ATACD Workshop

Actor-Network Approach and Modeling Cultural Dynamics

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Understanding Stability in Social Dynamics by

Modeling Sociological Agent as Combination of Non-Determined Stochastic Automata

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Contents

Part of *A Topological Approach to Cultural Dynamics* Project (*ATACD)*,6th Framework program – www.atacd.net

- Developed jointly with *Center of Sociology of Innovation*, Ecole des Mines, Paris, related with earlier collaboration on *'indirect network approach'*. (*TACTICS Project, 4th FP, 1998-2000*)
- An attempt to develop a formalized methodology, based on the principles of *Actor-Network Theory* and describing the dynamics of what we call *'stacked'* or *'layered' actor-networks*
- A ‘mutual learning process’ between actor-network sociologists and math experts in topology and graph dynamics.

The sociological input

"Since social actions are governed by particular rules, the task of <u>theoretical sociology</u> may be defined as the analysis of social rules and their consequences, i.e., the dynamics they generate. The task <u>of mathematical (or computational) sociology</u> is, therefore, to construct mathematical models able to deal with social rules." (Klüver and Schmidt 1999)

This is precisely in what actor-network theory criticizes the traditional sociology (Latour 2005 - *Reassembling the Social)*.

⇒ In modeling social system on should get rid of the idea of 'pre-given rules' and a 'guidance', i.e. assuming the *instances that are 'selecting', 'estimating', 'making choices'* etc. during the dynamic process of change.

The sociological input (2)

- To push to its limits the idea of opportunistic evolution of a concrete social phenomena considered as ‘form of life’;
- To take ‘ex post’ stand to the processes going on in the specific ‘form of life’ to be modelled;
- To consider the properties of the studied entities (agencies, mediators, etc.) *as an outcome of the evolution and not as pre-given attributes;*
- The notions such as ‘rationality’ or similar are to be approached as actors’ (including researchers’) mode of accounting of the processes they are modelling.
- The mathematical models are consequences of specially designed and collected sociological (using both qualitative and quantitative methods) data *in specific areas,* they are build on these studies and are verify them.

The sociological input (3)

Functionalist approach (T.Parsons): social interaction as institutionalized set of social roles; merging of different roles in the social status of the individual.

Ervin Goffman: The importance of ‘mise-en-scene’ (staging) and ‘performance’.

P. Bourdieu: A more complex understanding of role interactions – the notions of *field*, *position* and *habitus*; *illusio* and ‘*practical sense*’. Still preserve the asymmetry between human individuals and the other types of agencies involved.

Laurent Thévenot and his “Sociology of Regimes of Engagement”

Stresses the varieties of bodily involvements in the regimes of engagement and investments of forms in structuring the interactions. *The explicit attention to the ability of the equipped human agency to ‘switch’ between different regimes of engagement and that this very ability is an essential aspect of the constitution of human agency*.

The sociological input (4)

The idea of ”emerging” and “stabilized” networks (Callon 1996). The notion of "state of the techno-economic network“ and the radical distinction between the two states:

- *emergent networks* (les reseaux emergeantes) or "emerging configurations" ,

- *long and well-established, stable networks* (les reseaux longs et etablis) or "consolidated configurations".

=> The importance of *learning and apprentisage,* of ‘*preparing the materials and substances*’*,* of work on *standardization,* etc. that makes the agents mobilisable and easy to deploy, thus allowing ‘programs to be defined in advance’, to judge based on the ‘states of the possible worlds’ identified in advance.

The relative closeness of the networks of interactions :

"...When the laboratory sciences are practicable at all, they tend to produce a *sort of self-vindicating structures that keeps them stable*.... As a laboratory science matures it develops a body of *types of theory* and *types of apparatus* and *types of analysis* that are mutually adjusted to each other. They become what Heisenberg notoriously said Newtonian mechanics was, "a closed system" that is essentially irrefutable. They are self-vindicating in the sense that any test of theory is against apparatus that has evolved in conjunction with it and with modes of data analysis." (Hacking, 1992, pp.29-30)

The sociological input (6)

The idea of 'stacked' actor-networks:

Formally independent networks that share some common entities as actors and/or mediators. These common entities are present in each network under different identities, which possibly could provide clues for understanding the stable patterns (i.e. the underlying topological structures) of social and cultural dynamics

Main questions to be explored:

- ’Incommensurability’ between actor-networks and their degree of ‘closeness’;
- The problems of identity of the actors and *mediators*;
- The phenomenon of ‘switching’ and preservation of ‘traces’ from acting in other networks (and under other identities) into current interaction, etc (Thevenot).

The aim (general):

To test the idea of ‘stacked networks’ against the empirically collected data describing network interactions between large number of agents.

