nodes.
- *Maximum Degree*- MaxDeg. This is the number of edges connected to a given vertex so that loops count double. If Maximum Degree is growing, it means that in the group of insurers some insurer has many more connections with others. In a situation of shock in such a vertex, the risk of spreading its effects increases.
- *Parameter α of the vertex degree distribution required to follow a power law*. This indicator measures the scale-free behavior of a network. The network is called scale-free if the distribution $P(s)$ of the number of links between the vertices follows a power law, i.e. it has (asymptotically) the form $P(s) = C \cdot s^{-\alpha}$, $\alpha > 0$, where α is a parameter specific to the given network. The power law followed by the degree distribution gives the network a kind of fractal self-similarity properties, which explains the name. A scale-free network is characterized by a small number of vertices having a large number of connections (such nodes are called hubs) and many vertices that have only one connection. Such a network is "favorable" to the propagation of systemic risk, and the companies-hubs that it has are systemically relevant. If the MSTs are scale-free, with the alpha value being closer to 2, it means that the MST structure is star-shaped, the hubs are high degree nodes.

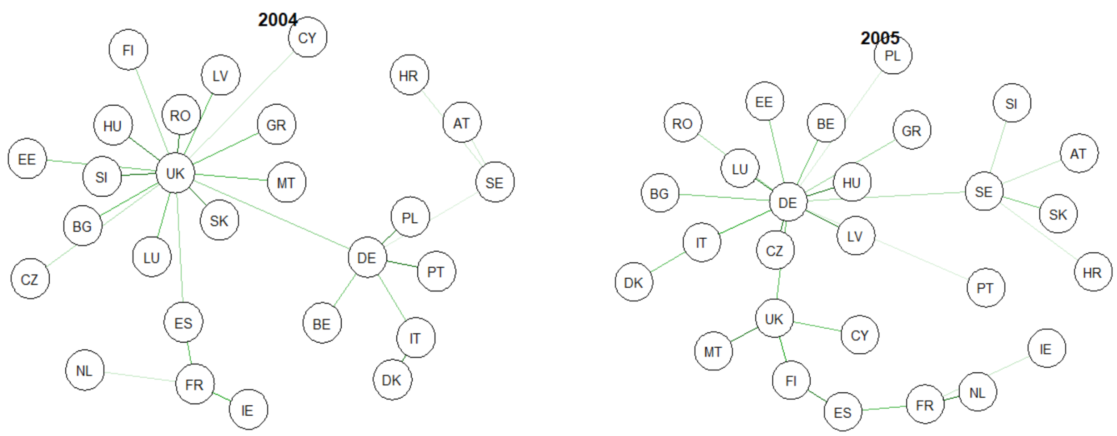
- *Diameter of the network* (Li, 2018). It is determined by choosing from among all the shortest paths connecting any pair vertices the longest one. For MST, this is simply the longest path in the MST. When Diameter decreases, it means that the farther lying nodes become closer.
- *Rich Club Coefficient* – RCC (Colizza et al., 2006; Li et al., 2018). The idea is that well-connected vertices connect also one with another. The RCC is defined to be $\phi(k) = \frac{2E_{>k}}{N_{>k}(N_{>k}-1)}$, where $\frac{N_{>k}\,(N_{>k}-1)}{2}$ is the number of all the possible paths between $N_{>k}$ vertices, $E_{>k}$ is the number of vertices of $N_{>k}$ nodes having degree $>k$. The effect of a rich club reduces system stability, which means that if RCC increases, then a perturbation can be more easily transmitted through the network. If the MST structure becomes more starlike and compact, which is accompanied by a stronger effect of a rich club, it is less resistant to shocks and more susceptible to infecting and transferring the effects of collapses on the financial market.
- *Assortativity* is a graphic measure. It shows to what extent nodes in the network associate one to another by similarity or opposition (positive or negative mating). Basically, the network's assortativity is determined for the degree (number of direct neighbors) of nodes in the network. Assortativity is expressed as a scalar $-1 \leq \rho \leq 1$. The network is said to be assortative when high-degree nodes are mostly connected to other high-degree nodes while low-degree nodes are mostly connected to other low-degree nodes. The network is said to be non-assortatative when high-degree nodes are connected mostly to low-degree nodes and low-degree nodes are mostly connected to high-degree nodes. Assortativity provides information on the structure of the network, but also on its dynamic behavior and robustness. The original definition of assortativity (Newman, 2002) for unweighted, undirected networks is based on the correlation between random variables. A negative Assortativity means that in each state the tree is rather non-assortative, i.e. the vertices tend to merge rather on a less similar basis: those that have a high degree with those that have few connections. This is usually associated with the previously described property of a scale-free network.

