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Clusters and communities: raising the bar towards open innovation 2.0 paradigms

Oscar Tamburis
Department of Veterinary Medicine and Animal Productions, University of Naples Federico II, Naples, Italy, and

Isabella Bonacci
Department of Economics, Management and Institutions, University of Naples Federico II, Naples, Italy

Abstract

Purpose – The growing success of open innovation practices in many firms raises the question of whether such principles can be transferred for reinventing public sector organisations. A paradigm based on principles of integrated collaboration, co-created shared value, cultivated innovation ecosystems, unleashed exponential technologies and extraordinarily rapid adoption is the so-called Open Innovation 2.0. The development of this approach reflects the perception that the innovation process has evolved. This study aims to explore new ways to study healthcare networks as key tool for innovation creation and spreading, by deploying the emergent paradigm of Open Innovation 2.0.

Design/methodology/approach – The study investigates the impact of clusters, or localised networks, involving industrial, academic and institutional players, in the (bio)pharmaceutical setting; the aim is to enrich the line of inquiry into cluster-based innovation by applying a social network analysis (SNA) methodology, with the aim to provide new perspectives for recognising how the set of interactions and relationships in the (bio)pharmaceutical context can lead to higher levels of knowledge transfer, organisational learning and innovation spreading.

Findings – Starting from the top ten (bio)pharmaceutical companies, and the top ten contract research organisations (CROs), the study helps understand that: the combination of the single big pharma company and the CROs to which great part of the work is externalised, can be compared to a community of transaction that deals with the supply and demand of a specific kind of goods and services; clusters can comprise either a single one or more communities of transaction; virtual CROs act as a community whose all components participate to the creation of value (co-creation), thus comparable to a certain extent to a community of fantasy.

Originality/value – Based on the novelty of the OI2/SNA combination approach to deal with the "complex" (bio)pharmaceutical industry, the outcomes of the present study mean to highlight: a comprehensive perspective for understanding the dynamics of modularity and their implications for innovation networks; the presence of innovation networks as main mean to promote and support paths of knowledge creation and transfer.

Keywords SNA, Clusters, Open innovation 2.0, (Bio)pharmaceutical sector, vCROs

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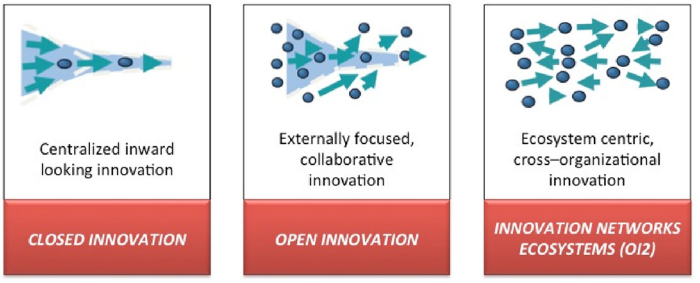
Introduction: shifting from OI to OI2

Innovation is a process both based on inspiration, as expressed by inventiveness, and on perspiration, as expressed by the number of people and time expended to achieve the final product (Levirs, 2014). In Schrage's (2004) terms, innovation = invention + adoption. Innovation means, therefore, capturing a number of changes in firms' approach to strategic

management of technology, that have emerged over the years as a response to significant modifications in the competitive environment, e.g. increased dynamicity and turbulence, the globalisation of markets and business activities, accrued competition (Gupta and Wilemon, 1996) and rapid advances in technology development (Bayus, 1994). In particular, these changes include the end of the linear model of innovation (Ortt and Smits, 2006), firms' increased reliance on external sources of technology (Chatterji, 1996; Roberts, 2001), their enhanced attitude towards using multiple channels for technology exploitation (Lichtenthaler, 2004) and the internationalisation of industrial R&D and innovation activities (Teegen and Doh, 2002; King and Martinelli, 2005) . In response to these external changes, companies have reorganised their innovation process becoming more open to the acquisition and integration of information, knowledge and skills that come from outside organisations, but are functional to their innovative strategies (Chesbrough, 2003; Lichtenthaler, 2008). A process of disintegration of the vertical chain of assets and skills necessary for innovation has, therefore, taken place, bringing to the affirmation of the paradigm of open innovation (OI), through which companies begin to acquire ideas and technologies from outside and, at the same time, exploit their ideas to other companies and technologies unused. In other words, OI can be defined as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation, respectively" (Chesbrough and Crowther, 2006).

The following step in the evolution of this paradigm is based on principles of integrated collaboration, co-created shared value, cultivated innovation ecosystems, unleashed exponential technologies and extraordinarily rapid adoption and goes under the name of open innovation 2.0 (Figure 1). For EU's Open Innovation Strategy and Policy Group (OISPG: European Commission, 2014, 2016), the OI2 paradigm is an innovation model based on extensive networking and co-creative collaboration between all actors in society, spanning organisational boundaries well beyond normal licensing and collaboration schemes. Its characteristic is the use of a "quadruple helix model" where government, industry, academia and civil participants work together to co-create the future and drive structural changes far beyond the scope of what any one organisation or person could do alone. This quadruple helix innovation approach is most successful when there is a shared vision and shared value is created. The development of this approach clearly reflects the perception that the innovation process has evolved, moving from vertically integrated companies to companies large and small that play an active role within a network (Langlois, 2003).