The *TACTICS Study*

TACTICS

TELEMATICS AND COMMUNICATIONS TECHNOLOGY INDUSTRIAL COMPARATIVE STUDY

- **A social sciences analysis of the supply and use of Advanced Communication Technology and Telematics (ACT&T) in Bulgaria, Romania and Macedonia and their effect on the transformation process and restructuring of the traditional industries**

Specifying the subject of study:

To study the supply and use of Telematics and Advanced Communication Technology means to identify specific *configuration of relations between the different kinds of agents* (individuals, institutions, technologies, standards, systems of laws and rules). These agents build different kinds of networks which when interacting, *evolve around distinct patterns*, as viewed from the 'perspective' of a only one type of actors (AC&T firms).

These patterns are described as a end number of processes and phenomena *(relational variables)*, each outlining the sub-network of interactions:

1) with customers & <u>business partners</u>;

2) Financial relationships;

3) staff recruitment;

4) legal relationships;

5) relationships with public powers

Assumptions of the TACTCIS study

1) An outline of the relationships *by qualitative methods (interviews, analysis of texts, etc.)*; both *variables* and *categories in each variable* are defined by the actors themselves!

2) *Quantitative representative* study of the entire population of the actors chosen, based on the variables defined in previous step.

3) *Indirect network analysis* (Callon, Laredo, Tchalakov)

SAMPLES

Country	Updated Database	Sample
BULGARIA	3 081	306
ROMANIA	1 758	280
MACEDONIA	426	138

STATISTICAL ERRORS FOR THE VARIOUS RELATIVE SHARES WITH PROBABILITY OF 95% ARE AS FOLLOW:

Country	10%	20%	30%	40%	50%
BULGARIA	3,55	4,73	5,42	5,79	5,91
ROMANIA	3,43	4,57	5,24	5,60	5,71
MACEDONIA	4,45	5,93	6,79	7,26	7,41

Indirect network analysis :

1) *Network profile* - instead of the concrete networks, identification of groups of firms with similar structure of relationships with economic actors in the five domains (52 empirical variable)

2) *Clustering* of the empirical variables to obtain unique pattern for each group of firms (25 relational variables)

3) *Multiple correspondence analysis* - regrouping of the firms according to the similarity of their positions in the 25 relational variables *taken together.*

The clusters are not networks, yet they register the *involvement* of the firms in the specific relationships and their modalities!”

DOMINANT TYPE OF COMPETITION relational variable

Initial set:

competition in **price** of a certain product/service;

competition in the **quality** of a certain product/service

competition in promoting **new products**/services;

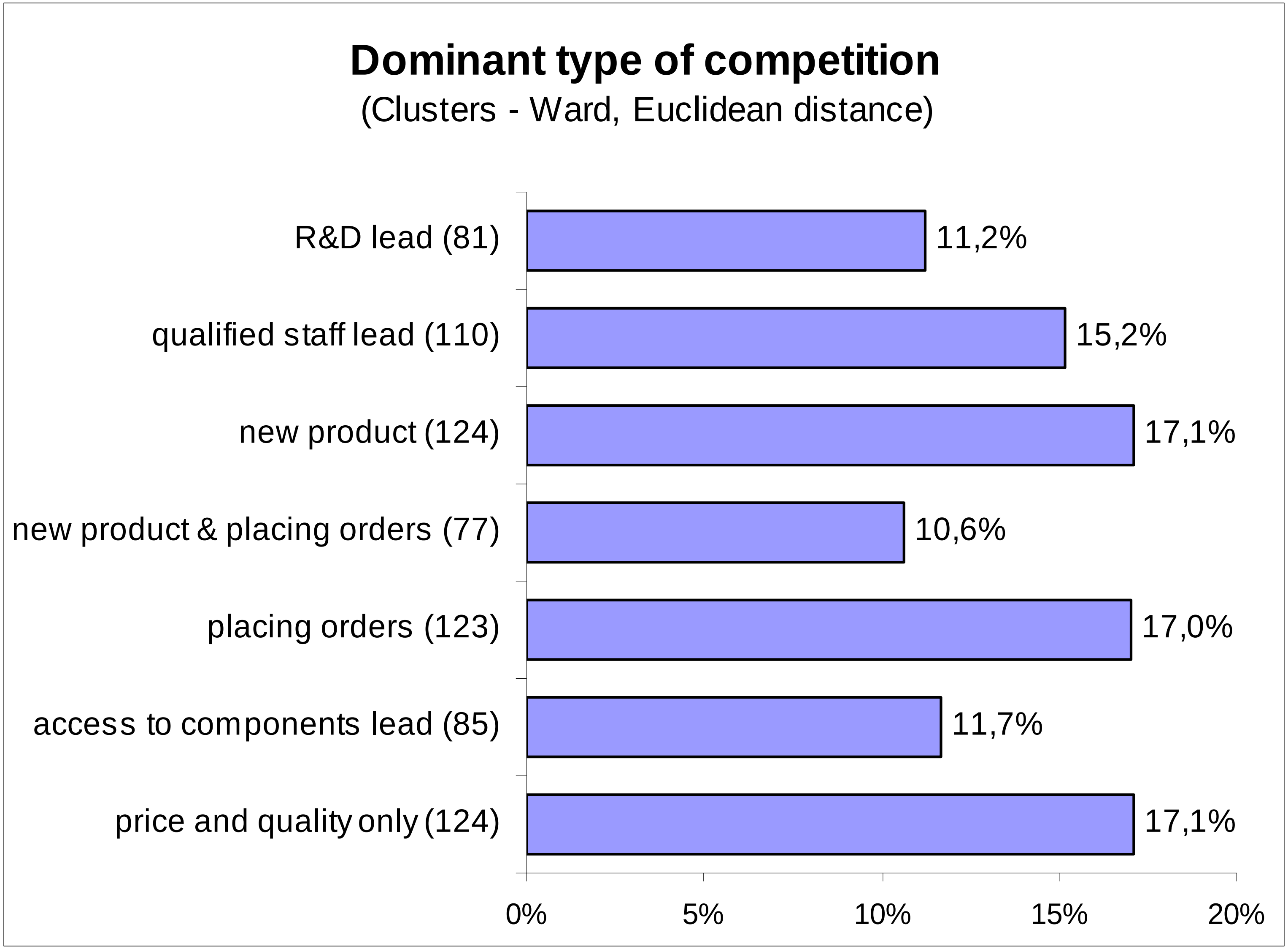
competition in placing **orders**/projects;