5. MST empirical results

In this section we will trace in particular the place and role in MST of the new countries from the UE enlargement in 2004. Below we present the MST for each period along with selected groups of countries. In each group we find countries with similar characteristics.

In 2004 MST (Fig.1) is slightly stretched, MaxDeg is 15, the biggest role in the context of SR is played by UK and then DE. All the new EU members apart from Poland are globally similar to the UK; in the MST we see them connected to the UK. Poland is connected to Germany.

Fig.1 MST 2004, 2005

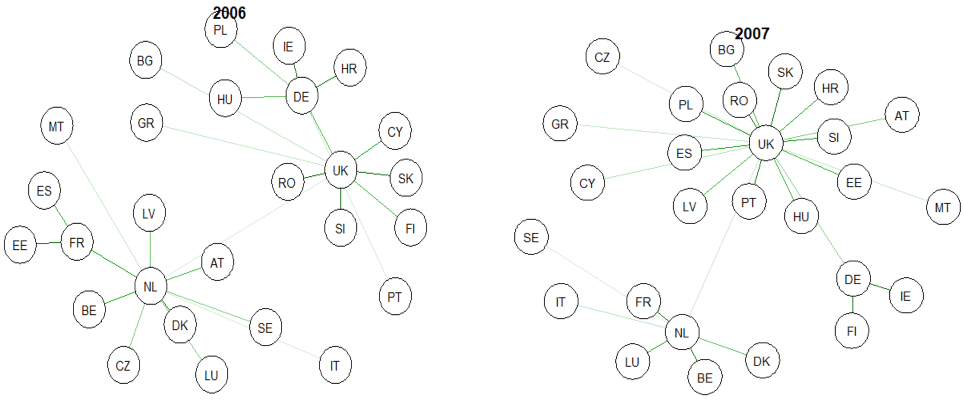


Source: Own calculations.

In 2005 (Fig.1) the roles of UK and DE change, one replaces the other. The MST structure shows that the insurance markets of most newly admitted countries are falling into the DE insurance market. In terms of SR, MST changes its character into more chainlike than starlike. This structure is safer when it comes to propagating financial turmoil causing SR.

In 2006 (Fig.2), a new dominant country (a new hub) appears: NL, whose degree is 11, as for the UK. Nevertheless, the UK has a more important position due to the connection with DE, which has several connected countries. The tree is typically scale-free. It has three hubs and many vertices with single connections. In 2007 (Fig.2), the tree is shrinking. UK still dominates.