The constant progress of the OI paradigm is tied to the multiple variations affecting the surrounding environment, amongst which it has to be mentioned the need to involve as



Source: Adapted from Curley and Salmelin (2013)

Figure 1.
The evolution of innovation

many people as possible within the innovation process, as well as the importance of support from ICTs, that play as a first rate factor of cooperation between subjects (Marino and Tamburis, 2005). A central role is then played by the concepts of value and shared vision: corporations change their logics, shifting from a small-period optimisation of financial performances, to the pursue of a broader optimisation of both internal performances and social conditions – that is, the creation of value for the social context the corporation lives in. Speaking therefore of OI 2.0 (OI2, from now on) means the search for a new organisational logic, based on principles such as: integrated cooperation, innovation ecosystems implying the participation of multiple actors within the innovation processes, rapid adoption and use of technologies able to generate high performing values, thanks to which the traditional "borders" between activities fade out (Song *et al.*, 2009), and the creation of networking between innovators and the surrounding environment becomes possible. Similarly, the existing gaps between lab researchers, R&D activities and the final users, are overcome, in favour of an easier and more effective "open cage" of interactions.

It is important to note that OI2 (as was OI in the first place) does not propose a strategy of working with external parties; instead, it is about leveraging internal R&D. OI2 encourages companies to expand their pool of resources to achieve their growth objectives. Such phenomenon has mainly taken place in sectors characterised by complex innovative processes and long lead time, as in the case of the (bio)pharmaceutical industries, which use the advancement in information technology to make the innovation initiatives multilateral in nature: this involves multiple actors from all over the world making the innovation network boundary more porous. Pharmaceutical biotechnology is a relatively new and growing field in which the principles of biotechnology are applied to the development of drugs. A majority of therapeutic drugs in the current market are bioformulations, such as antibodies, nucleic acid products and vaccines. Such bioformulations are developed through several stages that include: understanding the principles underlying health and disease; the fundamental molecular mechanisms governing the function of related biomolecules; synthesis and purification of the molecules; determining the product shelf life, stability, toxicity and immunogenicity; drug delivery systems; patenting; and clinical trials (Mallela, 2010). This means that ICTs push towards the OI2 paradigm by providing them with more flexible approaches to the innovation, allowing therefore a greater integration between traditional and innovative services and products, and eventually shifting from an innovation decided and driven from few high-qualified subjects, to an innovation born from multiple and multidisciplinary skilled actors. Thus, users are no longer seen as passive receptors, but as active parts of the innovation process, or better a value co-creator. It is easy, therefore, to conclude that the more the connectivity and networking dimensions increase, the more the users will be called to act as value co-creators, with high expectations (Curley and Formica, 2013).

The objective of this paper is to demonstrate how new forms of organisation (CROs: contract research organisations) that arise in the big pharma field in response to these changes are intended as development platforms for innovation, especially considering that their synergistic combination with the use of ICTs determines the transition from real forms to virtual forms of organisation (vCROs) able to spread innovation more quickly and make more lasting effects. In particular, the present work intends to investigate the impact of clusters, or small worlds – i.e. localised networks involving industrial, academic and institutional players: D'alise *et al.* (2014), Giustiniano and D'Alise (2015) – of vCROs in the (bio)pharmaceutical setting; the aim is to enrich the line of inquiry into cluster-based innovation by applying a social network analysis (SNA) methodology, with the aim to provide new perspectives for recognising how the set of interactions and relationships in the

(bio)pharmaceutical context can lead to higher levels of knowledge transfer, organisational learning and innovation spreading: this makes possible to study how (bio)pharmaceutical companies have organised over time to exchange technologies and pieces of knowledge with different classes of external organisations (e.g. universities, competitors) along the different stages of the R&D and innovation development process (e.g. drug discovery and drug development), in accordance to the fundamental principles on which the OI2 paradigm is based.

Innovation networks ecosystems in the (bio)pharmaceutical industry

High-technology industries with their rapidly developing innovation and knowledge base serve as an important source for national economies. In such a dynamic and competitive industrial environment, no single firm has the ability to keep pace with the growing scientific and technological progresses without external partners (Cantner and Rake, 2011). This is particularly true for pharmaceutical research and development (R&D), remained a sequential and insular process for the most part of the past 50 years (Getz and Kaitin, 2012), a situation that – by the way – stands amongst the triggers of a major decline in R&D productivity in the industry during the first decade of the twenty-first century, as widely documented (DiMasi *et al.*, 2003; Munos, 2009). The adoption of an initial OI perspective in the high-tech sector of pharmaceutical biotechnology has, therefore, represented a new R&D model that holds great promise in transforming the drug development process by integrating capabilities and expertise amongst a diverse collective of internal and external stakeholders. The creation of a tight inter-firm network of R&D collaboration has become an unavoidable strategy for innovative companies (Chiaroni *et al.*, 2008; Roijakkers and Hagedoorn, 2006; Salman and Saives, 2005) and, as a result, the sector has witnessed a sharply increasing frequency and typology of inter-firm partnerships between large established pharmaceutical firms and a range of biotechnology companies (Hagedoorn and Roijakkers, 2002; Powell and Grodal, 2005; Rothaermel, 2000), successfully creating a track for high-technology companies to achieve progress in knowledge and innovation (Roijakkers, 2003). The R&D network formation grounds on the choice-based perspective that is emphasised in the network theories: from this view, the cooperation between pharmaceutical companies and biotechnology firms is based on their reciprocal interests to the extent of their complementarities. Such network cooperation has become a "small world" to the extent that vast numbers of firms with different national origins were all connected to each other, which consequently has globalised the world market in the high-technology sector (Krogmann *et al.*, 2013). This offered pharmaceutical biotechnology firms various opportunities to increase their efficiency of R&D efforts, reduce their cost and risk investing in the launching R&D projects and create options for knowledge and innovation development. In many cases, partnerships have been created with academic research centres, thus providing an important mechanism for gaining access to cutting-edge science and new technologies, whilst allowing the company to lower overhead and investment in expensive discovery tools and technologies (Kaitin, 2011a). It is, for instance, the case of Pfizer's newly created regional Centres for Therapeutic Innovation and Eli Lilly's Innovation Fellowship Awards Programme that represent those companies' commitment to academic–industry partnerships, whose goal is to bridge the gap between basic research discoveries and the commercial development of new medicines (Getz and Kaitin, 2012). The importance of academic alliances has resulted in a geographic re-centralisation of the remaining in-house R&D hands-on activities close to the centres of academic excellence (Boston, Cambridge and Oxford). Lab-based R&D facilities have been replaced by virtual research and project management units to collect and preserve the scientific expertise in the