competition in gaining access to certain **raw materials** & **components**;

competition in employing qualified **staff**;

competition in receiving subsidies from **state funds**

competition in **R&D.**



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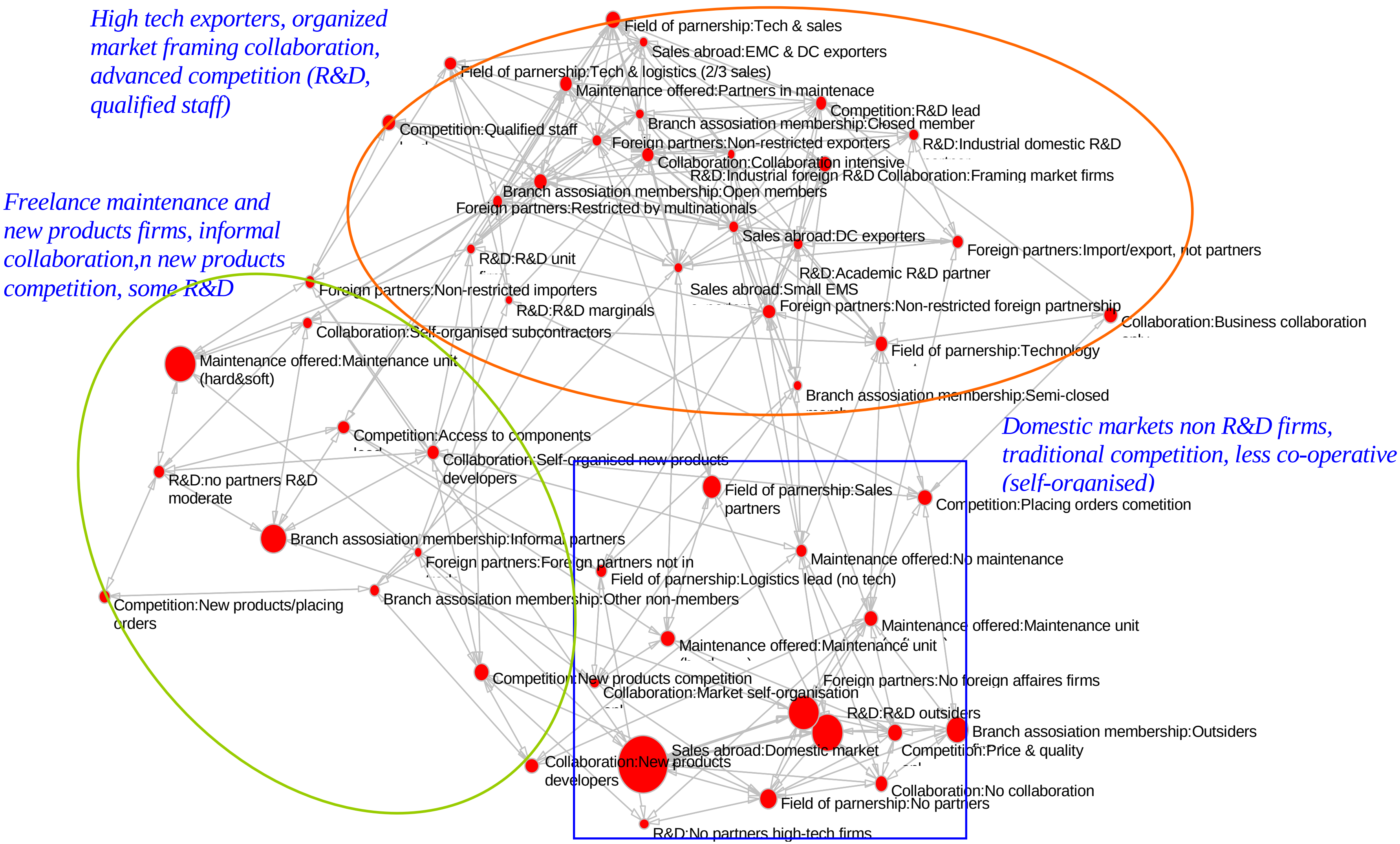
Business partners (Réseau Lu 20% cut of significance)



