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Cognitive modeling of reinsurance flows on the global reinsurance market

Abstract

The article studies one of the areas of the world globalization processes – formation, interaction and regulation of financial flows of world reinsurers. Mathematical formalization of the relationships of countries' reinsurance flows is proposed to be built on the basis of cognitive maps and correlation analysis. Identification of relevant areas of global reinsurers' development is conducted on the basis of indicators of consonances of mutual influence, interaction and centralization.

Keywords: reinsurance activity, global reinsurance market, cognitive maps, nonlinear programming of consonances of mutual influence, interaction between concepts, centralization of interaction.

JEL Classification: G22.

Introduction

Convergent processes on the financial market, interpenetration of segments of the financial system and transnational character of reinsurance activity cause significant problems for the research and regulation of reinsurance under conditions of formation of the national economy (Kuzmenko, O., 2014; Pahnenko, O., 2012). The importance of a comprehensive study of reinsurance flows on the global capital market is also caused by the active use of insurance and reinsurance operations for the legalization of money obtained by criminal means as well as its withdrawal from circulation and its transfer abroad (Boyko, A., Roienko, V., 2014). Interaction of national reinsurance companies internationally necessitates the development of new methodological instruments for the research of reinsurance flows at the meso-level. The studies of the past years were focused on determining the financial flows of insurance companies only on the micro level (Kozmenko, O., Kuzmenko, O., 2011; Boyko, A., 2010).

In the last decade international reinsurance market was characterized by high levels of capitalization, moderate growth of tariff rates and significant profitability. These patterns in the development of the global reinsurance market led to the growth of competition on it and constant search for new markets (Standard & Poor's, 2012).

At the same time, the problems that reinsurance market players face are associated with significant losses from disasters around the world, unstable investment markets, new software for disaster modeling and increasing demands of regulatory

authorities. Investment income in 2011-2014, which contributed to the profitability of reinsurance companies, declined as interest rates and profitability reached the lowest level.

A significant risk for further progressive development of the international reinsurance market is the stagnation of developing countries' economies, ongoing macroeconomic instability and cyclical financial crises. As a result, international reinsurers are withdrawing from the markets of former Soviet countries and reducing their activities in Eastern Europe.

The described developments make it necessary for international reinsurers to transform themselves, to adapt to the new conditions or to consolidate.

In these conditions it is important to regulate the world reinsurance market on the basis of unification of national systems of state regulation. But the principles declared in Solvency II as well as the IAIS requirements do not solve these problems leaving the supremacy of national requirements to reinsurance activities in such countries as China, Brazil, India and the US, where regulatory requirements limit the ability of international reinsurers to compete with local entities (Standard & Poor's, 2013).

Therefore, the current trends in the development of the international reinsurance market require the search of new instruments to monitor the activities of its members. The research of relationships between not only insurance (reinsurance) companies with cedents of other countries, but between reinsurance companies of non-residents among themselves. Thus, the wish of state authorities to integrate into the global economic and financial environment in general and within the framework of reinsurance activities requires adequate identification of the nature of relationships between cedents and retrocedents – the level of priority of

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reinsurance operations for insurance companies and formation of strategic plans for further development of the world reinsurance market. That is why it is important to model reinsurance flows through the use of cognitive maps that will make it possible (using market-based levers of influence on reinsurance market) to ensure its stable development, while maintaining optimal redistribution of risks at international level and to improve the reliability of reinsurance operations.

Considering the current level of world science it is proposed to carry out the modeling of dynamic systems applying cognitive maps and calculating consonances of mutual influence between concepts (countries), the interaction between concepts and the indicator of interaction centralization (Aguilar, J., 2002; Axelrod, R., 1976; Kosko, B., 1986; Avdeyeva, Z., Kovryha, S., Makarenko, D., Maksymov, V., 2007; Kuznetsov, O., Kulinich, A., Markovsky, A., 2006).