therapeutic areas of interest (AstraZeneca, Neuroscience iMed, Cambridge, MA, USA) (Raja and Sambandan, 2015).

Contract research organisations

The value chain of the pharmaceutical industry is complex, highly dependent on policies for drugs approval and increasingly disaggregated, with big pharma collaborating in different ways with smaller actors (Raja and Sambandan, 2015). To this end, the acquisition of OI2-based principles has consolidated the importance and expansion of outsourcing which, in turn, has set as a source of business opportunities seized by the industry: it is the emergence of companies that provide services related to research in the clinical/(bio)pharmaceutical fields and which are known as CROs. They are distinguished from the clinical research organisations – with which they share the acronym – that manage and perform mostly activities related to clinical studies, and that, as such, should be rather considered as a subset of the CRO. In the overall, CROs provide support primarily in activities related to the central phase of clinical trials of (bio)pharmaceuticals or diagnostic medical device, in particular: study design, drafting of the medical protocol, selection of clinical sites involved, enlisting of patients, site monitoring, data collection and analysis of the results by means of parametric biostatistics. In the latter cases the term CRO, as seen, is also interchangeably used as an acronym for organisation of clinical research (see Figure 2).

More in general, CROs provide specialised services by means of business modalities that, although customisable according to the requirements of the company, can be summarised in three main organisational forms (Figure 3):

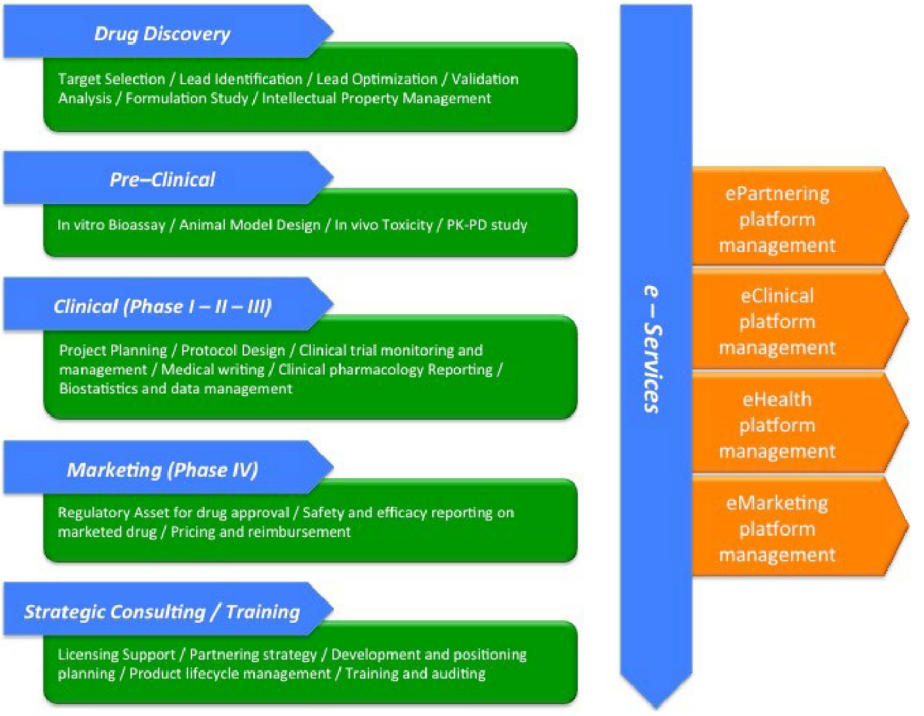


Figure 2.
Drug development value chain

- *FIPCo* (fully integrated pharmaceutical company): traditional model of the vertically integrated pharmaceutical company;
- *FIPNet* (fully integrated pharmaceutical network): the companies move away from the traditional model, filling the gaps through partnering. The FIPNet enables the creation of a network through three lines of action: outsourcing (Level 1), OIed R&D (Level 2) and corporate venturing (Level 3) (Raja and Sambandan, 2015); and
- *VIPCo* (virtually integrated pharmaceutical company): a fully disintegrated but vital company, as it outsources/contracts extensively for services at any point (s) in the value chain, providing access to complementary assets outside the firm. This allows the company to maintain control of the product development process and defer the point at which they plug into the value chain.

