Multilayer network analysis of innovation intermediaries' activities:

methodological issues and an application to a regional policy programme

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ISSUE The growing importance of policies sponsoring innovation intermediaries (Howells, 2006; Lazaric et al, 2008; Kauffeld-Monz and Fritsch, 2013; Russo and Rossi, 2009; Caloffi et al, 2015) asks for appropriate analytical tools. **We suggest a network perspective (a) to analyse the multidimensional activities of innovation intermediaries and (b) to assess the contribution of the agents involved in their activities.**

CASE STUDY Methodological issues are addressed within the context of an application to a regional innovation policy in Tuscany. The industrial structure of this region includes a large number of **small and medium-sized enterprises** (SMEs) having relatively few connections with universities and other regional research hubs. In the period 2011-2013, the regional government funded 12 'innovation poles' to strengthen the regional innovation system; to support the development of a range of knowledge-intensive services; to encourage technology transfer and to stimulate the innovation capabilities of regional (SMEs). Specific goal of the innovation poles: to support the regional innovation system by promoting common activities between regional actors: universities, research organizations, KIBS, large businesses, SMEs.

RESEARCH QUESTIONS

Innovation intermediaries create links between agents, facilitating the exchange of information and creating opportunities for joint actions to boost innovation. In turn, through the different activities they perform, those agents create indirect connections between the intermediaries.

a) centrality of agents

With regard to the case study, the 12 innovation intermediaries (organized to provide a range of services, including brokering and matchmaking) have **mobilized a large number of agents** that were directly involved **with different roles in the creation of the regional system of technology transfer**: 46 organizations managing the poles, 420 technicians and consultants, more than 100 research laboratories and 8 incubators were pooled to supply innovative services to more than three thousand members, mainly SMEs, of the 12 poles.

- → **To which extent are the poles pivotal agents in those multidimensional interactions?**
- → **Who are the other pivotal agents?**

b) detecting the overlapping communities

To analyse the structure of the network, we focus on overlapping communities of agents doing different activities together.

- → **What is the emergent structure of communities supporting the regional innovation system?**

METHODOLOGY: multilayer perspective

We adopt the multilayer analysis introduced by De Domenico *et al.* (2015, PRX), who extend to multiplex networks the setup developed by Rosvall and Bergstrom (2007), based on **information theory**. *Infomap* solves the main problem with Newman and Girvan (2004) in identifying communities of very different sizes. The algorithm operates by minimizing the description length of a network and the loss of information due to clustering. Since there is no reason to exclude **overlapping communities**, the adoption of *Infomap* to multilayer analysis is more appropriate than other methods that maximize modularity producing disjoint clusters. **By taking into account the multilayer structure of networks one can assess new features emerging from nodes interacting in the different layers**.

A random walker is used to compute flows among nodes (in the same and different layers). As for teleportation in Page Rank algorithm, the random walker jumps, with probability r=0.15. If two nodes in two different layers tend to be visited with similar patterns, they are associated to the same community that becomes a multi-layer community. **As layers are themselves informative, the outcome is a more realistic and informative clustering**. For each agent-node, **the algorithm computes the total information flow** resulting in the aggregate network and from the state-node's activity in the various layers.

Moreover, the algorithm identifies the **overlapping communities** and **the intercohesive nodes** (Sewell 1992; Stark & Vedres 2008).

With regard to our case study, we identify **six modes of interaction-layers** (Fig. 1): Shareholding of organizations managing the poles; Leading and managing the poles; Collaboration agreement, Service provision; Being seconded to a managing organization and providing work services to a pole; Membership to a pole. Descriptive statistics of agents' activities in the layers are summarized in Fig 2.

Fig. 1 Graph of 3,896 agents, by mode of interaction (layer)

*Legenda: **nodes' colours**: black nodes with white figures: poles; managing organizations; KIBS; personnel, all other types of agents, **edges' colour:** by layer*