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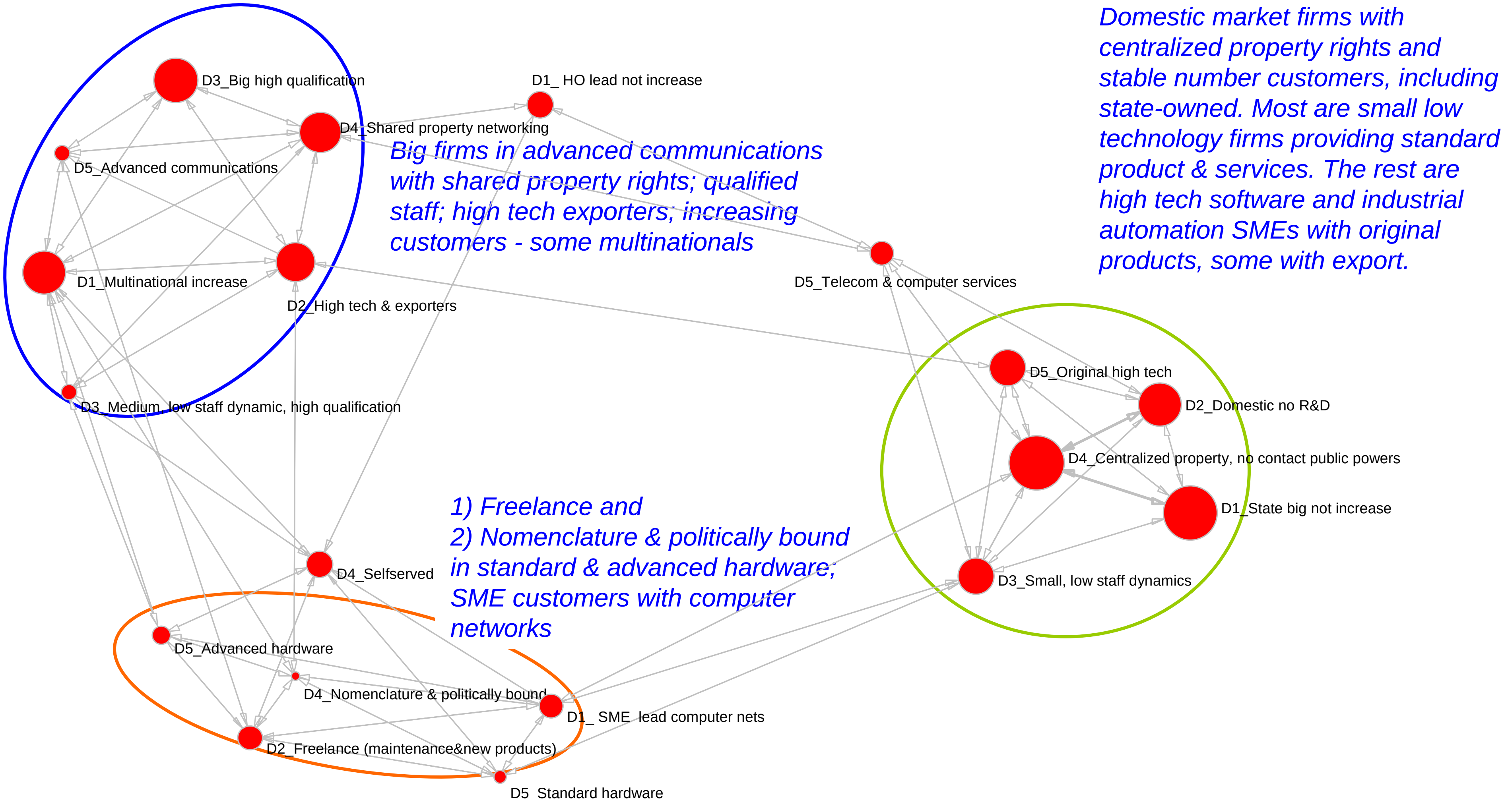
Relationships between five domains' profiles (second level)

