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Abstract

We attempted to analyze informal organizations of researchers sheltered in two departments of Biosystems Engineering, an emerging branch of Engineering. We did it by mapping and analyzing co-authorship among researchers. Biosystems is one of the most recent branches of Engineering, with roots grounded in problems and technics detached from Agricultural Engineering, Environmental Engineering, and Agronomics. The scope of this new field is not yet a unanimity among its practitioners. Despite the size of the two Departments studied be almost the same (24 researchers in ZEB, 26 in LEB), LEB is significantly more connected than ZEB. In ZEB just 9 (37.5 %) researchers had co-authored inside department at least one paper published from 2012 to June of 2014; in the same period, 21 (80.8%) of LEB researchers had shared the authorship of at least one paper. As expected at the light of their characteristic graphs, LEB performed better than ZEB. From 2012 to June 2014, LEB`s members published 212 complete papers, while ZEB`s published 150 ones. The average per researcher was 8.15 in LEB, and 6.25 in ZEB. The production of ZEB is also more concentrated in ZEB than in LEB. This fact is consistent with domination numbers of ZEB and LEB characteristic graphs. The history of ZEB and LEB sheds light on its informal organization. LEB seems to be an offspring of previous accumulated activity in the fields that originated Biosystems Engineering. The creation of ZEB was possibly top-down oriented.

Key words: *organization theory; informal networks; non-market transactions; institutions; graphs, graphs theory; connectivity.*

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1. Introduction

The proposition that a firm is “a legal fiction” constituted by “a nexus for a set of contractual relationships among individuals” (JENSEN; MECKLING, 1976) can be generalized to many others organizations, since one adopts a broad concept of contract. When two or more researchers are engaged in a project, they share a loosely defined set of “property rights” that provides incentives to cooperation, including the right to co-author papers and or other intellectual products. We attempted to analyze informal organizations of researchers sheltered in two departments of Biosystems Engineering, an emerging branch of Engineering. We did it by mapping and analyzing co-authorship among researchers.

Biosystems is one of the most recent branches of Engineering, with roots grounded in problems and technics detached from Agricultural Engineering, Environmental Engineering, and Agronomics. The scope of this new field is not yet a unanimity among its practitioners. Nunes and Viegas (2014) identified three distinct conceptions of Biosystems Engineering, quite possibly correlated with technological areas of origin of the professionals involved:

(i) Biosystems Engineering as the fusion of Agricultural Engineering, Forestry and Environmental, motivated by reducing the weight of agriculture and the new roles that the rural areas assumes in developed economies;

(ii) Biosystems Engineering as the application of Information Technology to management systems in which (nonhuman) living beings occupy a central role;

(iii) Biosystems Engineering as set knowledge and techniques required to intervene in the "living systems", ie complex systems with the ability of self-organization.

Cooperation inside scientific or technological communities can be identified by the activities of its practitioners, such as exemplar achievements, the common use of devices, materials and methods of research and development, the focus on a narrow set of relevant technological problems, and, among others, the presence of undergraduate and graduate courses, with stable over time similar curricula (NUNES; VIEGAS, 2014). Besides formal organizations, e.g. colleges, institutes, and departments, informal ones emerge spontaneously to explore complementary competences and or to allocate efficiently the effort of researchers.

Formal and informal structures can either enhance the performance of a research community or jeopardize resources by raising transaction costs. We try to detect informal groups inside formal organizations, to discuss if they match or not. Bilateral or multilateral cooperation relationships can promote the emergency of complex organizations, stable at least in the short run. Cooperation among members of an academic department can aim either the exploration of research complementary competencies, or the capture of available resources.

The performance of researchers sheltered in the same department is probably more sensitive to informal networks than to formal bureaucratic ties. The analysis of informal networks, we hope, will provide insights about how academic departments work, and will suggest elements to inform theirs development strategies. Concerning the two departments of Biosystems Engineering considered (ZEB at FZEA - Faculty of Animal Science and Food Engineering and Esalq, at Esalq - Luiz de Queiroz College of Agriculture, both belonging to University of São Paulo) does the formal organization materialized in the department reflects a previous cooperation network built spontaneously? Is the department a juxtaposition of weakly tied researchers? Does the relevant institutions (norms of university and college) contribute to shape the formal organization?

