Emerging communities in multilayers networks: analysis of a regional policy programme

Margherita Russo* | Simone Righi Riccardo Righi
Department of Economics | University of Modena and Reggio Emilia | Italy
Annalisa Caloffi
Department of Economics and Mangement | University of Padua | Italy
Federica Rossi | Birkbeck University | London | United Kingdom
*corresponding author margherita.russo@unimore.it

poli.in — Analisi e modellizzazione dei Poli di innovazione in Toscana

REGIONE TOSCANA — UNIMORE UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

Issue: intermediaries in innovation processes

With 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), a need has emerged for appropriate instruments to analyze their activity.

In our approach we adopt a network perspective to highlight the multidimensional network created through the activities undertaken by innovation intermediaries.

Data: Tuscany policy programme 2011-2014

We ground our analysis on a unique database of a regional policy supporting the creation of specialized intermediaries in the Italian region of Tuscany. In the programming period 2007-2013 (effectively starting from 2010), the regional government of Tuscany funded twelve '**innovation poles**'.

Tuscany's industrial structure includes a large number of SMEs having relatively few connections with universities and other regional research hubs. **Goal of the policy:** to strengthen the regional innovation system; to support the development of a range of knowledge-intensive services; to encourage technology transfer and stimulate the innovation capabilities of regional small and medium-sized enterprises (SMEs)

The regional innovation intermediaries (organized to provide a range of services, including brokering and matchmaking) bring together a number of universities and innovative service providers with potential end-users of these services. Their main goal is to promote linkages between regional actors: universities, public research organizations, KIBS, large businesses and SMEs.

Research questions

a) centrality: of innovation poles vs other agents

The creation of innovation poles has 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, technicians, 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. Through the different activities they perform, the various agents create connections between the poles; the poles, in turn, create links between agents, facilitating the exchange of information and creating opportunities for joint actions to boost innovation. Table 1 summarizes **multiple belonging** of the agents involved in the system created thorough the poles.

Table 1 From the individual poles to the regional innovation system: number of poles in which individual agents belong

	1 Pole	2 Poles	3 Poles	4 Poles	5 Poles	Total
consortium's particpants	26	13	2	4	1	46
Laboratories	>100*	43	8	1	0	>100
member companies	2.599	411	140	16	1	3.154

A relevant question is to assess whether the 12 poles have different centrality positions in the systems and to which extent other agents play a central role.

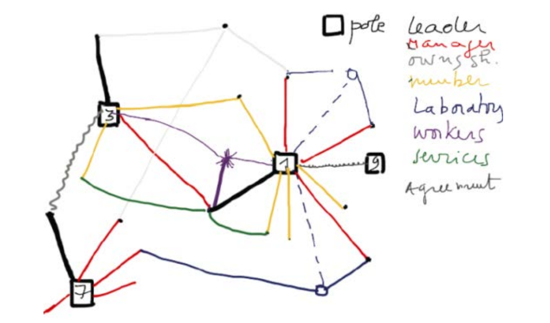
b) detecting the overlapping communities mobilized by the creation of intermediaries in the multilayer regional innovation policy

We analyze the intermediaries infrastructures with a focus on the multidimensional linkages across those intermediaries infrastructures. This kind of "network of networks perspective of analysis" asks for identification of more relevant agents and interactions. We identify **nine** modes of interaction grouped into two main domains that support the entire system of the poles.

First domain_**agents promoting the system of poles**: this network involves both the organizations **directly managing the poles**, through the creation of temporary associations (with a **leader**), and the **organizations having shareholdings in those managing organizations**.

Second domain_**competence networks**: it is initiated by the system of the poles (**managing organizations and the leader**), through the **provision of services** by the various operators, and also through the **skills of employees and consultants**, the **collaboration agreements** with parties outside the poles, and through the **facilities of laboratories and incubators**. Fig. 1 sketches the types of relations across different layers. By creating such multilayer networks we focus on interrelations between the poles based on the activities, undertaken jointly, in supporting the member companies.

Fig. 1 Nodes, linkages, layers



Methodology: multilayer network perspective

For each of these two domains we examine the **characteristics of the networks** and the **centrality index of the agents involved**. Moreover, by adopting the analysis of multilayer networks (recently developed by De Domenico et al., 2015), we identify and compare the **emerging communities in aggregate networks and in the multilayer networks** with regard to the networks promoting the poles and in the competence networks.

Rosvall and Bergstrom (2007) introduced a method based on information theory to reveal communities. It solves the main problems with Newman and Girvan (2004) especially in identifying communities of very different sizes. It operates by minimizing the description length of a network and the loss of information due to the clustering. De Domenico et al. (2015) extends the setup to multiplex networks, showing that by taking into account the multilayer structure of networks one can see new features emerging from nodes interacting in the different layers. **Communities maximize the probability of remaining into a cluster when starting from one of the nodes in that community.** A **random walker is used to compute flows among nodes in the same layers**. With some probability (r=0.15) the random walker jumps across layers (such as the teleportation in the PageRank algorithm). If two nodes in two different layers tend to be visited with similar patters they are associated to the same community that becomes an multi-layer community. Thus the algorithm is able to identify both communities identified in one single layer and communities identified on multiple layers. As layers are themselves informative, the outcome is a more realistic and informative clustering.