(Réseau Lu 40% cut of significance)



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While giving us an overarching connectivity between different networks of relationships, TACTICS model did not played attention to *relative closeness* and *autonomy of* each networks. Often they have its own ‘time’ (internal dynamics) which should be take in account. Moreover, the ‘time’ of intra-network dynamics and ‘time’ of inter-network dynamics might be different!

Hence the idea of ‘stacked networks’ and modeling of their interactions…

The aim (specified):

Unlike TACTICS Study, keep the relative autonomy of networks (named ‘large’ - big number of actors involved).

Each large network modeled by the methods of discreet mathematics: the actors under their specific ‘network identity’ are represented as *stochastic automata, i.e. given the input and their internal properties, their output is a probabilistic distribution*.

In turn, each actor is considered as a small (Ego) network, comprising ‘his’ automata in the corresponding networks.

Two sources of ‘large networks’ dynamics:

1) some automata ‘innovate’ (does not react as supposed to the probabilities allowed by a script) in a purely stochastic manner;

2) some automata ‘innovate’ because of the ‘interference’ with the other automata of the same actor (interactions in the small *Ego* network)

Easy to be said, difficult to model!

We believe this is possible only by ‘local models’, based on the data from empirical studies of specific networks. They allow ‘anchoring’ of the optimal states the stochastic automata are tending to, instead these optimal states to be defined by purely calculative approaches, leading to ‘combinatorial burst’…

1. The network is an ordered set **G=(A, S)** of agents **A** and of their relations **S** $\subseteq$ **AxA.**

Mathematically this is an orientated graph with apexes **A** and edges **S.**

2. Every agent (subject or *actor* in a network) **a**$\in$**A** is represented as a *finite stochastic automaton* processing information (symbols).

Actually this includes not only exchange of signals (symbolic exchange), but also material exchange and bodily interactions They are modelled by specific scripts.

We assume that the exchanges are already formalized in different ways by the agents themselves.

3. Every network and the agents themselves are compound systems, in which processes with different speed and intensity are taking place, including the processes of *self-organization* and „*self-learning*”.

In these processes both the number and properties of the relationships **S** and the inner states of the agents **a** are tending towards an ‘optimal’ (minimal) configuration**,** so that they can process the incoming symbol information for *acceptable time* and pass on the output an *acceptable response* - for them and the other agents in the networs.

$\Rightarrow$ As a result of self-organization and „self-learning" both the relations in the network **S** and the agents **A** evolve with the aim to optimize the flows of exchange so that it can be process effectively.

III. 2. Network optimization processes and their results – eight points:

Eight assumptions about the indigenous process of network optimisation (based on empirical studies of real networks):

1. *The links in a given network **S** are grouped over time in layers* (or ‘planes’), characterized with *determinate speed and intensity of exchange* – S_1, S_2,…. S_n.

   Each of these layers could be considered as *an actor-network with specific properties and functions* and characterized by its typical timing and intensity of the information exchange between the agents;

III. 2. Network optimization processes and their results - eight points:

2) In an evolved network **S** the *agents break down into a set of finite automata* $\mathbf{a_1}$, $\mathbf{a_2}$,.... $\mathbf{a_n}$, everyone of which is responsible to his own sub-network: $\mathbf{a_k \Leftrightarrow S_k}$.

These are the concrete "personalities" or actors, which play a certain role in corresponding sub-network.

3) The separate layers (sub-networks) $\mathbf{S_1}$, $\mathbf{S_2}$,.. $\mathbf{S_n}$ interacts between them, but the *speed and the exchange intensity are different for each type of actors (finite automata) in the specific layers*.

We assume that the speed of the interactions between the layers (sub-networks) is slower by an order of magnitude. We could define this exchange between sub-networks S_1, S_2,.. S_n as **"cultural exchange"** in the network.

4) The interaction between sub-networks (layers) corresponds to the internal information exchange between finite automata $\mathbf{a_1, a_2, \ldots\ a_n}$ each agent **a** is composed of, i.e. its *Agent (ego) network.*

In social sciences the external manifestations of this internal exchange are often named as “cultural”, “ethnical” or with some other specific name.