Developing the methodological approach that would solve the problem, it should be noted that reinsurance is characterized as a complex dynamic system, the basic elements of which are interconnected and mutually conditioned. In addition, there are situations in which it is impossible to unambiguously determine all aspects of implementation of component parts (works) of the complex due to the high degree of uncertainty (incomplete and inaccurate information about the situation when it is necessary to make management decisions) that accompanies the process of regulation. The specifics of reinsurance necessitates the development of instruments of economic and mathematical modeling that will not only solve the above-described problems, but make a reasonable short-term and long-term forecasting. It is proposed to carry out a graphical reflection of the system of the study's objects investigating the relationships between them – making a simple graph, the nodes of which are the concepts of subject areas, while the curves describe their cause-and-effect relationships (Kuzmenko, O., 2014):

$$F = (K, Z, A), \tag{1}$$

where $K=\{K1,K2,\dots,Kn\}$ is a set of concepts (nodes) of the graph;

$Z: (Ki,Kj) \rightarrow e_{ij}$ – a function of quantitative assessment of the cause-and-effect relations between concepts (nodes) of each pair, the value of which corresponds to the range from “-1” to “1” (the extreme cases of strong positive and negative relationships);

$A: Ki \rightarrow Zi$ – a function of activity of the system's concepts, which can assume two values at any time of managerial decision-making, “0” – a concept identified as inactive, “1” – the corresponding node of the graph is active.

Examining the basic principles of creating cognitive maps one could argue that an adaptation of this approach to the definition of conceptual aspects in regulating reinsurance flows of countries will take place considering the following advantages: ability to predict the system's behavior over a specified number of iterations in the future, by providing a sequence of vectors of its possible conditions (taking into account the consequences of events in any probable situations); the prospect of developing a mechanism for effective adjustment of bad decisions; comprehensive analysis of the relationships between the links of the studied complex to determine high priority centers of influence.

Regarding the practical aspects of building a scheme of relationships of reinsurance flows we should, first of all, determine the system-building components of the analyzed complex. Thus, the concepts (nodes) of the system of reinsurance are the countries of implementation of this type of operations, while quantitative estimates of the cause-and-effect links between concepts of each pair of countries are meaningful (medium and high-strength relations) coefficients of pair correlation between the respective trends (inner range of Table 1).

Table 1. Coefficients of pair correlation between reinsurance flows of countries

Country (concept)	Russia	Great Britain	Germany	USA	France	Austria	Switzerland	Others
A	1	2	3	4	5	6	7	8
Russia	1.00							
Great Britain	-0.53****	1.00						
Germany	-0.63****	0.73***	1.00					
USA	0.33	-0.89**	-0.55****	1.00				
France	0.42	0.19	-0.02	-0.32	1.00			
Austria	-0.48	0.85**	0.92*	-0.73***	0.22	1.00		
Switzerland	0.20	0.56	0.06	-0.56	0.71***	0.27	1.00	
Others	0.00	0.75***	0.37	-0.92*	0.62****	0.59****	0.77***	1.00

Note: groups of areas (countries) of reinsurance risks: * – the first group ** – the second group *** – the third group **** – the fourth group.

The analysis of the data presented in Table 1 makes it possible to determine and analyze four groups of areas (countries) with various quantitative assessments of cause-and-effect relations between the respective concepts. Thus, high-density of relationships (the absolute value of 0.92) is in the area of direct interdependence “Austria – Germany” and reverse influence “Other countries – USA”. High levels of reinsurance and insurance premium volumes in Austria are accompanied by similar indicators in Germany. At the same time reinsurance risks for the area “Other countries – USA” can be characterized as a services-interchange, that is, an increase of premiums transferred to reinsurance of one country (group of countries), accompanied by a decrease (displacement) in another country, and vice versa. The second group of areas (countries) of reinsurance risks is made up of pairs “USA – Great Britain” and “Austria – Great Britain”, quantitative assessment of cause-and-effect relations between the respective concepts are 0.89 and 0.85 respectively. Thus, an increase in reinsurance volumes in the United States by 1% is due to a decrease of this indicator in the UK by 0.89%, which requires making a decision regarding the choice of the most promising area of reinsurance operations. Austria and the United Kingdom have the opposite trend, which determines the volume of reinsurance in each other as the pair correlation coefficient assumes a positive value (0.85) at the level of close relationship.

