OPERATIONALIZATION OF THE COMPOSITE MODEL OF THE FINANCIAL NETWORK OF THE ECONOMY. CEFIMO 2010 EXPERIMENT*

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Rezumat

Economia poate fi abordată ca o rețea, rețeaua financiar-monetară reprezentând o componentă a acesteia, caracterizată prin compoziție, configurație şi arhitectură. Această abordare permite modelarea compozită a rețelei financiare, rețea financiară compozită semnificând un ansamblu de interacțiuni între părți delimitate (reale sau nu), independente, care se autosusțin reciproc în cadrul ansamblului, semnificația părților fiind definită numai în cadrul acestor interacțiuni.

Modelarea compozită a rețelelor financiare complexe permite divizarea unui model în module, fiecare dintre acestea cuprinzând un set de componente, prin această abordare rețeaua interacțiunilor interbancare a fost divizată în cinci module, încercându-se interpretarea şi evaluarea transmiterii şocurilor şi a neplăților în cadrul rețelei.

Experimentul CEFIMO (Centrul de **Ce**rcetări **Fi**nanciare şi **Mo**netare) relevă, pe baza unui set de parametrii, impactul expunerilor bancare, a interacțiunilor şi a comasărilor asupra contagiunii în rețea a neplăților şi, totodată, deschide posibilitatea analizei riscului de lichiditate şi extinde, prin diferențiere, a rețelei interbancare modelabilă compozit.

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Abstract

The economy can be approached as a network, the financial-monetary network being one of its components, characterized by composition, configuration and architecture. This approach allows the composite modelling of the financial network; the composite financial network is an assembly of interactions between independent, delimited parts (real or not) which support each other within the assembly; the signification of the parts is defined only within these interactions.

The composite modelling of the complex financial networks allows the division of a model in modules, each of them including a set of component. Thus, the network of the interbanking interactions has been divided into five modules, trying to interpret and evaluate the transmission of the shocks and non-payments within the network.

CEFIMO experiment reveals, on the basis of a set of parameters, the impact of the banking exposures, of the interactions and merging on the network contagion of non-payments and opens the possibility to analyse the liquidity risk and expands, by differentiation, the analysis of the composite interbanking network.

Keywords: financial network, financial system, monetary financial flows, composite model

JEL classification: C54; E44; G17.

The paper approaches, in a concentric and concerted perspective, the financial system and its components using the network theory, reconsidering the systemic vision on the financial assembly and placing its dynamics within a network of interactions which provide it with flexibility and explicative and interpretative adaptability. The network approach of the financial assembly allows a realistic understanding of the structure and functioning of the composing systems and subsystems included in the financial and monetary networks, of the behaviour of the financial and monetary entities within the network.

The objective of the paper is to set the grounds and to interpret the necessity for a composite modelling of the financial network, the composite organisation of the financial network, which presumes interpreting the system as a multitude of interactive singularities.

Within this vision we attempted the, more or less explicit, composite modelling of the different aspects of the financial network, the operationalization of the develop models and the methodological construction of a composite model of the interbanking interactions. The model is submitted, under hypothetical conditions, to experimental tests focused on the significant parameters of the interbanking market, tests whose purpose is to reveal the phenomenon of contagion, of propagation of non-payments, of the banking bankruptcy within the banking system.

The paper has four chapters connected within a synergic approach, each chapter being a basis for the next chapter.

The **first chapter**, the ***Financial network of the economy***, approaches the following aspects: system and network, approaches of the financial reality, composition, configuration and architecture of the financial architecture of the economy, characteristics of the financial network of the economy, behaviour of the financial network of the economy.

Considering the *financial reality as a system* actually means *reifying a concept*, a construct which wants to *explain not to understand, to comprehend this form of existence of some specific human activities*. The systemic approach of the financial reality can be valid in the perspective of the practice, even of the praxis, providing the possibility to *construct, organise a formal space for existence* of the financial reality; however, understanding its movement, its flow, becoming and transformation presumes a network approach, that is to say, reconsidering the explicative, reductionist approach.