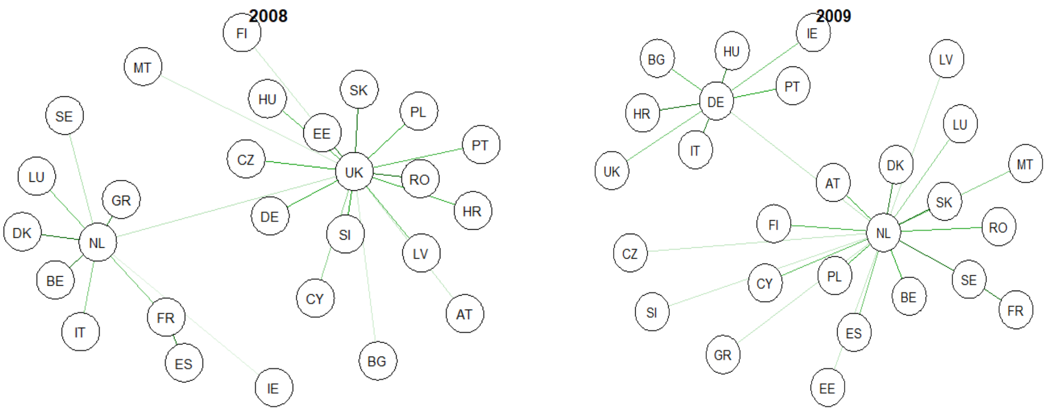
Fig. 2 MST 2006 and 2007



Source: Own calculations.

In 2008 (Fig.3) the tree was already very shrunken. UK still dominates. However, during 2009, i.e. in the middle of the crisis, the UK is losing strength and is at the end of the MST having only one connection. As we know, the growth of the UK economy had been based on credit rather than production for many previous years. Economic growth was fueled by financial services related to the real estate market and retail sales. When in 2009 real estate prices had fallen sharply and loan costs had increased, the insurance sector responded to this crisis. The UK market became similar to HR, BG, HU, IE, PT, IT and UK changed places with DE that is now the new centre of the hub, while Netherlands took the role of the dominant on the insurance market with a degree equal to 19. APL is very much falling (see Fig.9). The MST (Fig.3) is starlike.

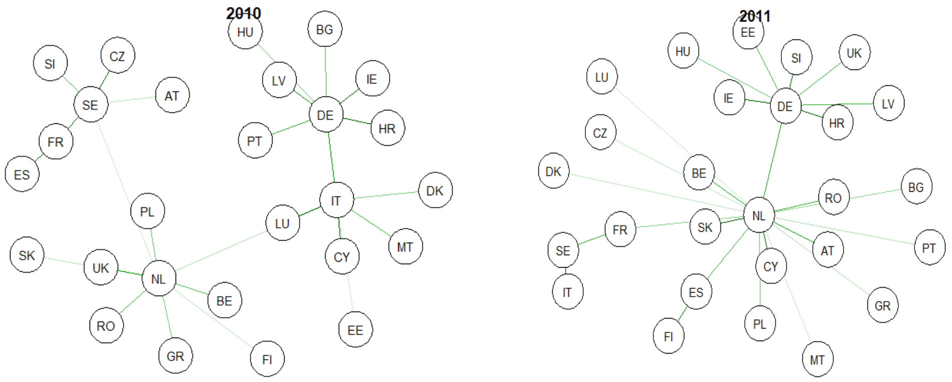
Fig. 3 MST 2008 and 2009



Source: Own calculations.

After the crisis (Fig.4), MST is diastolic. Markets are varied. There are not two, as a year earlier, but four relatively even groups.