The third group of areas of reinsurance in Ukraine is made up of countries, the density of relationships between which is high and belongs to the range from 0.7 to 0.8. These areas are the following pairs: Germany – United Kingdom, other countries – Great Britain, Austria – USA, Switzerland – France, other countries – Switzerland. Among these countries only Austria and the United States are interchangeable, which is confirmed by the calculated negative coefficient of pair correlation, while the countries of other areas of the group are complementary in terms of premium volumes transferred to reinsurance.

The fourth group of reinsurance areas of Ukraine, although containing the largest number of system-building components, is characterized by an average density of relationships between countries – from 0.5 to 0.7 in absolute value. In addition, it should be noted that only for 1/3 pairs of countries of this group an increase in reinsurance volumes is accompanied by their increase in the countries of influence. Countries of the fourth group have a destructive impact on the reinsurance market of Ukraine since the total amount of active reinsurance is reduced.

Visual representation of the relationships between areas (countries) of risk reinsurance involves the creation of a scheme of relationships of reinsurance companies’ operations around the world (Fig. 1), which is based on the data of Table 2.

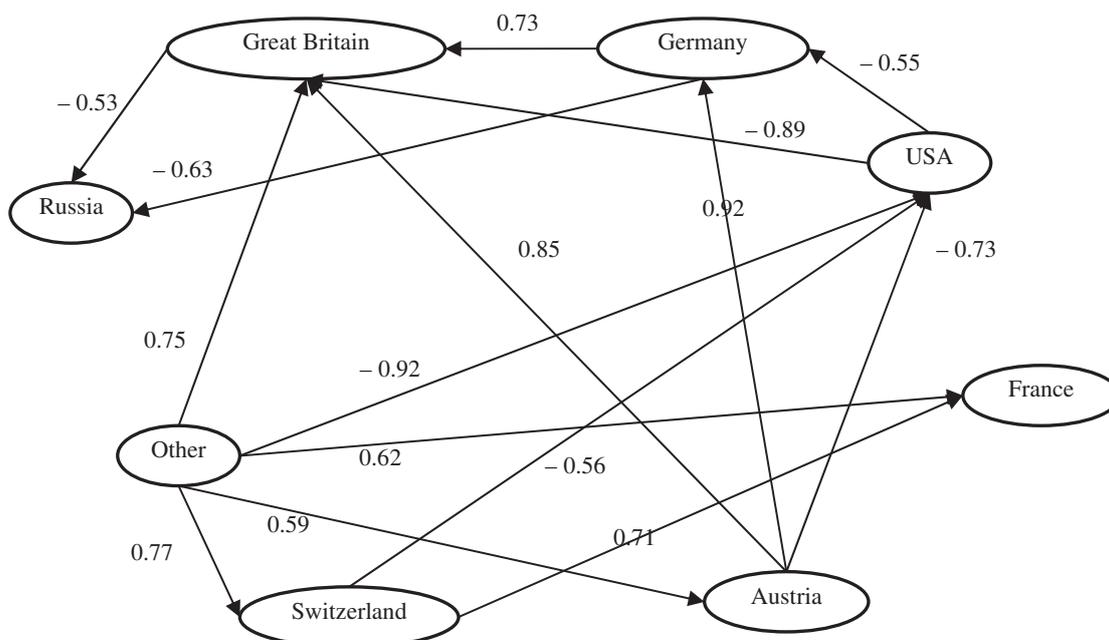


Fig. 1. The scheme of relationships of reinsurance operations of insurance (reinsurance) companies around the world

Mathematical representation shown in Fig. 1 takes the form of a matrix 8x8 reflected in the internal array of Table 2. In addition, elements of this matrix include the values of cause-and-effect relations between concepts (nodes) of the graph shown in Fig. 1, only medium and high strength relations because the introduction of the concept of reinsurance regulation based on the weak relationship between the concepts can complicate the model without increasing its adequacy.