III. 2. Network optimization processes and their results - eight points:

5) We assume that each of the networks **S** in its evolution strives for decrease or completely expels the interactions between its sub-networks (layers, planes). To this end rules are set up, which inhibit, suppress or even exclude these inter-layers' interactions.

The complete ignorance of inter-layer interaction, however, is impossible - the automata $\boldsymbol{a_1, a_2, \dots a_n}$ *aways preserve some symbol exchange between them as part of one and the same agent* ***a.*** *This 'outer' pressure engenders internal conflicts both inside the individual agent* ***a*** *and into the network* ***S.***

As a consequence….

6) Every agent **a** regularly falls in conflict situations, in which it have to 'choose' a strategy on his behavior.

This is possible to model: from game theory we knows that even in the simplest situation – for example antagonistic game – *mixed strategies* are the most effective.

(From a finite set of possibilities $\mathbf{v_1}$**,** $\mathbf{v_2}$**, …,** $\mathbf{v_r}$ the player choose in accidental way a concrete possibility **v** with probability **p**.

Von Neumann and Morgenstern's *Minimax theorem:* for every player there is only one mixed strategy - i.e. the distribution of probabilities ($\mathbf{p_1}$**,** $\mathbf{p_2}$**, …,** $\mathbf{p_r}$), in which the player achieves average maximum result from high number of attempts.)

Hypothesises on 6) :

- *When interacting in network* **S** *with the help of automaton* $\boldsymbol{a_k}$***,*** *the agent* ***a*** *performs a kind of self-learning,* to behaves in an optimal way, according to the results predicted by game theory.

- The ***a***'s *behaviour is not dictated by 'wise' considerations*" (or rational calculative process), but rather *it is a result of a selection process in frame of the network* **S** *and corresponding sub-networks:* if the agent does not behaves adequately enough he fall away from the network after some period of time.

This is precisely a ***natural selection process****,* and no just rational judgements, which finally defines the type of behaviour we describe here and below.

III. 2. Network optimization processes and their results - eight points:

7) The assumption 6) in turn leads to the requirement the automaton a, playing in sub-network **S**, to be not deterministic, *but stochastic one:* his 'decisions' at the output are not completely definite by the input and by his inwardly condition, that they are accidental.

(The distribution of probability of choice (p_1, p_2, …, p_r) for respective output v_1, v_2,… v_r will change depending of the assessment of the result of choices made according to criteria provided above, point 6)

- If the result of choice on $\boldsymbol{v_j}$ is unsatisfactory, the probability $\boldsymbol{p_j}$ decreases while other probabilities increase; if result of choice on $\boldsymbol{v_j}$ is satisfactory, the probability $\boldsymbol{p_j}$ increases and others decrease.

If these alterations in the probabilities' distribution are adequate to real situation, then distribution (p_1, p_2, … p_r) will tend to the optimal, as it follows from the Probability theory's Law of big numbers.

III. 2. Network optimization processes and their results - eight points:

8) In the framework of each sub-network (layer) $\mathbf{S_k}$ every automaton $\mathbf{a_k}$ is characterized both with the number of links (number of edges, which go in to him, and number of edges, who go out of him) and with the intensity of the interactions in these links. In other words for each edge (rib) $\mathbf{r_{ij}}$, which signifies symbol exchange from $\mathbf{a_i}$ to $\mathbf{a_j}$ we should attribute an level of influence $\mathbf{w_{ij}}$, that this exchange exert on $\mathbf{a}$.

This somewhat simplifies the mode - ***it became possible to consider the sub-network S as a full and ordered graph!***

As in the situations where there are no any interaction between $\mathbf{a_i}$ and $\mathbf{a_j}$ we will admit that $\mathbf{w_{ij}}= 0$. The necessity to introduce this assumption stems from practical observations. For example the phenomenon of *trust* – the agents trust differently various sources of information (of credit, of goods, etc.) and react to them in a different way.

III. 3. Modelling statics and dynamics of the stacked networks

- The evolution over time is described as an actor-network process with two regimes – *stationary* and *evolutionary*.

  The above assumptions (1-8) are sufficient to describe given network in a stationary regime. **But to describe an evolving network we *need possibilities of change in-built into the model.***

- Network evolution as induced by relatively small group of agents – such as the entrepreneurs in the economy. This group will be named **‘generators’** (of changes). The agents called ‘generators’ are possibly three types:

  1) who create - **creators**;
  2) who ‘sell’ the emerged relationships to other agents - ‘**sellers**’
  3) who link creators and sellers – **intermediaries**.

  The differences could be modelled by: specific script (marker); specific inner states of automaton; script generated by automaton.