This approach considers that all the components of the financial reality, irrespective of their nature, are entities, flows and fields *equi-potentially distributed, having specific determinants and attributes within the network.*

The network approach of the financial reality is a *configurational, distributivist and attributive approach dominated by the relation, flow, the latter composing fields of entities delimited concentrically and determinatively.*

The network approach recovers the *hermeneutic, why not comprehensive, features* of the market in understanding the financial reality, traits which were for some time smothered by a reductionist and mimetic mathematic and logic formalism. The market actually is

the reality of people's activity and in this sense, the financial market, in a holistic and synergic, concerting interpretation, is a network of flows, fields and entities which the systemic explanations and practices try to push within a dichotomist logic, in a organising teleological rationality of concerting origin, obviously administrative-bureaucratic, which is the dream of any imperialism of explanation.

The flow is what passes from one entity to another, linking them, relating them, keeping them together, the *primary flow* for the financial reality interpreted as the reality of the monetary values, representing the *flow of the purchasing power* which can be found as financial reality in four revealing flows: *the flow of values, the cash flow, the flow of instruments and the flow of money.*

The systemic approach of the financial reality, when it refers to the flow, refers primordially to the flow of instruments which appears under different forms, the diversity of the financial instruments being extreme. The flow of financial assets, the asset actually being a financial good, is represented by the flow of instruments; the cash flow is absorbed by the flow of instruments, the debts, which are expressions of the cash (but not monetary) flow, becoming credits, bonds, securities, cambia, mortgages etc.

The organisation, which is the expression of the form, is characteristic to the networks, particularly to the financial networks; generically, the organisation is the "matrix" within which the information messages flow, the location of the entities and the relations between them forming the architecture of the network. The dimensions of this architecture are its morphology, configuration and composition.

The economic entity connects the monetary flows using a specific interface called treasury. There are two types of complementary flows: accounting monetary flows and financial monetary flows.

The primary monetary network which is formed by the interconnected monetary network and their interferences, is exceeded by the accounting monetary flows and reconfigured into a secondary monetary network of intermediation within which manifest as transfer monetary units having as representative the bank entity which creates money, intermediates the cashing and payments between the productive entities in different manners (cash and wired), instruments (banknotes, , payment order, cambia, checks, electronic messages),

techniques (letter of credit, compensation, electronic payments) and circuits (telegraphic, by phone, computer).

This secondary network consisting of the financial monetary flows, remunerated and non-remunerated, on which the financial currency moves, ensure the transfer of the actual currency, particularly of the scriptural currency, from the entities having financing capacity to the entities having financial needs.

The monetary flows generated by these monetary entities of intermediation catch the productive economic entities of any nature, within a complex monetary network delimited within three distinct and interactive networks: the network of monetary creation; the network of monetary mobilisation and the network of monetary transfer.

The interactivity of the financial network has a concentric architecture on four concerted levels, which can be represented within a complex model of the reflexive network of the financial system.

A plurality of networks forms within the financial space; the composite integration of all the networks sub-networks and entities is done through interactive flows of different nature and contents, the resonance of the network being often achieved by synchrony, local or general interferences and dissonances.

The financial network, characterized architecturally by morphology, configuration and composition, has several network characteristics which are essential for the “behaviour” of the financial assemblies and not only, as networks. These characteristics are: interactivity, synchronicity, resonance and multitude.

The analysis of the financial and monetary networks uses the following measurable dimensions which can be used for their quantitative, formal characterization: interdependence, neighbourhood, centrality, centralization, clustering coefficient, cohesion, density, length of the bond, radiality, expansion, structural cohesion and structural equivalence.

Resonance is omnipresent within the economic and financial networks, the material and financial interactive flows symbolising continuous quanta of information which are transferred, via electronic networks, to all the entities of the composite network.

The composite nature of the financial network means the form in which the whole composite manifests, this network being characterized by a strong integration of the composing parts which

become intrinsic components of this whole. The composite financial network, of any kind and size, consists of sub-networks which play determined roles, missions within the network, acting independently according to rules and protocols set for the whole network. The most relevant example of composite financial network is the capital market, the stock exchange being the systemic form of this network.