Adequate reflection of all existing processes of the mechanism for regulating reinsurance according to areas (countries) cannot be made without taking into account the following key aspects that were not identified in the array of statistical data in Table 1.

The presence of not only direct but also indirect links between concepts (countries), that is, such cause-and-effect relations between the nodes of the graph in Fig. 1, which are not directly connected by arcs, but condition each other by indirect relations through other concepts. An example of indirect relations is Russia and other countries that are not directly linked, but it is possible to trace their interdependence through Great Britain, the volumes of reinsurance of which are determined by other countries and which at the same time has an impact on Russia.

Detection of such relationships between concepts that have neither direct or indirect influence on each other; the study determines the centers of activation of reinsurance activity allowing the current system to acquire new properties (uncharacteristic system-building components). This process is caused by the functioning of the reinsurance market as a complex dynamic system.

Table 2. Matrix of the mechanism of regulation of reinsurance between countries

Concept	Russia	Great Britain	Germany	USA	France	Austria	Switzerland	Other countries
Russia	0	0	0	0	0	0	0	0
Great Britain	-0.53	0	0	0	0	0	0	0
Germany	-0.63	0.73	0	0	0	0	0	0
USA	0	-0.89	-0.55	0	0	0	0	0
France	0	0	0	0	0	0	0	0
Austria	0	0.85	0.92	-0.75	0	0	0	0
Switzerland	0	0	0	-0.56	0.71	0	0	0
Others	0	0.75	0	-0.92	0.62	0.59	0.77	0

These deficiencies are solved by proceeding from Table 2 (initial matrix) to the matrix of 2n*2n dimension by carrying out calculations based on the following formula (Kuzmenko, O., 2014):

$$\begin{aligned}
 e_{ij} > 0 &\Rightarrow r_{2i-1,2j-1} = e_{ij}, r_{2i,2j} = e_{ij}, \\
 -e_{ij} < 0 &\Rightarrow r_{2i-1,2j} = -e_{ij}, r_{2i,2j-1} = -e_{ij},
 \end{aligned}
 \tag{2}$$

Where e_{ij} is a quantitative assessment of cause-and-effect relations between the i -th and the j -th concepts;

$r_{2i-1,2j-1}, r_{2i,2j}, r_{2i-1,2j}, r_{2i,2j-1}$ – elements that determine the rows and columns of the transformed (considering indirect links between countries) matrix for the mechanism of reinsurance regulation.

Thus, the ratio (2) can be described as explicit and implicit links between the countries of reinsurance implementation.

Further processes of the mechanism of reinsurance regulation should be based on the calculation of cumulative relationships and interdependencies between concepts, which can be identified with the help of formula (3) (Kuzmenko, O.V., 2014):

$$\tilde{R} = \bigcup_{i=1}^n R^i = R \cup R^2 \cup \dots \cup R^n,
 \tag{3}$$

where R is a matrix of values of direct and indirect relations between the concepts of active reinsurance;

\tilde{R} – a matrix of generalized characteristics of cause-and effect reinsurance.

A thorough and comprehensive analysis of all processes of the mechanism of reinsurance regulation as well as the relationships between their basic concepts includes a preliminary division of cause-and-effect relations between countries into two groups: direct and inverse relationships. It is proposed to identify cause-and-effect relations with positive and negative ingredients based on the following ratios (Kuzmenko, O., 2014):

$$v_{ij} = \max(r_{2i-1,2j-1}, r_{2i,2j}),
 \tag{4}$$

$$\tilde{v}_{ij} = - \max(r_{2i-1,2j}, r_{2i,2j-1}),$$

where v_{ij} is a quantitative evaluation of positive (direct) relation between the i -th and the j -th concepts;

\tilde{v}_{ij} – quantitative evaluation of negative (inverse) relations between the i -th and the j -th concepts.