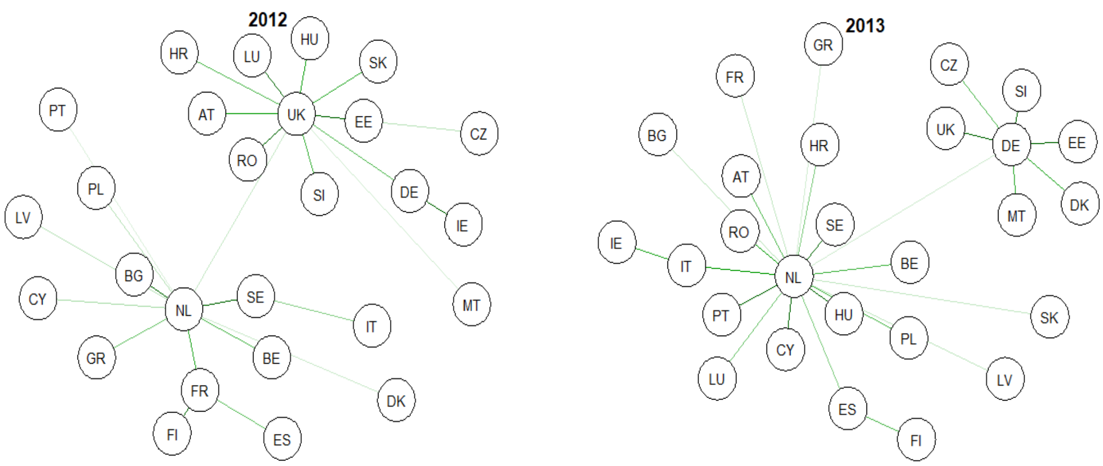
Fig. 4 MST 2010 and 2011



Source: Own calculations.

However, in 2011 (Fig.4), when we have a crisis of excessive public debt in the euro area, MST is shrinking again. UK is not regaining its position. NL dominates. In 2012 (Fig.5), the UK regains its strength and again becomes dominant on the insurance market. However, we are observing the crisis in DK, where the first waves of immigration begin. The DE market is becoming more and more like the IT market.

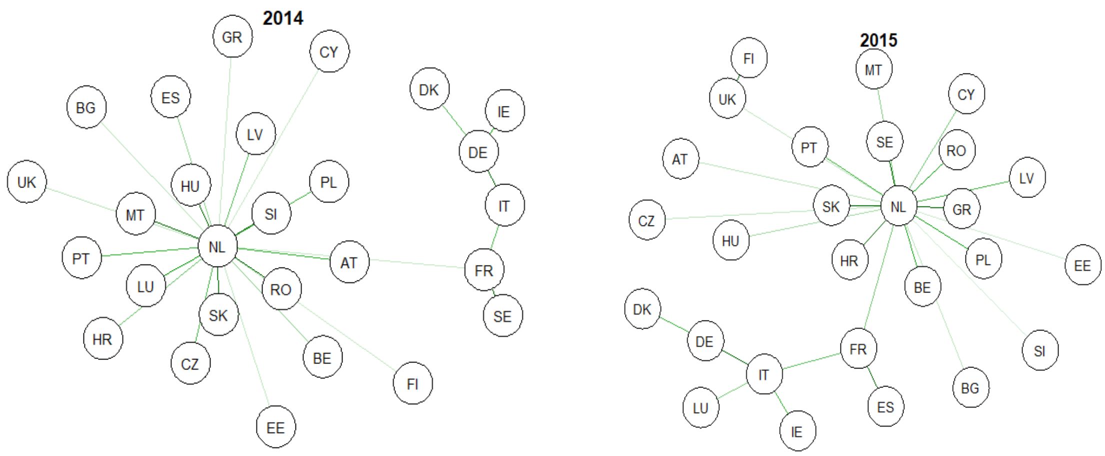
Fig. 5 MST 2012 and 2013



Source: Own calculations.

MST in 2014 and 2015 (Fig.6) is starting to change its structure. NL still dominates, DE and IT are clearly disconnected along with FR, SE, which have increasing problems with immigrants.