Virtual communities and virtual contract research organisations

A virtual community creates value when it can effectively meet four basic elements: a specific interest, relationships, entertainment and a commercial exchange. This allows to draw the bounds, although purely theoretical, between three different categories of communities, namely: communities of transaction, interest and fantasy:

- The communities *of transaction* have the same aim to facilitate the matching of supply and demand of goods and services and to provide the necessary range of information useful to the realisation of such exchanges. They represent a new kind of intermediary, a trader able to attract a critical mass at the site of suppliers and customers to facilitate the performance of transactions (Hagel and Armstrong, 1997).
- The communities *of interest* arise instead from sharing a passion, an opinion, an activity amongst community members. They pursue the goal of providing specific information services to help participants to acquire or to deepen knowledge on the topic of interest and develop interpersonal relationships. The ability to exchange or buy products constitutes an additional service and possible.
- The communities *of fantasy* are instead places devoted to leisure where often you wear the clothes of fictional characters and so participate in interactive games. The true ability to create value for the community today lies in being able to develop both the social dimension and the economic one, i.e. to pursue a strategy of "integration". The vertical communities are not only located into electronic markets in which each user, exploiting the information, potential of new technologies,

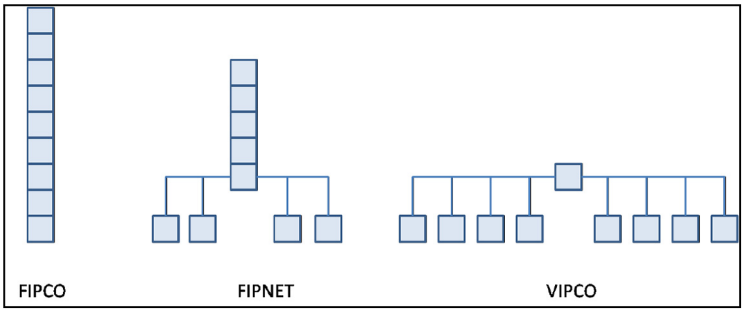


Figure 3. Vertical disintegration from FIPCo to FIPNet to VIPCo

research to lower costs and the counterparty into transactions, but rather encompass a space in which the community dimension is vital in the process of value creation. The fiduciary component plays a fundamental role in the transactions. The high capacity of organisation and control of transactions is combined with an equally valid knowledge management entered and spread throughout the network. These two elements allow a virtual system to achieve good results in terms of participation of users in relation to the different services that are offered (Bonacci, 2007).

All this brings out the various benefits that an enterprise can draw from access to a virtual community: ability to greatly expand the effectiveness of its action and communicative than working in isolation in the network; reducing time and costs associated with the research and identification in the global dimension of electronic networks. Virtual communities can provide a valuable opportunity to benefit from the advantages offered by new technologies in terms of effectiveness and efficiency in the implementation of transactions, but also for exchange of knowledge and innovation (Bonacci, 2007).

The development of vCROs, as organisations comprised of autonomous communities of scientists and service providers, managed by a central source of capital and leadership, and engaged in open and coordinated collaboration, is a good example of new opportunities seized by the (bio)pharmaceutical sector in the light of the above described changes. Sector enterprises have become aware of the impossibility – in terms of cost and time – to possess internal knowledge, as well as the necessary competencies for all stages of the drug development value chain, so they have seen in outsourcing the best strategy to stay competitive and be on the market. The spread of the model of vCROs and offshoring is also because of another important element in the innovation process concerning CROs, that is the ongoing digital revolution in the pharmaceutical sector, which can be identified in three main strands (Kaltenbach, 2014; Sundgren, 2014; Parek *et al.*, 2016):

- *e-clinical*: refers to the deployment of technologies such as electronic data capture, clinical trial management systems or randomisation and trial supply management systems, commonly using interactive voice response systems, electronic patient diaries and other applications);
- *e-marketing*: such concept can be in turn divided into three categories: end user (including doctors and hospitals), mostly based on providing reports, scientific data, etc. to the specialists to start the promotion of a new drug; bulk drugs, not visible to the end users and mostly involving established drugs like antibiotics, antipyretic, etc.; API (active pharmaceutical ingredients) as pure B2B declined within the (bio) pharma sector; and
- *e-health*: also in this case, more than one scenarios can be considered: e-health services to enhance disease models and biomarkers (the clinical programmes are seen as a real-time interaction patient evaluation that allow much more information to be captured than the "traditional" clinical trials. Furthermore, the diagnostic tools are supported by sophisticated re-use and data mining of health information from EHRs and other record systems); improving clinical study design by e-health services (re-using of EHR data by the project team during the study design and protocol development; enabling a network of hospitals to precisely identify the patients in its EHR repository who match an issued protocol, for finer-grained examination of these patients' EHR against the protocol).

The switch to a virtual drug discovery model can retain the potential to promote scientific innovation and drastically reduce the costs of drug research, actually addressing two of the

major challenges facing the industry in a single stroke. As a consequence, CROs fit now in a virtual R&D scenario in which the core expertise of pharmaceutical companies is progressively shifting to develop, through a number of different disciplines, the networking capabilities and partnering, or to interact with virtual organisations and combine all the resources at available to enhance the process, the product and the company as a whole. In this context, an effective outsourcing has precisely the role to make continually skills, ways of thinking and innovative forms of organisation, not always present in many companies. CROs become, therefore, a platform that can be defined of net-sourcing, in which to create a network of partnerships and skills that meet the needs of all possible stakeholders, up to the patient/end-user, who can take advantage of a product/service innovative, effective and personalised.