2. Methods

The primary source of data are the researcher's curricula published in CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico). We construct two adjacency matrices, one for each department of Biosystems Engineering (FZEA and Esalq), to capture relationships among researchers. If two members of the same department are both authors of a paper published from 2012 to 2014 (June), they are linked. Each one of adjacency matrices generated a graph by means of the software UCINET 6.519 (BORGATTI; EVERETT; FREEMAN, 2002). Then, we analyze and compare the resulting graphs: number of vertices and edges, components, degree of vertices, and so on. Finally, we try to interpret the attributes of graphs in terms of features of the communities of researchers.

3. Discussion

Some characteristics of the graphs are associated to relevant features of corresponding organizations. A graph is an object consisting of two sets: a set of vertices or nodes and set of edges.

In the present analysis of two Biosystems Engineering departments (ZEB and LEB), we construct a graph for each department, in which vertices or nodes represent researchers and edges denote that the researchers connected by the edge are coauthors of at least one paper published during 36 months from January 2012 to June 2014.

Co authorship has considered here an imperfect proxy of cooperation between researchers. However, on the one hand, there are cooperative activities that do not generate published papers; on the other hand, co authorship may arise from opportunistic behavior of researchers subject to the "publish or perish" rule. The performance evaluation indices adopted by universities may not weight the value of a paper by the (inverse) number of coauthors, conferring to papers some attributes of public goods. This is an inevitable limitation of the present study.

A graph in which it is possible to travel along edges from each vertex and reach any other vertex is “connected”. A connected graph is one in which every two vertices belonging to it are linked by an edge. The number of connected sub graphs, excluded the isolated vertex (zero degree vertices), denotes subgroups that interact weakly, or not interact at all. There is cooperation inside subgroups, but not between subgroups.

The degree of a vertex is the number of edges that join it to other vertices of the same graph. A vertex of degree zero is an isolated element; a vertex of degree one is joined to just one distinct vertex, and so on.

In a complete graph, every vertex is connected to all other vertices. If a graph G has v vertices, it will be complete if G has $(v^2 – v)/2$ edges, since connection is a symmetric, anti-reflexive relation. A complete graph depicts an organization in which every member interacts with every other members. Despite this organizational form maximizes the interaction among its members, the resulting structure will probably be inefficient, especially when the number of members (vertices) is large.

We assumed that an edge connecting two vertices produces opposite effects that compensate each other. An additional connection allows the exploitation of complementary competencies and hence produces a benefit greater than the sum of individual benefits, but it is not costless. Communication demands time and effort.

The members of an organization share a lot of common information. If everybody talks to everybody, it will emerge probably a lot of redundancy, and the connection costs will be high. We assume that vertices (= researchers) have a limited capability to process information, at least in terms of time dedicated to communicative action. In this perspective, an efficient organization has an optimal number of connections in which the marginal benefit equals the marginal cost of connecting.

A graph with many disconnected or isolated sub graphs represents an organization that is not able to explore the complementarities among its members. Such a graph may denote a high level of heterogeneity among members or among clusters of members. In this case, the formal organization does not reflect an intellectual effective cooperation, but cooperation and competition for resources bureaucratically allocated. The functions of formal organization, related to provision of infrastructure and services, are different from the functions performed by informal networks.

In a more efficient arrangement all vertices are connected, but in a resource saving way. Small teams may have a democratic structure, in which everybody is free to keep in touch with everybody else. Broader structures can connect these small groups by few specific channels.

The vertices of a graph may be ranked according their degree. The presence of some high degree vertices denotes a hierarchical structure, since some vertices seems to provide more benefits than other to whom connected them.

The classical firm depicted by Jensen and Meckling can be properly represented by a class of graphs named stars, in which only one edge has the maximum degree (v-1 edges, in a graph with v vertices), and all other vertices have degree one. This structure does not afford gains from complementarities among the vertices of degree one. Information is very concentrated, not to say monopolized by the nucleus of the star.

The organization faces a tradeoff between redundancy costs and value of productive interactions. Two extremes graphs represent the poles of this tradeoff: a trivial graph, in which all vertices are isolated, and the complete graph, where everybody connects everybody. In the first case, there is no redundancy, neither gains from cooperation; in the second case, there is full communication, but redundancy is maximum. In the limit, where everybody have the very same information set, the organization reproduces itself, and become unable to innovate. As Nelson Rodrigues, a Brazilian playwright, said, “Unanimity is dumb”.