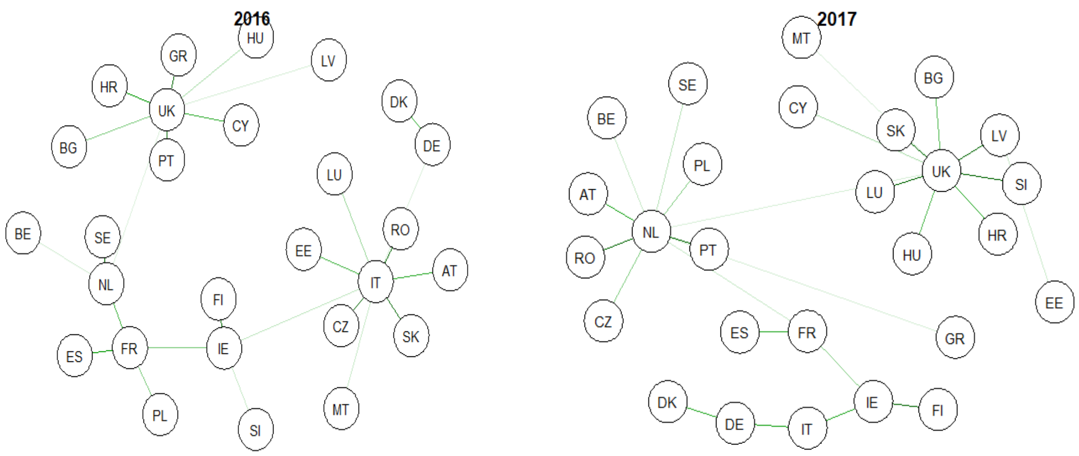
Fig. 6 MST 2014 and 2015



Source: Own calculations.

In 2016 and 2017 (Fig.7) we are coming back to some stabilization on the insurance market in Europe and differentiation of markets. The tree has very large APL and low MaxDeg.

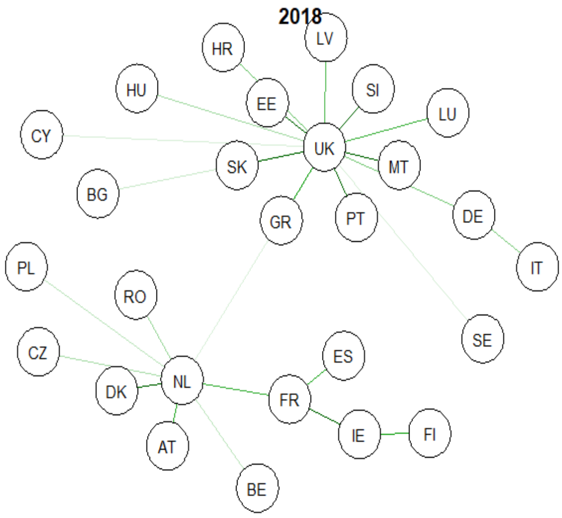
Fig. 7 MST 2016 and 2017



Source: Own calculations.

In 2018 MST (Fig.8) is again becoming a double star. Markets are divided into two groups. The dominants are UK and NL.