In virtual organisations, the network makes it possible to keep an agile enterprise design, yet capable at the same time of pro-respond to change and reduce the variability of the results. Potential sources of risk still exist and are linked to the significant tangible and intangible resources put together amongst networks and each other interdependent. The dependence, as previously highlighted, can, in fact, be a source of risk, but it also works as a driver of profit sharing, given that the network is determined by the contribution of each partner to the project. The vCROs offer, therefore, a comprehensive platform of possibilities collaboration that a partner may have available for the search process and development of a given product: the strength of the CRO is to coordinate and optimise the entire study based on an end-to-end partnership model, also known as a one-stop shop. The company's main task remains the creation of value, and then the monitoring of the entire process, ensuring a fair exchange between partners, as well as good communication and high transparency. This minimises the fixed costs for infrastructure and staff, producing value in a shorter time and, consequently, a faster return on investments.

Research problem

The acquisition of the OI2 model has consolidated the importance and expansion of outsourcing causing the emergence of the vCROs, as *new wave* of the dynamics of innovation transfer, capable of enabling the translation between scientific and technological discoveries and information, gaining access to new business opportunities.

Starting from these premises, the paper aims at investigating the clusters of vCROs as a specific form of alliance, in the setting of the pharmaceutical industry, and its impact on innovation. Clusters have become a prevalent form of industrial organisation, and their innovativeness is considered to be a key source of regional and national competitive advantage. The work tries to analyse some aspects concerning the effects of networks on clinical research. Clusters are localised networks (Curzio and Fortis, 2003), territorial aggregations of different players, that usually arise when business segments require high levels of specialisation from multiple contributors (Ghadar *et al.*, 2012). They can have a more or less formalised structure and, in any case, they assume a network configuration through contractual mechanisms.

As seen in Figure 2, the pharmaceutical R&D process is organised as a strict sequence of different stages that are better performed through the involvement of different players assuming different roles in the healthcare value chain (e.g. research, manufacturing, provision of care and regulation). In such a context, organisations often decide to work on a multiplayer basis to speed up the multistage process of pharmaceutical research through the sharing of scientific knowledge and the division of labour and the inclusion of patients in clinical trials, to foster enrolment and the fulfilment of protocols. Interactions between complementary players, who have different roles in the value chain, are, therefore, needed

for innovation. Firms must deal with the new systemic dimensions of technology and research. Nonetheless, the progressive standing out of virtual vertical model business, because of the intrinsic difficulty of generating an equal value creation in each part of the value chain, has driven us to adopt the "small world" concept, as introduced by D'Alise *et al.* (2014) meaning *highly dense clusters or hubs randomly connected to other clusters or hubs by weak ties in a sparse structure*. The reference to this kind of structure allows us to deal with the literature on clusters and networks theoretically in many ways.

To this end, the adoption of the SNA fits with the research objective: assuming in fact that the relationships occurring between actors are held to actors' roles inside a network (Cross and Parker, 2004; Meneguzzo and Cepiku, 2008), the whole set of nodes/actors (with their peculiar features) and the set of ties (e.g. connections, relations and/or interactions for the exchange of resources) give origin to a social network (Powell, 1990) that can be can be articulated on different levels: *interpersonal* (a single person belonging to an organisation), *intra-organisational* (a specific people group within an organisation), *inter-organisational* (a set of relations existing between organisations). In this case, SNA is meant to analyse inter-cluster network characteristics and their impact on the cluster's innovative performance, overcoming the limits of the absence of significant contributions examining clusters of clusters, by using appropriate sets of indicators and graphic instruments. Moreover, the present work intends to contribute to the literature debate on the network structure as most beneficial for innovation: a small world network structure could provide an intermediate solution between sparse and dense (i.e. "virtual") structures that are complementary, trying to establish its connection to innovation outputs.

Accordingly, the research questions can be summarised as follows:

RQ1. What is the "shape of the bridge" between OI and virtual organisation forms in the light of the small-world network structural characteristics?;

RQ2. How can clusters stand as answer to innovation transfer issues?

Analysis

We explored the arguments mentioned in the previous sections by using a social network approach (Bonacci and Tamburis, 2015) applied to the worldwide pharmaceutical industry. We started our research by listing the top ten pharmaceutical companies and the top ten CROs (Table I).

With the help of reliable sources like the US Cluster Mapping Database, or first rate website (e.g. www.pharma-iq.com or www.centerwatch.com), online libraries, newspapers

Table I.
Top ten world-wide pharma companies and CROs 2017 (classified by revenue)

#	Pharmaceutical companies	Contract research organisations
1	Pfizer	Quintiles
2	Merck	Parexel
3	Johnson and Johnson	Covance
4	Roche	PPD
5	Sanofi	Icon
6	Novartis	PRA Health Sciences
7	Abbvie	INC Research
8	Astra Zeneca	Charles River Laboratories
9	Gilead	Chiltern
10	Amgen	SGS

and archival data (official documents, previous studies on clusters), we managed to identify some amongst the most valuable relationships between companies and CROs, as well as some amongst those between companies, CROs and surrounding academic and institutional organisations. With reference to the already mentioned Pfizer's and Eli Lilly's initiativers, in both cases the organisations are comprised of autonomous communities of scientists and service providers, managed by a central source of capital and leadership, and engaged in open and coordinated collaboration: this strategy has been recently adopted because of the benefits that out-licensing provides under certain circumstances (Getz and Kaitin, 2012; Raja and Sambandan, 2015). It is also the case of the "virtual company" Bio Data Bridges (www.biodatabridges.com/Clientel) that works as an external contractor for some amongst both the pharma companies and the CROs reported in Table I.