The 'creators', unlike previous two group, are characterized by *the specific properties of their 'work' as stochastic automata.*

This means that according to the model they are supposed to generate new sequences of symbols, which did not existed in the network. Hence these new sequences of symbols did not influenced the internal states of the other agents, modelled as automata.

It is precisely the stochastic nature of these automata that allows us to model the process of network evolution.

Conclusion

The assumptions, presented above are not exhaustive. Our purpose is to build a models with the smallest possible number of assumption, that can describe quantitatively with some accuracy some empirically studied phenomena. To what extent the above assumptions are acceptable we will know after eventual realization of the model and the planned test with real data arrays.

Preliminary estimation of TACTICS Data for the purposes of designing a stochastic automaton

Specifying the subject of study:

To the feasibility of our ideas, we need to define the automaton based on statistical data on specific field of relationships. It will allows:

1. To define the internal states of the automaton, based on statistical dependencies between variables

2. To define the ‘stable states’ the network is tending to, based on frequency distribution of the modalities of the key network variable

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Definition of the sub-networks of ‘Business partnerships’

C1 – competition
C3 - collaboration
C8-9 – membership in associations/clubs
C13 – use of consultancy

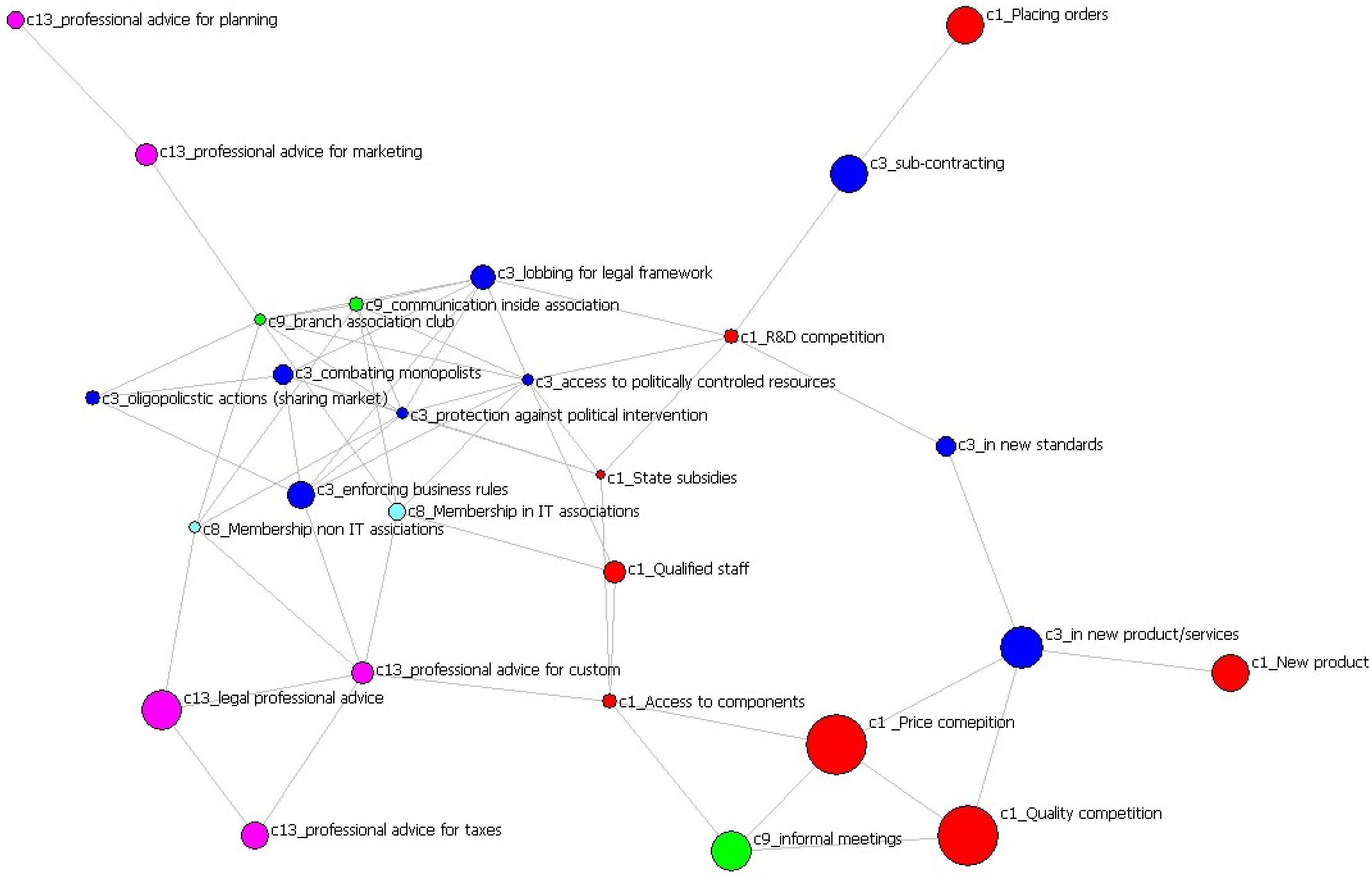
Degree of influence (relation’s weight)