Results

Table 2 summarizes the descriptive statistics of the network promoting the poles, the competence network, the full multilayer network and the network of each individual layer. The first three are connected networks.

Table 2 Descriptive statistics

	Network promoting poles	Competence network	Full Multilayer network	Service	Service lab	Own Lab	Share holder	Worker	Seconded	Collaboration	Cons Leader	Manag Org
Number of Nodes	369	1472	3050,5	733	167	227	340	432	466	166	24	54
Number of Edges	523	2393	4247	790	155	186	365	520	464	281	24	140
Avg Shortest Path	4,662	3,974	4,005	Inf	Inf	Inf	Inf	Inf	Inf	3,333	Inf	2,700
Density	0,0069	0,0025	0,0020	0,0290	0,0112	0,0073	0,0063	0,0056	0,0043	0,0205		0,0978
Diameter	8	7	7	Inf	Inf	Inf	Inf	Inf	Inf	5	Inf	5
Clustering	0,1062	0,6129	0,5306	0,0097	0,0000	0,0210	0,0007	0,0000	0,0086	0,0581	0,0000	0,1021
Mean Degree	2,6775	4,1050	3,8523	2,1555	1,8563	1,6388	2,1471	2,4074	1,9914	3,3855	2,0000	5,1852
Num Connected components	1	1	1	8	12	48	4	2	16	1	3	1
% of Nodes Giant Component	100%	100%	100%	96%	35%	29%	96%	95%	74%	100%	67%	100%

Aggregate network vs multi-layer network

Fig. 2 and Fig. 3 present graphs of the aggregate network and those of each individual layers. Colors group different categories of agents. The **aggregate graph** (Fig. 2) shows a more connected zone and several peripheral agents; from the **individual layers** (Fig. 3) we can single out who are the most connected agents. However in both cases **we miss the interplay of some agents on more than one layer**.

Fig. 4 highlights multilayer flows vs aggregate flows: it shows that by **collapsing layers in a single networks reduces the flow index and also changes the relative position of some agents**. Ranking of the top 36 agents (selection to include all the 12 poles) is presented in Fig. 8.

From Fig. 5 we observe the similarity across layers: some managing organizations are more active than others in several layers and belong to the same communities.

Fig. 6 and Fig. 7 compare the multilayer flow, respectively, with the aggregate flow and the eigenvector centrality.

Fig. 2 Graph of the aggregate network (categories of agents)