In regard instead to Astra Zeneca's mentioned research and management policies, this fits in particular with its main marketing processes, focused on transforming doctors into business partners before creating effective work instruments so that the process owner is a medical science liaison (Goncharuk and Getman, 2014).

Using the UCINET VI software (Borgatti *et al.*, 2002) an "n x n" sociometric matrix was drawn in the first place reporting for all the rows and the columns all the entities above described; a weight (going from 1 to 7) was then assigned for each cell according to the strength of the connection. In particular, the cells corresponding to the same entity on both the row and the columns were not considered (each entity is of course completely connected with itself). The cells corresponding to connections for which no information was gathered were as well left blank. The following cluster analysis resulted in 20 different clusters of companies, CROs and their surrounding industrial, academic and institutional organisations; amongst these, six clusters were selected as they featured similar number of nodes, spanning between a minimum of 114 and a maximum of 133, significantly higher than the number of nodes showed by the other clusters. As for the attributes to highlight, we considered:

- the nodal characteristics: for each node in the clusters, we identified the type of organisation, in particular the role in the vertical chain (whereas it was possible to sketch a precise vertical chain). We obtained different categories for the firm type (e.g. biotechnology, pharmaceutical, academic institution, etc.) and the states in which the firms are located. We used the sources mentioned above; and
- The cluster's characteristics: the number of employees and the cluster's specialisation (from the US Cluster Mapping Database).

As for the relational data, the study of the marketing strategies of the mentioned firms (as previously suggested) made possible to investigate into the transactions and agreements between the nodes of the cluster related to R&D, so to highlight short-range intra-cluster and long-range inter-cluster ties. Intra-cluster ties are ties between the nodes belonging to the same cluster, whilst inter-cluster ties are ties between nodes belonging to different clusters. One node can be simultaneously in different clusters, and this is another case of an inter-cluster tie (even if the tie will occur between two divisions of the same firm).

As the focus is on the impact of the ties on a firm's innovative performance, we filtered the output to keep just the alliances of selected types, namely R&D agreements and manufacturing agreements. Thus, using NetDraw, a tool from UCInet suite, a visual representation of our big pharma "Small World" network comprising the selected six clusters was constructed. In the table, the long-range, inter-cluster ties are summarised: each of the six clusters is connected to external clusters through

the linkages of its nodes to other clusters' nodes; the width of each segment represents the strength of the connection as a function of the number of ties. In this way, we reconstructed both the whole network and the single sub-units of the network, which are clusters. Along with it, some amongst the most important quantitative measures for use in the SNA were developed, i.e. network cohesion (density: a measure of the relative number of connections; standard deviation: a measure of the variability amongst the whole set of connections of the sociogram) and network centrality (network centralisation index: measures the degree to which a network approaches a perfectly symmetric or "star" network). The cliques analysis then worked out the main amongst the possible "high density subgroups" derivable from the network breakdown. Such elements are showed in Figure 4.

Results and discussion

OI relies on a flexible, coordinated and integrated community of internal and external stakeholders, each contributing unique competencies and energies. These partnerships also rely on leading-edge technologies to create collaborative working environments and to share data, governance and operating procedures and risk (Hunter, 2010). To this purpose, what emerged from the analysis of the data retrieved is that the combination of the single big pharma company and the CROs to which great part of the work is externalised, can be compared to a community of *transaction* that deals with the supply and demand of a specific kind of goods and services (Figure 5). Moreover, as the single CRO can cooperate at the same

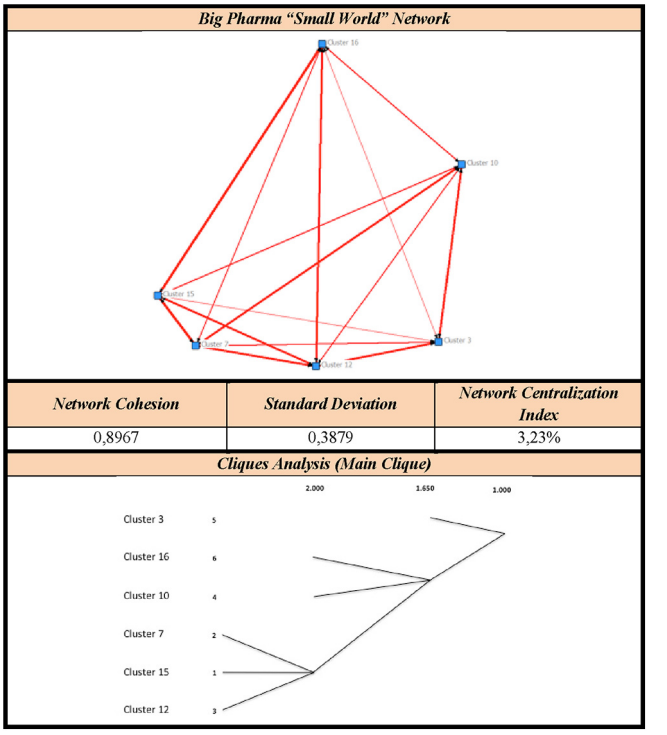


Figure 4.
Big pharma "Small World" Network and main SNA-related properties

time with more than one company, it can be, therefore, stated that CROs create intra- and inter-cluster communities of *interest*, as they share a specific task within the wider community of transaction (porous inter-firm R&D network boundaries); this implies in the final analysis that a cluster can comprise either a single or more than one communities of transaction.