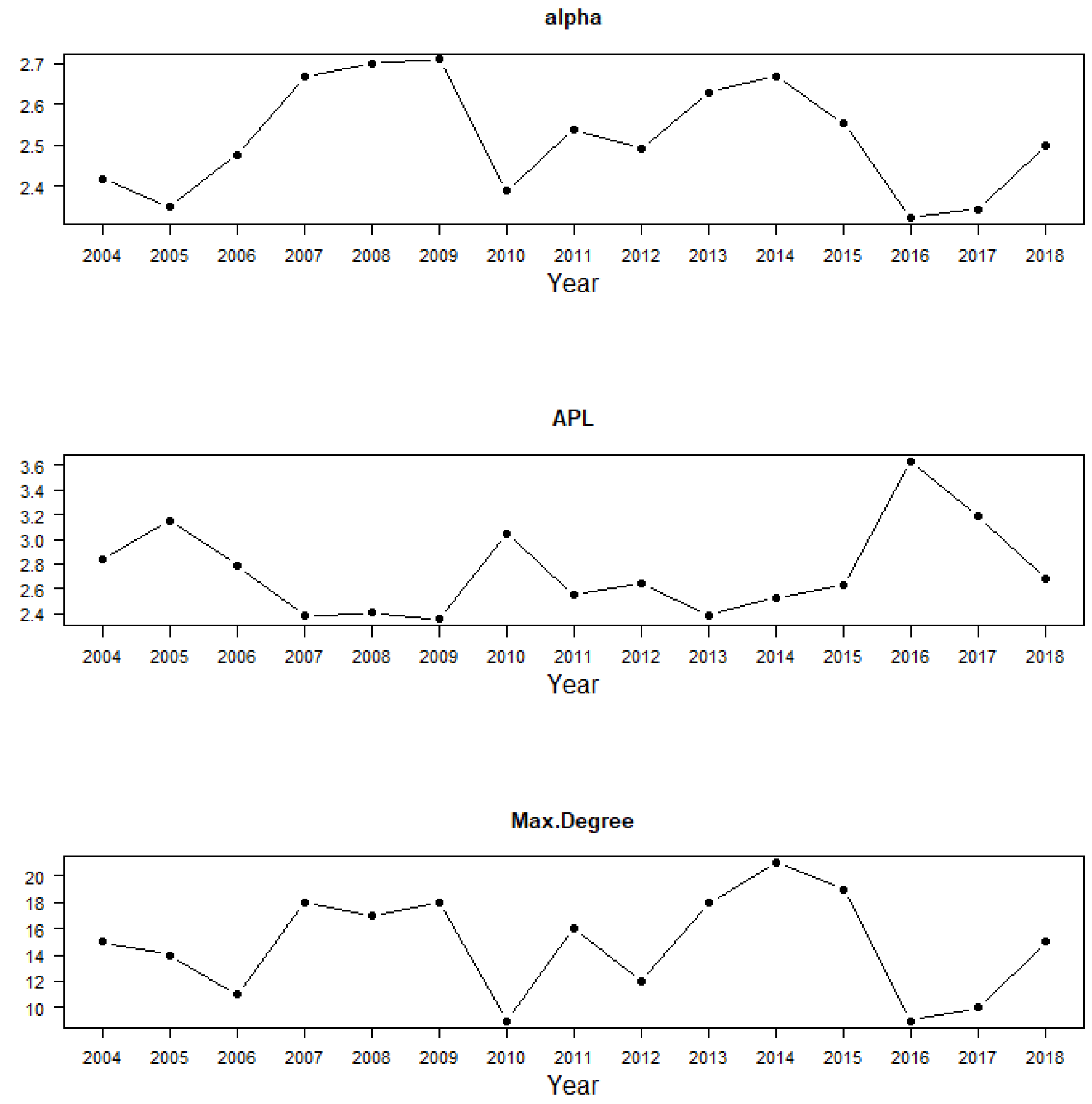
Fig. 8 MST 2018



Source: Own calculations.