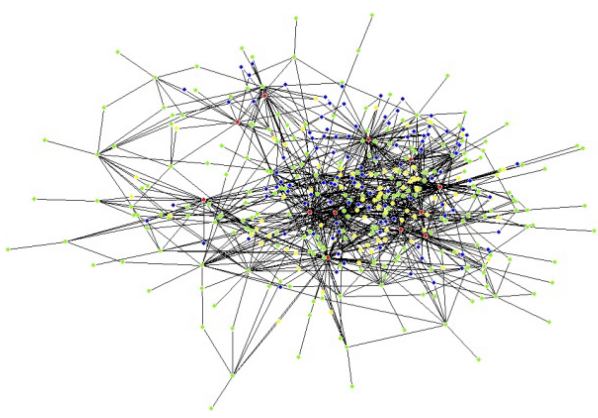


Fig. 3 Graphs of each layer

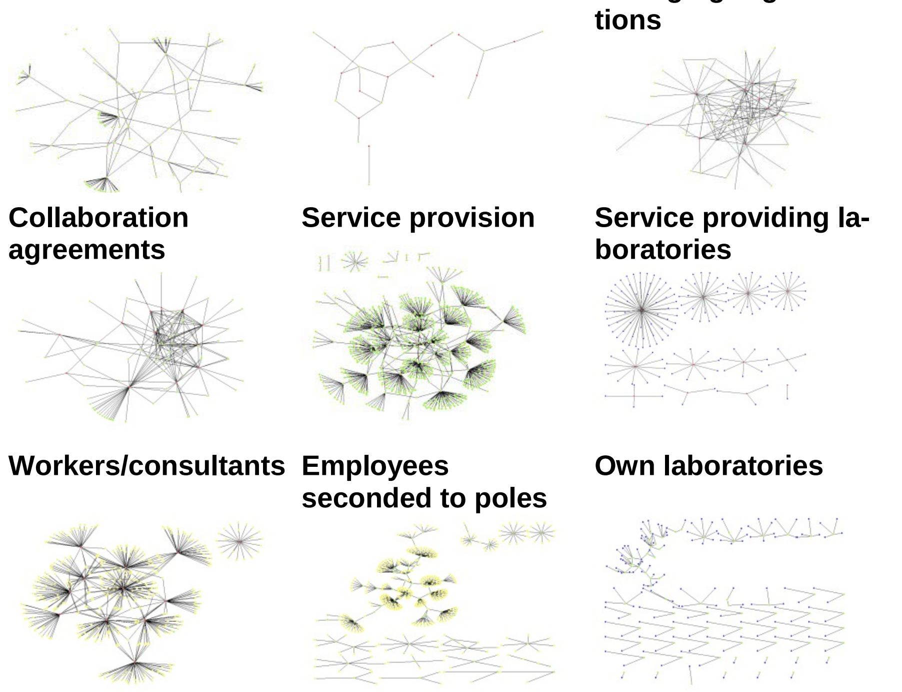


Fig.4 Active nodes per layer

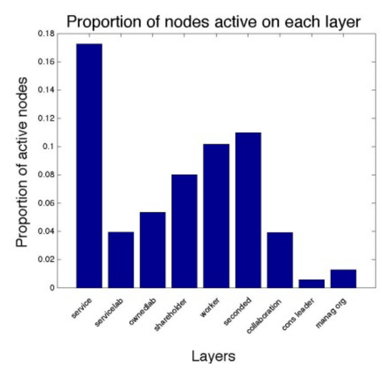
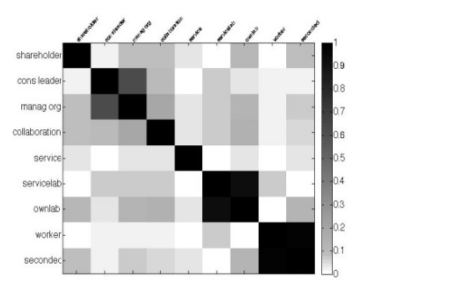


Fig.5 Similarity across layers



Fraction of nodes in different network layers that are assigned to the same communities

Fig. 6

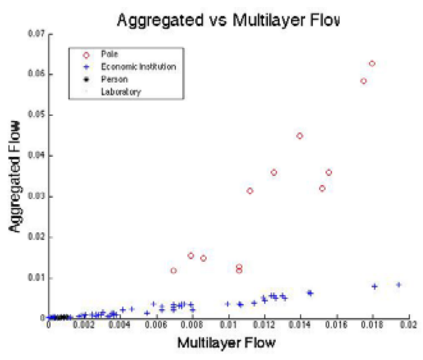


Fig. 7

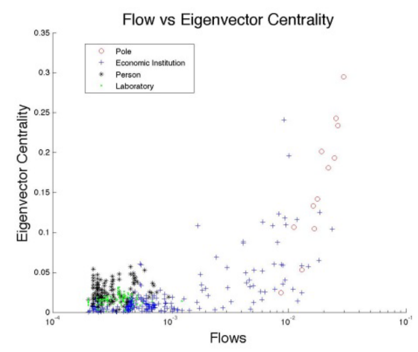
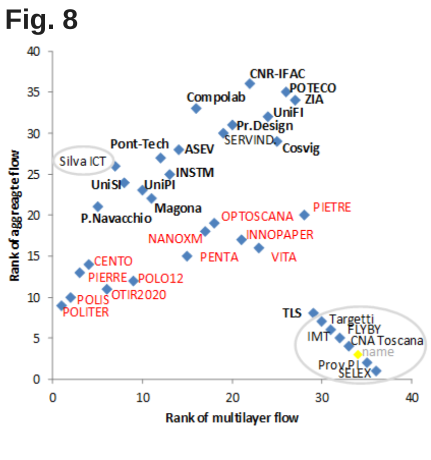


Fig. 8



CONCLUSION: In the regional innovation system, innovation poles are supported by the multidimensional activity of a number of managing organizations, and some of them have a more central role in the system: not only university and research centers, but also some service centers, and even individuals, are in the top position in information flows.

References

Caloffi, A., F. Rossi, and M. Russo. "The emergence of intermediary organizations: a network-based approach to the design of innovation policies." Handbook on Complexity and Public Policy (2015): 314.

De Domenico, M., et al. "Identifying modular flows on multilayer networks reveals highly overlapping organization in interconnected systems." Physical Review X 5.1 (2015): 011027.

Kauffeld-Monz, M., and M. Fritsch. "Who are the knowledge brokers in regional systems of innovation? A multi-actor network analysis." Regional Studies 47.5 (2013): 669-685.

Lazaric, N., C. Longhi, and C. Thomas. "Gatekeepers of knowledge versus platforms of knowledge: from potential to realized absorptive capacity." Regional Studies 42.6 (2008): 837-852.

Rosvall, M., and C.T. Bergstrom. "An information-theoretic framework for resolving community structure in complex networks." Proceedings of the National Academy of Sciences 104.18 (2007): 7327-7331.

Russo, M., and F. Rossi. "Cooperation Networks and Innovation A Complex Systems Perspective to the Analysis and Evaluation of a Regional Innovation Policy Programme." Evaluation 15.1 (2009): 75-99.

Acknowledgements

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

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