As Figure 4 shows, in the first place, the quasi-star-like sociogram of the network makes clear the good level of network cohesion (> 80 per cent density and < 40 per cent deviation) (Cordaz, 2005). Besides that, all the clusters are central to each other (in terms of *betweenness centrality*), although the cliques analysis suggests that clusters 12 and 15 show a slight greater rate of *outcloseness*. As hereafter explained, such properties somehow reflect on the possibility to provide answers to the research questions.

RQ1 investigated the impact of the small world network structural characteristics on the cluster's innovation output. According to D'Alise *et al.* (2014), the integration of the short-range clustering and the long-range reach was considered to have a positive impact on the cluster's innovative output. As for our research, CROs being a *platform of net-sourcing* (Lukensmeyer and Torres, 2008) means that they have become able to somehow "upgrade" the drivers that lead companies to the outsourcing choice, thus achieving:

- an over-accelerated time to market, a critical factor in the drug development process;
- a *glocal* dimension of improvement, meaning helping the development process by means of a tailored mix of knowledge deployment on local level and project management on global level; and
- an increasingly rapid access to advanced technologies, which minimises times and costs related to purchasing, installation and staff training.

If an OIed R&D network granted to large pharmaceutical companies to successfully undergo the challenges of technological innovation during the so-called "biotechnology evolution" and keeps their dominant position in the high-tech industry (Chiaroni *et al.*, 2008), the improved collaboration with a new kind of external actors (e.g. academic research

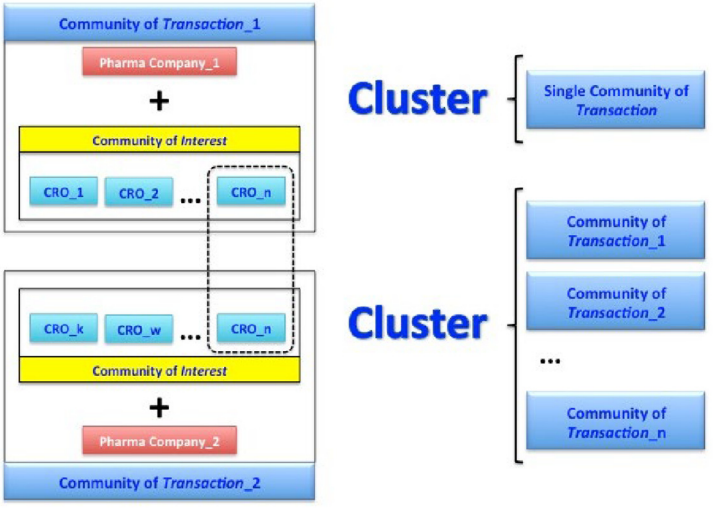


Figure 5.
Pharma companies and CROs as members of communities of interest and transaction (on the left); clusters as comprised of either one or more communities of transaction (on the right)

centres) has set into motion an OI2ed R&D network cooperation based on the mentioned "quadruple helix model" of innovation to drive changes far beyond the scope of what any one organisation can do on their own (Curley and Salmelin, 2013). The result has been the rising of a further network of externalisation (virtualisation) of the productive processes, especially for (but not limited to) CROs, as they deal with the great part of the drug development value chain, for which opportunities have arisen to increase their efficiency of R&D efforts, reduce their cost and risk investing in the launching R&D projects and create options for knowledge and innovation development (Gottinger and Umali, 2008).

An overlap between two peculiar phenomena has, therefore, occurred: on the one hand, the single CRO that builds a network of cooperation with more than one big pharma company; on the other hand, surrounding industrial, academic and institutional organisations that build networks of cooperation with both companies and CROs. The emerging virtual entity was already introduced as "comprised of autonomous communities of scientists and service providers, managed by a central source of capital and leadership, and engaged in open and coordinated collaboration" and, as a matter of fact, acts as a community whose all components participate to the creation of value (co-creation), thus comparable to a certain extent to a community of *fantasy* (Figure 6).

Virtual outsourcing stands then as a means of bridging networks between clusters: this kind of organisational model pushes towards the deverticalisation of the bio-pharmaceutical sector on the whole, allowing the increasing of strategic alliances between big- and small-sized companies, as well as between companies and research institutions, favouring the information flowing in spite of shorter innovation cycles, industrial R&D's escalating costs, as well as dearth of resources (Enkel *et al.*, 2009). Inside a vCRO, the transfer of knowledge becomes much more easier, so innovation can stem (and spread) more effortlessly, as it hosts an integrated partnership that spans the entire R&D continuum – from drug discovery through development and commercialisation of new medical therapeutics. Large pharmaceutical companies provide resources, regulatory experience and infrastructure (e.g. scale manufacturing, marketing and sales); surrounding research centres supply basic and translational research capabilities and access to cutting-edge science; small pharmaceutical and biotechnology companies provide innovative discovery and early development capabilities; CROs and investigative sites deliver clinical research operating and execution capabilities; and patient groups help set the research agenda, provide access to study volunteers and, in some cases, contribute research funding (Kaitin, 2011b). This allows to answer *RQ2*: whereas traditionally, innovation was conceived as mostly transferred from hubs (out-degree centrality) towards peripheral actors or intermediaries, often big pharmaceutical companies or incumbent biotechs, the virtualisation sheds light on the phenomenon of the "strength of weak ties" (Granovetter, 1973): if resorting to the virtualisation means (amongst the rest) optimising the entire production process according to an end-to-end partnership model, the sum of n ties, besides the different extent of weakness (or strength?), causes high-density clusters that can bear localised phenomena of Schumpeterian radical innovation. This is, in turn, transferred through waves of gradual intensity, thanks to the creation of networks modelled by a "global sustained innovation". This also means that the lack of a sole central actor in favour of a (virtual) multi-central structure eventually shifts the idea of *coopetition* (which emphasises simultaneously cooperative and competitive behaviour amongst organisational units: Tsai, 2002) to a far upper level that also implies (as community of fantasy) a collective use of shared knowledge to pursue common interests.