The results of calculations with formulas (3) and (4) are the statistical basis for the research of regulation of reinsurance in the world's countries from the standpoint of analyzing the effectiveness of their implementation and structural changes. It is proposed to quantitatively reflect these aspects based on the calculation of indicators for a system of reinsurance regulation:

1. consonance – quantitative assessment of the degree of confidence to the sign of interaction between concepts (positive – direct relationship of the positive ingredient, negative – inverse relationship of the negative ingredient) (Kuzmenko, O., 2014):

$$c_{ij} = \frac{|v_{ij} + \tilde{v}_{ij}|}{|v_{ij}| + |\tilde{v}_{ij}|}, \quad (5)$$

2. interaction – quantitative assessment of the highest level of influence between the concepts (countries) of reinsurance in terms of the density of relationship (Kuzmenko, O., 2014):

$$p_{ij} = \text{sgn}(v_{ij} + \tilde{v}_{ij}) \max(|v_{ij}|, |\tilde{v}_{ij}|) |v_{ij}| \neq |\tilde{v}_{ij}|, \quad (6)$$

The results of practical calculations are presented in Table 3.

Table 3. Matrix of quantitative assessment of interaction between the concepts of the mechanism for reinsurance regulation according to areas (countries)

Concept	Russia	Great Britain	Germany	USA	France	Austria	Switzerland	Others
Russia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Great Britain	-0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Germany	-1.02	0.73	0.00	0.00	0.00	0.00	0.00	0.0
USA	1.03	-1.29	-0.55	0.00	0.00	0.00	0.00	0.0
France	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Austria	-2.16	2.49	1.33	-0.75	0.00	0.00	0.00	0.0
Switzerland	-0.58	0.72	0.31	-0.56	0.71	0.00	0.00	0.0
Others	-2.67	3.21	1.53	-1.79	1.17	0.59	0.77	0.0

The analysis of the data of Table 3 makes it possible to draw the following conclusions:

- ◆ within the framework of identifying future trends in the functioning and development of reinsurance activities the biggest share is determined by the relationship between the volumes of premiums transferred for reinsurance to Great Britain and other countries, which are self-complimenting countries;
- ◆ less influential, but also crucial are such areas of influence as the relationships between Russia, Austria and other countries. Typical for this group of reinsurance is inverse relationship that provides for mutual exclusion of reinsurance operations in case of their implementation in one of the following areas of influence: Austria – Russia, other countries – Russia;
- ◆ indirect level of influence on reinsurance volumes typical for such areas as the USA –

Russia, Austria – Germany, other countries – Germany, other countries – France.

In addition to these indicators, to investigate the patterns inherent to the mechanism of reinsurance regulation according to areas (countries) a statistical analysis is used which is based on the calculation of the following indicators:

- ◆ consonance of influence of the *i*-th concept (country) on the system of reinsurance, that is, the mean value of the quantitative assessment of confidence to the sign of influence of the *i*-th country on all other countries in the context of implementation of this type of operations (Kuzmenko, O., 2014):

$$\bar{C}_i = \frac{1}{n} \sum_{j=1}^n c_{ij}, \quad (7)$$

- ◆ consonance of influence of the *j*-th concept (country) on the system of reinsurance, that is, the mean value of quantitative assessment of confidence to the sign of dependence of the volumes of reinsurance premiums transferred to the *j*-th country on all other areas of research (Kuzmenko, O., 2014):

$$\bar{C}_j = \frac{1}{n} \sum_{i=1}^n c_{ij}, \quad (8)$$

- ◆ interaction of the *i*-th concept (country) with the system of reinsurance, that is, the mean value of quantitative assessment of the prioritized impact of the *i*-th country on all other countries according to the indicator of the density of relationships in the context of implementation of this type of operations (Kuzmenko, O., 2014):