Probably redundancy raises costs very fast with the number of edges in the graph. In small groups, acting like teams, redundancy will have lower cost, compared with large groups. Gains from cooperation emerge from members having complementary skills. If members are close substitutes from each other, the costs of interaction will probably exceed its benefits. In order to any two members act as complements, they cannot have the very same capabilities, but they need to share some common knowledge and common goals. Members extremely heterogeneous can hardly cooperate, because of differences related to scientific or technological paradigms, languages, perceptions, and even goals. Members that are too much similar each other sometimes can harvest benefits from division of tasks, but not from complementarities.

Hierarchical structures arise to cope with the informational trade off. A star type graph can be connected to small complete or almost complete sub graphs, and sub graphs can be connected each other by a small number of edges, maybe one. This kind of structure seems to be efficient to transfer relevant information between groups that work in parallel.

Despite the size of the two Departments studied be almost the same (24 researchers in ZEB, 26 in LEB), LEB is significantly more connected than ZEB. In ZEB just 9 (37.5 %) researchers had co-authored inside department at least one paper published from 2012 to June of 2014; in the same period, 21 (80.8%) of LEB researchers had shared the authorship of at least one paper.

Excluding isolated researchers, the LEB graph showed just one component or "piece" (see TRUDEAU, 1993, for a definition), while ZEB has two, one of them composed by two researchers collaborating among them, but isolated from the rest of the department.

The domination number of a graph is the minimal number of vertices that cover all vertices contained in the graph. In other words, the domination number is the cardinality of the minimal set of vertices that have as direct neighbors all vertices in the graph (CHARTRAND; ZHANG, 2012). Intuitively, the domination number is the number of vertices that brakes the graph, if they are dropped out. ZEB's domination number is just 2, suggesting that research activity inside the department is concentrated in few heads. The higher the domination number, more the group is integrated. Low domination numbers denote groups that probably will not reproduce themselves if key members abandon the group for any reason.

A department of a college can work as a "nexus of informal contracts" overlapping the formal ones. The informal and spontaneous network is associated to the performance of individuals and groups and suffers the influence of bureaucratic mechanisms of governance of colleges.

As expected at the light of their characteristic graphs, LEB performed better than ZEB. From 2012 to June 2014, LEB`s members published 212 complete papers, while ZEB`s published 150 ones. The average per researcher was 8.15 in LEB, and 6.25 in ZEB. The production of ZEB is also more concentrated in ZEB than in LEB. This fact is consistent with domination numbers of ZEB and LEB characteristic graphs.

The graph of LEB`s co authorship exhibits a nucleus formed by vertices of degrees 4 to 6. Vertices of lower degree are connected to the nucleus, suggesting that the structure of relationships fosters the absorption of new information from weak ties. LEB seems to be open to outsiders.

The division of labor is inversely proportional to concentration of research products (as a proxy of research effort). In ZEB, the outside information come through the researchers in the nucleus of the graph.

The history of ZEB and LEB sheds light on its informal organization. Before the creation of LEB, Esalq offered undergraduate courses in Agricultural Science, Forestry, and Environmental Management, domains closely related to Biosystems Engineering. Esalq also offers several graduate courses, Agricultural Engineering Systems among them. FZEA offered undergraduate courses in Animal Science and Food Engineering before the creation of Biosystems Engineering undergraduate program. Until now, FZEA does not create a graduate program in Biosystems Engineering.

LEB seems to emerge as an offspring of previous accumulated activity in the fields that originated Biosystems Engineering. The creation of ZEB was possibly top-down oriented. Since a department is also a device to capture resources bureaucratically allocated, agency problems are not negligible to understand changes in formal organization of Brazilian public university.

4. Conclusion

Graph theory seems to be a promising framework to model social networks. We expect to apply quantitative methods to identify attributes of networks and to associate these attributes to institutional environment and the history of organizations.

We constructed graphs representing co authorships inside two Biosystems Engineering departments (ZEB and LEB) belonging to two colleges (FZEA and Esalq respectively) of

University of São Paulo (USP). The underlying assumption is that co authorship is closely related to cooperation among researchers.

The very same formal organization (departments organized according the statutes of the University) supports different informal networks of researchers. The informal organizations of LEB and ZEB are different with respect to connectedness and concentration. Publishing performance reflects these differences. As well institutions, informal organizations matter.