The behaviour of the composite network circumscribes to the following defining organisation dimensions: organicity, reasonability, decentralism, interactivity and transience.

The composite financial network consists of sub-networks which are interconnected and interactive, differentiated and specialised, distributed within the network function of network nature and size. These sub-networks can be called financial and monetary modules because they can be found in any composite financial network: operational modules, protective modules, compensative or redundant modules, connecting modules, recuperative modules, inhibitory/stimulating modules, coordinating-regulatory modules.

Compared with the traditional financial system, the financial network based on the internet has the following behavioural properties: (positive) network externalities; standardization; interconnection; personalization.

The principles of the financial networks can contribute, for instance, to understanding the distribution of wealth in the monetary economies. The acknowledgement and detection of these new distributive patterns might allow learning to use them in order to organise and make decisions, making possible new forms of coordination and new forms of monetary and financial policies. The key principles of the financial networks are: communication, transparency, knowledge, innovation, regulation, responsibility, governance, personalization, deconcentration.

The **second chapter** of the work, the **Composite model of the financial network of the economy**, approaches the following aspects: the composite modelling of the financial network complexity, abstractization and interpretation of the composite model, formalization of the composite model of the financial network.

A composite model is a model is a model which contains several parts, the composition of the models being essential to the development of the complex heterogeneous networks and systems for the simulation of particular models, being able to express the

architecture and behaviour of the network, the structure and functioning of the system.

The composite modelling aims, particularly complex systems, networks of systems; many contemporary and future systems integrate several simple or complex subsystems, the dynamic models being capable to specify their structure and behaviour with the purpose to analyse, evaluate, design, develop and test the functionality of these systems.

In terms of extension and intension of the configuration, composition and architecture of the interactions, the networks are of three types: simple networks, complicated networks and complex networks.

All the processes in nature interact. In many networks, however, there is a set of blocks, basic systems which interact nonlinearly in order to form systemic composite structures or functions with an identity which claims more explicative instruments than those used to explain the blocks within the system.

The defining features of the complex networks are: dispersed interaction, non-global control, interactive, concerted organisation, continuous adaptation, continuous niches of novelty, dynamics which are far from equilibrium.

The composite modelling of the financial networks allows dividing a model into modules, each of them having set of components. This is an essential stage in the specification of the model, model decomposition and composition being a real challenge when the models are heterogeneous in terms of the formal specifications (for instance, the discrete and optimising models have different structural and behavioural specifications).

Many networks from the real world can be abstractized systemically as consisting of two parts, one is the operation and the other is the control. At a higher level of abstractization the functional models and the control models of a given network of systems may be regarded a algorithms which exchange data about the state and composition of the network systems, under properly defined restrictions. The operation/control pair can form a symbolic relation in which one id concerned with the operations of the network process, while the other is concerned with the control of network management. The dynamics of operation can be described in a variety of forms such as: discrete, continuous or a combination of the two, the control

being done by feedback, by event control, by fuzzy control. The operation and control are two layers, levels of the network, which leads to the concept of multi-layer which gives advantage to the use of hybrid, composite models and of simulation.

With the concept of multi-layer modelling it is possible to use a single modelling formalism to describe the operation and its control. However, if a network has parts with dynamics which are intrinsically different, a formalism of multiple modelling is required.

Modelling formalism consists of two parts: specification of the model, which is the mathematical theory and which has different kinds of architecture and behaviour, structure and operation that can be described with them, and the determination, solving algorithm, which specifies a calculation which any model can make, which is described according to the specification of the model.

The approaches of the composite models are classified in formalisms of mono-, super-, meta- and poly-modelling, supplying different capabilities of composition. The first two rely on a concept which, sometimes, correspond principially to a single formalism for the modelling of the different parts of the system. On the contrary, the last two describe the situations in which different modelling formalisms are crucial for the description of the complex network parts. Despite the differences between the composite models, each approach must ensure that the interactions between the parts of the composite model are properly defined structurally and behaviourally.