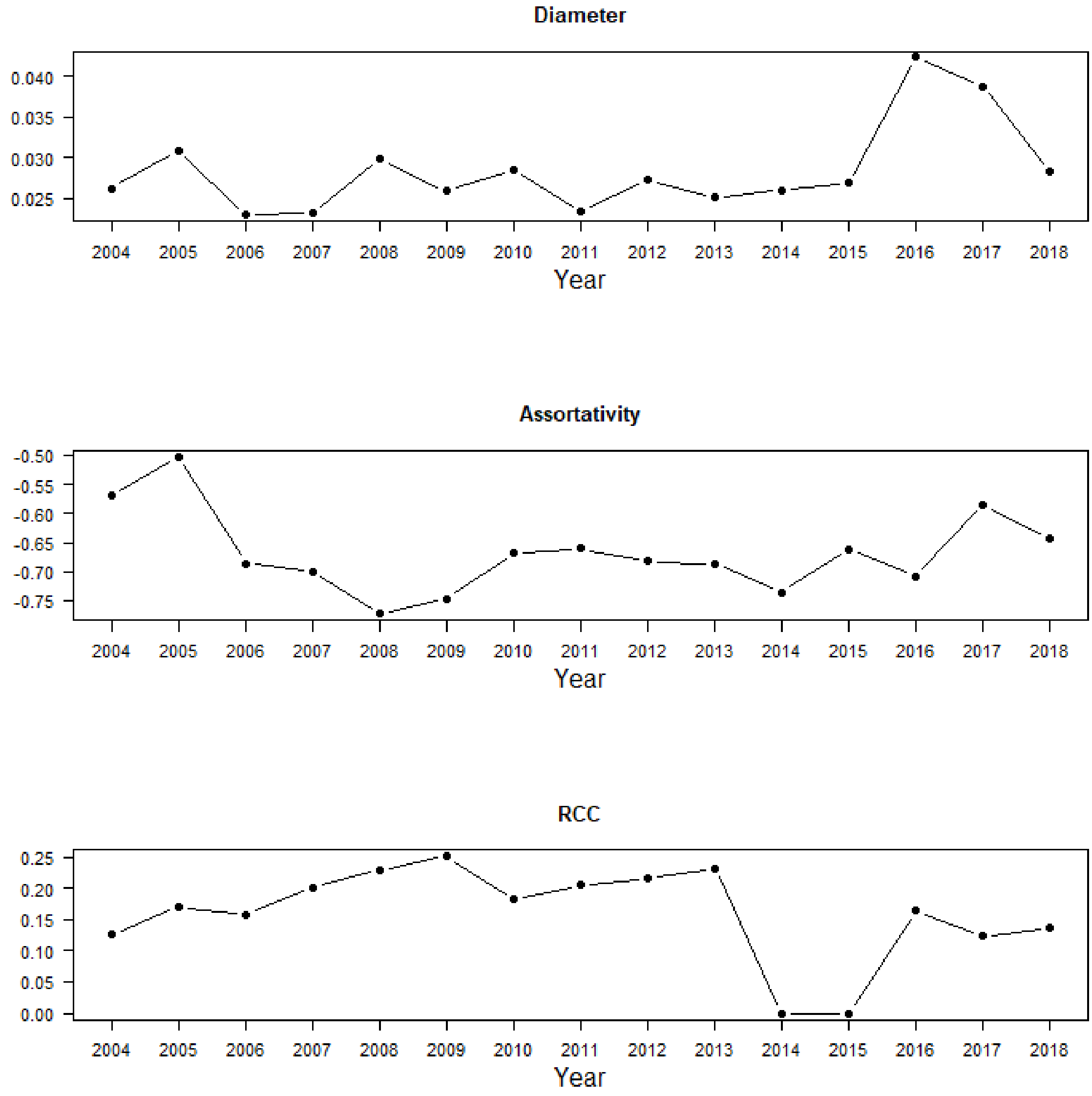
Below are the empirical results of the analysis of MST topological indicators. Figure below (Fig. 9, Fig. 10) show the alpha graph, the APL graph, the MaxDeg graph, the Diameter graph, the Assortativity graph, and the RCC.

Fig. 9 Topological indicators MST: alpha, APL, Max. Deg in years 2004-2018



Source: Own calculations.

Fig. 10 Topological indicators MST: Diameter, Assortativity, RCC in years 2004-2018



Source: Own calculations.

6. Conclusions from the MST analysis in the context of SR

The above charts show that crises were felt globally in the insurance sector. MST is scale-free because alpha belongs to the range (2,3). In 2007, 2008 and 2009, i.e. before and during the subprime crisis, APL decreases, MaxDeg increases, which promotes the propagation of SR. A similar situation occurs in the years 2011-2014, during the crisis related to excessive public debt. The diameter has only slight deviations, except in 2016 and 2017, which is illustrated by the MST chainlike structure. The assortativity is negative, i.e. the vertices are connected on the principle of a large difference in terms of connections. This is perfectly reflected by the MST. The countries with numerous connections (hubs) are linked with countries that have only individual, single connections. It is most visible in 2008 in the star-like structure of MST. RCC for k=3 is relatively high. Only in 2014 and 2015 we observe low values of this measure. In these years, MSTs have a significantly different structure. Countries with a large number of connections are not connected to a country with equally numerous connections. The most important countries are NL and UK – the latter is dominant in many periods, and due to the specificity of the country's economy, during the 2009 subprime crisis it suffers a defeat being moved to the periphery of the MST.

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