C2 – the strongest competition
C4 - the strongest collaboation

Definition of the sub-networks of ‘Business relationships’

C1 – competition

- Price comepition
- Quality competition
- New product
- Placing orders
- Access to components
- Qualified staff
- State subsidies
- R&D competition



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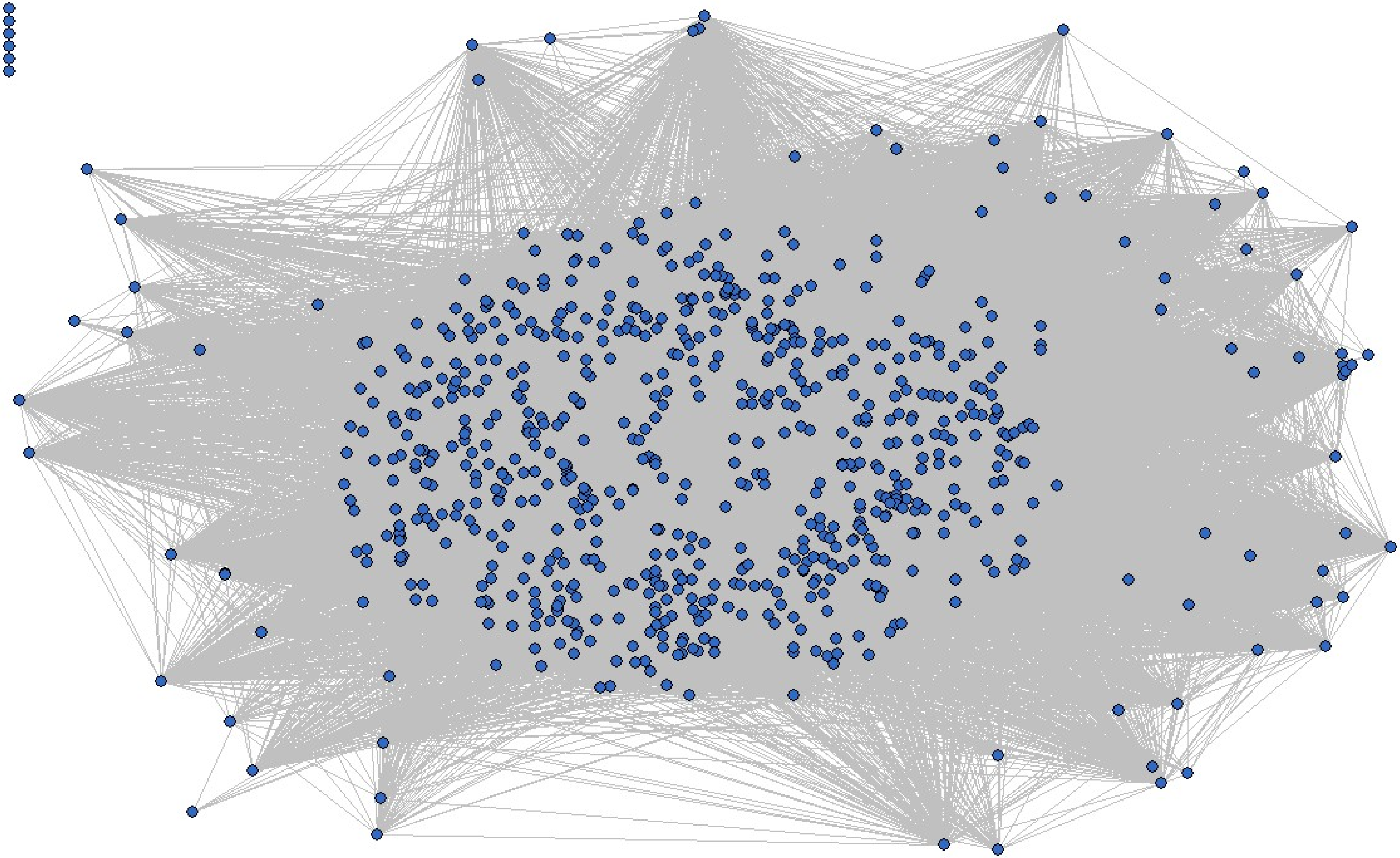
Network of relationships (dependencies) between variables in ‘Business partnerships”



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Thank you!