Usually, a single modelling formalism is used to specify an aspect of the network, the mono-modelling providing several important advantages, such as the hierarchical decomposition or composition of the model in parts which can be treated systematically. The modelling formalisms help the modellers specify the dynamic systems within the networks using a properly defined syntax and semantics. The syntax specifies the possible structures for inputs and outputs, states and functions, representing the specification of the model, while the semantics specifies the structural and behavioural elements, being the algorithm of the model.

The separation of model specification from the solving algorithm allows the different composability of model specification and the interoperability of the algorithm, depending on the approach of composability.

The formalism of the general modelling helps describing and solving a model, irrespective of a specific field, which is why often model composability is considered independently of the field of application. Modelling a specific field is possible with the mono- and super-models and also with the meta- and poly-models.

The composite modelling of the complex systems of the system networks allows elaborating composite projects introducing changes and transformations within the financial systems.

The composite project is an assembly of projects having a common theme, methodology and organisation; each composing project has different objectives and functionalities, but they are interconnected and interact during the process of accomplishment and implementation.

The composite design of the adaptation, transformation and reconfiguration of the financial networks provides an standardized framework for the development, configuration and implementation of several distinct projects which have a common mission, but different objectives. The composite design uses common resources for the accomplishment of the interactive projects, which intersect their various operational and functional components.

The configuration of the composite model reveals two types of essential links: interactions and interconditioning, which provide structurality and functionality to the designed system.

The process of rational composite design contributes to the interdependent conception, planning, implementation, execution and evaluation of all component projects, involving all the network entities, using objective criteria of measurement, disregarding the delayed or isolated activities conducted by design groups not integrated within the composite project.

The financial flows generated and supported by these entities form the nodal monetary-financial network, revealing in a simplified manner the financial environment of these entities. This network, being a composite network, comprehends the following types of networks: network for monetary creation, network of monetary mobilization, network of monetary transfer, negotiative monetary-financial network and regulative financial network.

Concentrically, the financial network can be approached from various perspectives, delimiting categories of networks such as: the

nodal network of the regulative monetary flows, also called instrumental monetary network.

The composite model of the complex monetary network includes the defining monetary flows and entities of the economy, the entities being delimited in five characteristic blocks: the block of subjects, the block of promoting productive entities, the block of the governing entities, the block of the monetary entities, the block of markets.

The five blocks are assembled compositionally, forming the composite monetary network which is represented in a simplified manner by the composite model of the network within which the monetary flows, which are the dynamic component of the network architecture, can be delimited dually as follows: generative flows and distributive flows; liquidative flows and substitutive flows; conversion (transformation) flows and transfer flows; mobilisation flows and placement flows; capitalization flows and coverage flows.

The complex network of the monetary flows reveals the following distinct categories of defining elements: institutions of the financial network, instruments of the financial network and flows of the monetary network.

The composite (architectural) composite model of the complex network, thus delimited, is characterized by the knots of the network – which can also be centres for monetary accumulation – differentiated institutionally (subjects, entities, markets) and by the network interactions represented by flows and instruments.

From the compositional perspective, the composite model of the monetary network, in its extension, is defined by the following properties: density of the network, differentiation of the network, centrality, equi-potentiality of the network.

The composite model of the monetary network, its configuration and composition, allows a matrix approach of the architectural model. The three distinct compositional elements of the architecture (subjects, entities and markets) can be represented modularly at the dual intersection (junction) of the lines and columns showing the existence or non-existence of the connection (relation).

Sequentially and correlatively, the following matrix forms of the model can be ascertained: the primary structural matrix, the instrumental-institutional matrix, the functional matrix, the aggregate matrix of the financial operations, the dual matrices and the financial operations.

Using the two matrices of the portfolios the vector of the monetary balances is determined, which is characteristic to the monetary institutions at a specific moment (end of a period of flows).

On the basis of the primary structural matrix, which shows the existence or non-existence of a connection between the two entities, and using the matrices shown above, the matrix form of the composite model of the complex monetary networks is constructed, which we call the matrix of the crossed flows.