Networks of connections are innovation, but also production systems that influence global product performance: strong linkage between innovation and emergence of network

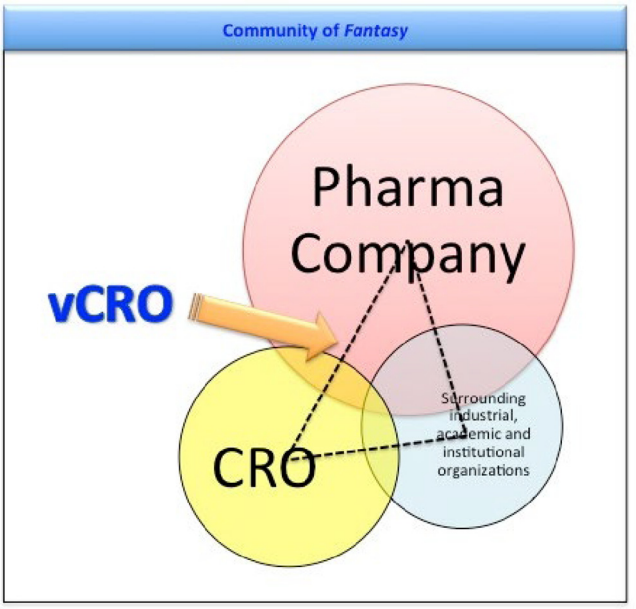


Figure 6.
A vCRO as a community of fantasy

structures thus exists, supported particularly by recent evolutions regarding the mentioned scale-free models of alliances (deverticalisation) (Gay and Dousset, 2005).

Conclusions

The main contribution and results of the study were to introduce a first attempt of an "Open Innovation 2.0/Social Network Analysis" combination approach for the analysis of the "complex" pharmaceutical industry, enriching the line of inquiry into cluster-based innovation, and providing new perspectives for recognising how the set of interactions and relationships in the pharmaceutical context can bring to higher levels of knowledge transfer, organisational learning and innovation spreading. Based on the literature that shows an increasing importance of network structures and the increasing amount of international research collaboration in pharmaceuticals, we explored differences in collaboration patterns on the country level in different areas of (bio)pharmaceutical research and their developments over time. We used the SNA to visualise collaboration networks and to calculate network statistics for different disease groups. Moreover, we analysed endogenous network dynamics, i.e. mechanisms within the network that are responsible for new connections being build up or existing ones being cut off. Inside such processes, the importance of the users increases, too. This approach was based on the premise that individuals are influenced by direct and indirect exposure to other person's attitudes and behaviour; by access to resources through the network; and by the individual's location in the interpersonal network. In particular, we tried to implement the impact of a cluster's *small-world* network structural characteristics as well as of nodal characteristics on the cluster's innovative performance. Addressing with such approach, the potentialities of the CRO within a "Virtually Integrated pharmaceutical company" organisational model allowed us to highlight:

- a comprehensive perspective for understanding the dynamics of modularity and their implications for innovation networks; and
- the presence of innovation networks as the main mean to promote and support paths of knowledge creation and transfer.

A cooperation network between firms is not distinct from a social network between people. Innovative approaches in co-creation of value can in fact turn into innovatice approaches in co-creation of care (Brenner *et al.*, 2018). Globalisation makes the world narrow and small, and the distance is no longer an obstacle for the connections. Furthermore, integrating into such a research network enables high-tech firms to optimally share the resources that they possess. As a result, they would have opportunities to access the resources available in the whole world and exchange technological and innovative information with greater facilities (Krogmann *et al.*, 2013).

The peculiarity of the suggested approach offers room for improvement; the structure itself of innovation outcomes and transfer needs to be tested because, as pointed out elsewhere (Hoyer, 2011; Bonacci and Tamburis, 2016), weak and strong ties between companies and employees increase the social capital and contribute to information exchange and problem-solving solutions within an innovation value chain.

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About the authors

Oscar Tamburis is a Management and Industrial Engineer, with a PhD in Health Organisation Management and a Post-Doc in eHealth Dynamics. He is currently an Assistant Professor of Medical Informatics at the University of Naples Federico II, Italy. His main research interests concern innovation and strategic management for performance improvement in the public health field, with a particular emphasis on two main topics: the assessment and institutionalization of emerging technologies in healthcare organisations and the design and implementation of strategies for promoting knowledge-sharing behaviors among healthcare professionals. Oscar Tamburis is the corresponding author and can be contacted at: oscar.tamburis@unina.it

Isabella Bonacci is a Research Professor of Corporate Organisation at the University of Naples Federico II, Italy. She obtained her PhD in Business Economics and a degree in Economics both from Federico II University of Naples. She was a visiting scholar at the CMER, INSEAD Institute, Fontainebleau, France. Her research interests include economics of information systems, corporate relationships and new organisational forms, strategic use of ICTs to improve public corporate performances, with particular concern for the healthcare sector.