$$\bar{P}_i = \frac{1}{n} \sum_{j=1}^n p_{ij}, \quad (9)$$

- ◆ interaction of the *j*-th concept (country) with the system of reinsurance, that is, the mean value of quantitative assessment of dependence of the volume of reinsurance premiums transferred to the *j*-th country on all other areas of research according to the indicator of the density of relationships (Kuzmenko, O., 2014):

$$\bar{P}_j = \frac{1}{n} \sum_{i=1}^n p_{ij}, \quad (10)$$

- ◆ indicator of the interaction’s centralization, that is, quantitative assessment of the level of accumulation of financial flows formed as a result of reinsurance operations with different concepts within the global financial architecture (Kuzmenko, O., 2014):

$$E_i^p = \bar{P}_i - \bar{P}_j, \tag{11}$$

The results of calculations with formulas (7) – (11) are presented in Table 4.

Table 4. Results of analysis of the processes regulating the mechanism of reinsurance according to areas (countries)

Concept	\bar{C}_i	\bar{C}_j	\bar{P}_i	\bar{P}_j	E_i^p
A	1	2	3	4	5
Russia	0.00	0.75	0.00	-0.74	0.74
Great Britain	0.13	0.63	-0.07	0.73	-0.80
Germany	0.21	0.50	-0.04	0.33	-0.36
USA	0.27	0.38	-0.10	-0.39	0.29
France	0.00	0.25	0.00	0.23	-0.23
Austria	0.29	0.13	0.11	0.07	0.04
Switzerland	0.27	0.13	0.08	0.10	-0.02
Others	0.13	0.00	0.35	0.00	0.35

The data of Table 4 make it possible to form analytical basis for making informed managerial decisions regarding the capabilities and instruments of reinsurance regulation:

- ◆ indicators of consonances for the influence of concepts (countries) on the system of reinsurance (columns 1 and 2 of Table 4 \bar{C}_i та \bar{C}_j) suggest that the United States, Austria, Switzerland and Germany (0.27, 0.29, 0.27 and 0.21 respectively) are the countries without which and the cooperation with their assignors the development of the global reinsurance market is impossible. At the same time, it should be noted that in the modern conditions of the global reinsurance market the biggest dependence of reinsurers is observed within the companies from Russia and Great Britain (0.75 and 0.63 respectively);
- ◆ indicators of interaction of concepts (countries) with the system of reinsurance (columns 3 and 4 of Table 4 \bar{P}_i та \bar{P}_j) reflect the efforts of reinsurers to increase their premiums transferred to other countries. This tendency is quite logical considering the use of reinsurance operations in order to optimize and legalize the money obtained by illegal means. In addition, it should be noted that an intensification in the

development of the global reinsurance market in terms of its qualitative and quantitative characteristics is exemplified in the context of its interaction with reinsurers from Great Britain and certain destructive impulses existing in the system of risk reinsurance on the reinsurance market in Russia;

- ◆ based on the incidents of interaction centralization (column 5 of Table 4 E_i^p) we can form a conceptual foundation of the behavior of international reinsurers in relation to domestic companies. Thus, the biggest redistribution of financial flows created as a result of re-insurance by insurance (reinsurance) companies is observed in Great Britain. However, Russian reinsurers have a significant amount of reinsurance premiums. That is, for insurance companies Russian assignors are the source of minimization of their risks and their rapid redistribution on this market. In turn, Great Britain is a stimulant for the development of the global reinsurance market because collaboration with the UK reinsurers requires structural reforms not only in conditions of assessment and quality of risks assumed by insurers, but also reforming the entire infrastructure of the global reinsurance market.

Conclusion

It should be noted that the proposed methodological principles of the concept of reinsurance regulation based on cognitive maps make it possible:

- ◆ to carry out reinsurance modeling as a complex dynamic system to detect and study patterns in the functioning of the global reinsurance market;
- ◆ to form information base for making informed managerial decisions regarding the advisability of the transfer of insurance premiums to the relevant areas (countries) in conditions of uncertainty;
- ◆ to give a quantitative and qualitative assessment of cause-and-effect relationships between the areas (countries) of reinsurance.

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