Thus formalized, the matrix form of the composite model can be operationalized using either accounting methods, or statistical methods, giving the possibility to use the technique of grafts by segmentation.

The final matrix form of the composite model integrates the configuration elements of the complex network: the subjects, markets, entities, instruments, flows, operations; while the matrix of the crossed flows includes the monetary values of the relations between the monetary institutions of the complex monetary network.

Chapter three, Operationalization of the composite modelling of the financial network of the economy approaches the following aspects: informationalization and formalization of the composite model of the financial markets; composite matrix of the financial operations.

The financial market is a monetary reflexion of all the other markets which can be identified and defined in the society, particularly in economy, including an assembly of specific financial markets with defining traits which delimit them.

The financial market is dual showing two hypostases, often contradictory:

- Collecting financial market, which collects the monetary availabilities using two instruments: deposits and securities. There are two categories of participants operating on this market: those who offer availabilities (population households, companies, the state and even financial institutions) and the various collecting financial institutions. The latter can be delimited in banking institutions and non-banking institutions. The collecting market of the state is a distinct market, specific to the financial market of collection; the state secures financial resources, liquidities on this market.
- Placing financial market, which performs the direct or mediated distribution of the collected monetary resources to teh

subjects in need of funds and liquidities. There are two categories of participants operating on this market: the financial institution placing funds and those demanding liquidity (mainly the companies and the state, but the population households and financial institutions too).

The credit market consists of the interbanking market, major component of the monetary market, and the market for the economic credits (market of the public loans, of the consumption loans, of the mortgages etc.).

A distinct market, connected to the market of the public credits (counterpart of the market of public loans) is the market of the public investments where the state place, under different forms, liquidities necessary for the investments in economy.

The market of placements consists of the market for shares and market for bonds, the primary market and the secondary market, with the institutionalized form of the stock exchange.

On the basis of the relations between the institutions and instruments from the financial markets, the matrices of the financial market can be constructed: the distributive matrix and the distributive-integrated matrix. The latter matrix can be used to determine relations between its variables, showing the possible tensions or resistances within the institutional rates of the financial market.

The assembly of the financial markets, delimited institutionally, forms a network composed of financial flows, circuits and cycles, which ensure the movement of the availabilities coming from saving, towards liquidities necessary for investments. The composite model of the financial market network moves the funds, liquidities, from those who save to those who invest and returns, reimburses liquidities towards the borrowers against the associated prices (royalties, interest rates etc.).

The financial accounting shows notionally the variations of the debts of the institutional sectors, the distribution of the financial instruments by institutional sectors and the distribution of the sectors by financial instruments, showing in conclusion the capacity and requirement of financing the sectors, as well as the contribution of each financial instrument to the accomplishment of the financial operations.

On the basis of the information from the financial accounting, the matrix of debt variation can be constructed by financial sector and instrument, which allows determining and changing the significant

indicators of the financial flows. The matrix of debt distribution by institutional sectors and by financial instruments is used to determine the coefficient of financial concentration by distinct periods and in progress.

The statistical analyses of the accounting data regarding the financial flows, expressed by the value of the financial assets can reveal the variation of a monetary indictors such as the monetary basis, the level f economy monetization, the saving coefficient, function of the informational basis, of the level of detail of the account ting structure etc.

The national accounting system has coherent and adequate analytical instruments, to interpret and explain the financial phenomenology. The network approach allows revealing the interactions and codeterminations, the direct or indirect links, the positive or negative impact of the different financial assets on the entire financial situation of the economy.

Chapter four presents the **Composite model of the interactions of the interbanking market**, as well as the **CEFIMO experiment** on this model, using hypothetical data, in order to explain the contagion, the propagation of the risks generated by shocks on the interbanking market, through interbanking interactions.

From the perspective of the networks, a banking system can be represented by a set of knots (banks) which are connected by direct links, in our case interbanking exposures, with a predefined probability. The proportion of these connections (size of the interbanking exposures) determines the capacity of flow loss from one bank to another, the capital and the deposits being the first and last receiver of any loss.