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	ZEB	LEB
Vertices	24	26
Vertices - degree 0	15	5
Vertices - degree 1	2	7
Vertices - degree 2	2	2
Vertices - degree 3	2	4
Vertices - degree 4	1	2
Vertices - degree 5	2	3
Vertices - degree 6	0	2
Edges	13	29
Connected sub graphs	2	1
Dominating number	2	7

Table 1 – Attributes of networks inside Departments of Engineering Biosystems (ZEB and LEB)

	ZEB	LEB
Sum	150	212
Average	6.25	8.15
Standard Deviation	8.08	6.33
HHI	1114	617

Table 2 – Papers published in scientific and technological arbitrated journals

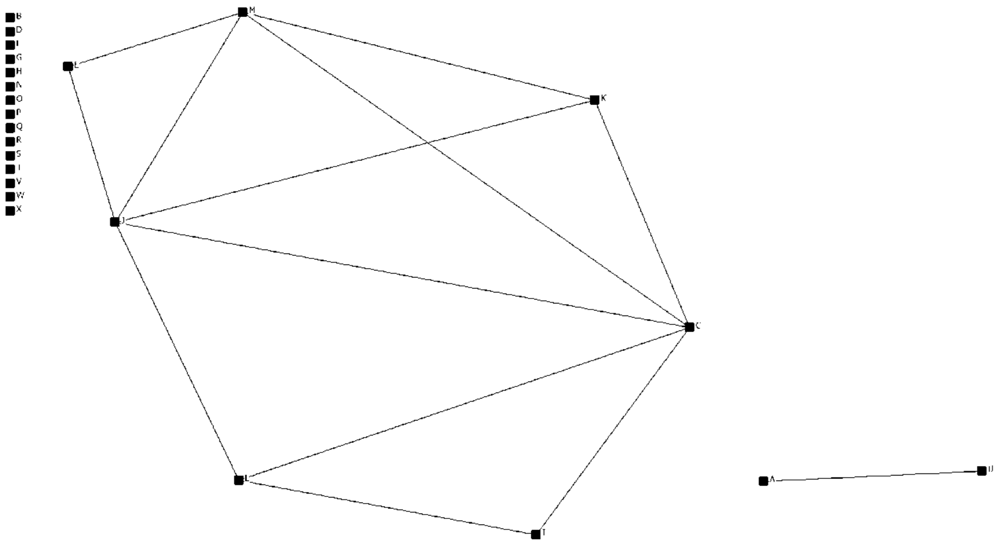

Figure 1 – Co authorship inside ZEB - Departament of Biosystems Engineering (FZEA-USP)

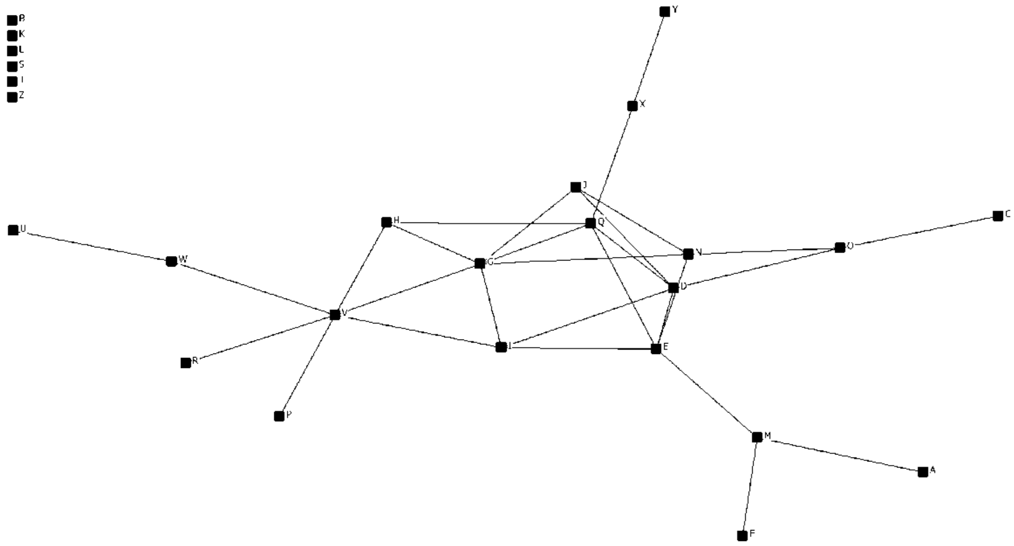

Figure 2 – Co authorship inside LEB - Departament of Biosystems Engineering (Esalq – USP)