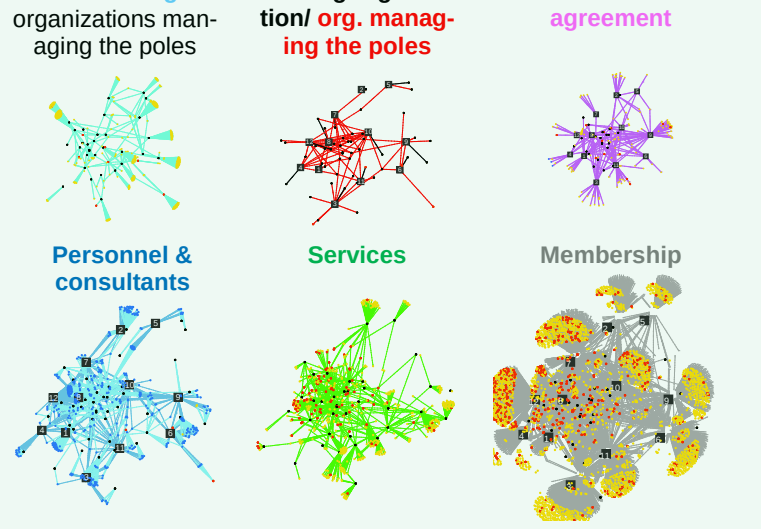
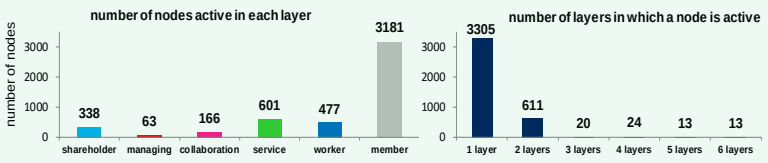


Fig. 2 Agents' activities in the six layers: descriptive statistics



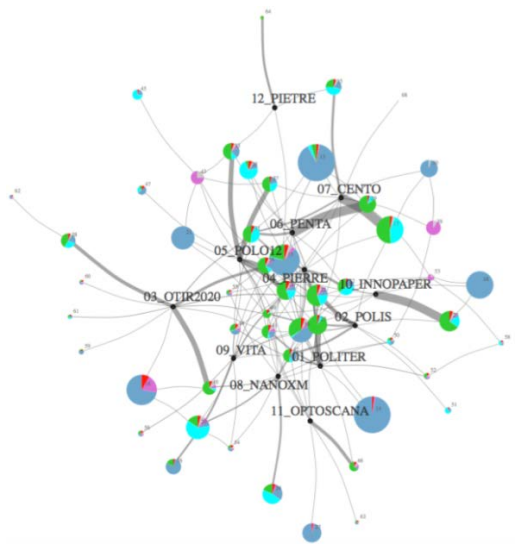
MAIN RESULTS

Pivotal agents: 55% of the Infomap flow is due to 58 agents, not only the 12 poles, but also the 46 managing organizations (with, respectively, 37% and 18% of the total flow).

Aggregate Infomap analysis: produces a large number of overlapping communities (44 out of 45) with 1,019 intercohesive agents (26% of total) active in 2 to 7 communities.

Multilayer analysis: produces 71 communities, 63 of them are overlapping (represented in Fig.3), with 605 intercohesive agents (15% of the total) mainly active in 2 communities.

Fig. 3 Multilayer overlapping communities



*Legenda **nodes' size** proportional to Infomap flow (*the 12 communities centred on poles are not represented in proportion to their size)*; **slices** represent the share of flow per layer (see colours in Fig 1); **edges' width** proportional to the number of agents in common between communities*

LESSONS from multilayer analysis

Methodological issues: (a) *Identification of layers*: is crucial for an effective analysis; (b) *Weights of interactions matter*: they are not comparable; (c) *Directedness*: in the case study does not affect ranking; (d) *Multilayer analysis* is very informative on structural aspects. **Analysis & interpretation:** (a) structural characters of the intermediation infrastructure; (b) Composition of the different communities; (c) Characteristics of intercohesive agents. **Current development**: modelling the relation between agents' Infomap flow and their performance.

Acknowledgments

Poli.in_Analysis and modelling of innovation poles in Tuscany [Analisi e modellizzazione dei poli di innovazione in Toscana] is a research project co-funded by Tuscany Regional Administration and University of Modena and Reggio Emilia, Italy

http://www.poliinnovazione.unimore.it/

SELECTED REFERENCES

Caloffi, A., et al. (2015) in *Handbook on Complexity and Public Policy*

De Domenico M. *et al*., (2015) *Physical Review X*

Kauffeld-Monz, M., M.Fritsch. (2013) *Reg. Studies*

Lazaric, N.C. *et al*. (2008), *Reg. Studies*

Rosvall, M., C.T.Bergstrom. (2007) *Proceed. Nat. Acad. Sciences*

Russo, M., F. Rossi. Evaluation (2009)