The approached problem refers thus to the role of the direct interbanking interactions as source of the systemic risk and to the possible bankruptcies that may occur due to the exposures.

The proposed approach conceptualises the main features of the financial banking using the theory of networks, allowing the use of a variety of essential market parameters. The way in which the flexibility of the interbanking market to the shocks is related to parameters such as the capacity of the banks to absorb the shocks, the dimensions of the interbanking exposures, the degree of interaction of the banking system, the degree of merging of the banking system.

The network of the banking system relies on two exogenous parameters which describe the random graft: the number of knots, of banks, N and the probability p_{ij} , that a bank *i* grants a loan to bank *j*, this probability being supposedly equal for all the bank pairs *ij*.

The network representation uses data from the balance sheets of the individual banks filled in consistently with the bank level and with the identities of the aggregate balance; the detailed description will use specific notations: total assets, external assets, interbanking assets, liabilities, deposits, interbanking loans.

The simulation of non-payment movement in the banking system, during the methodological experiment, took into consideration the following exogenous parameters: the number of knots, banks, the probability that a bank grants a loan to another bank, the proportion of the interbanking assets within the total assets, the net asset as percentage of the total assets.

In each comparative static simulation, one of these parameters varies, while the others have been maintained fixed. The real data experiment will allow revealing the essential aspects of the transmission of the banking exposures through the network of the interbanking connections (loans).

The hypothetical experiment tried to interpret the impact of the following parameters: net assets, bank capital, interbanking exposures, interactions between banks, merging, banking concentration, on the contagion of the effects produced by the general and particular shocks on the interbanking market,

Finally, the model has been used to open the possibility of the liquidity risk analysis. This risk appears when the bank assets must be sold, but there is not enough liquidity on the market to absorb them.

Briefly, the simulation tried to expand the use of the model from the behaviour of the homogenous networks to that of the heterogeneous, differentiated, stratified networks characteristic to the real world.

In conclusion, the proposed model tried to present synthetically the dependence of the systemic risk on the architecture of the banking system, applying the network theory with the purpose to build the banking system and then to analyse the elasticity of the system to non-payment contagion. The parameters are: the net assets, the size

of the interbanking market, the level of interaction, the merging of the system.

The level of elasticity, of flexibility of the system was analysed function of some parameters such as the net assets, the size of the interbanking market, the level of interaction, the merging of the system, from the view point of the central bank which has the responsibility to analyse and temper the systemic risk. Four main conclusions are relevant.

The *first conclusion* refers to the fact that the decrease of the net assets of the banking system determines the increase of the "contagious" non-payments, this effect being non-linear.

The *second conclusion* refers to the fact that an increase of the volume of interbanking liabilities might lead to a higher risk of non-payment impact, even in the situation when the banks have enough capital to be protected against the interbanking assets.

The *third conclusion* shows that the evolution of the contagion is a non-monotonous function (it has a discontinuously directed dynamics) of the number of interbanking interactions, all the other conditions remaining unchanged (*ceteris paribus* condition). When the level of interaction is low, an increase of the number of connections leads to a higher probability for contagious non-payments; however, when the interactions already are numerous, a further increase of the number of connections may lead to a higher capacity of the system to control the shocks.

The *fourth conclusion* refers to the fact that the banking system, the more merged it is, the more tends to be predisposed to systemic collapse under conditions of *ceteris paribus.*

The consideration of the incorporated (integrated) effects of liquidity shows that when the assets of the endangered bank are sold under conditions of limited liquidity within the financial system, its values may fall below their market value. Many assets are liquidated at very low prices, the presence of the liquidity effects increasing the probability of the systemic collapse for any aggregate capitalization and for any degree of interactivity between the banks.

The expansion of the analysis of the heterogeneous structures of the banking systems shows that the differentiated structures are not, necessarily, more predisposed to the systemic risk; this depends on the level of centrality, on the number of connections of the knot, of the central bank, so that the higher is the level of centrality, the

contagious payments will initially increase, but will decrease subsequently because the number of interactions of the central knot will dissipate the shocks.

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