Clusters and Innovation in the Life Sciences

Abstract. The paper presents a conceptual framework which faces clusters, or localized networks, in the life-science domains. Amongst the various lenses, it focuses on the relationship -if any- interlacing structural settings (clusters) and innovation by referring to the broader field of network theory approach. The final aim of the paper is to contribute to the extant literature by creating a theoretical framework able to describe the effects of intra-cluster and inter-cluster structural and nodal network characteristics upon the clusters' innovative performance. The work sheds light on the factors influencing different innovative performance across different domains in the life-science field.

Keywords. Innovation; knowledge; cluster; network; life-science; pharmaceutical; biotech; university

Introduction

Research has highlighted the importance of a network including various types of organizations as the locus of innovation, because the stock of knowledge itself is located in a complex system of interactions among different organizations. Innovation requires the convergence of many sources of knowledge and skills, usually linked through a network [1];[2];[3]. This is particularly true in a context such as the Life Sciences.

In fact, a traditional "linear model of innovation"[1] [4] does not adequately describe the actual life science innovation process, that implies a more parallel, interactive coupling of basic research, applied research, and experimental development. Complementary resources and knowledge are required to deal with the new systemic dimensions of technology and research, characterized by the scientific and technological interdependence of productive processes, and to deal with a complex, interdisciplinary, widly distributed knowledge base and with modular products. Reference [5], analyzing the biotechnology industry, emphasized the difficulty in identifying a single innovator in a context of increasing multidisciplinarity.

The life-science field is a highly regulated R&D setting, where the R&D process is organized as a strict sequence of different stages, that follow the protocols and involve different specialized players, assuming different roles and responsibilities and occupying different positions in the healthcare value chain (e.g., research, manufacturing, provision of care, and regulation). From an organizational point of view, not only the managerial components of R&D but also patent, regulatory, and commercial aspects are involved in all R&D stages and spur cooperation among firms

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[1] It proposes a smooth, unidirectional flow from basic scientific research to commercial applications; a sequencing of the different players' actions, without any feedback from later stages to the initial stage of research.

[6]. Therefore companies have become more and more dependent on collaborations, they work on a multiplayer basis to speed up the multistage process of R&D, and face with technological and market uncertainties, through division of labor.

Also, innovation in life-science industries is a dynamic process that can be described as a trial-and-error sequence, with feedback loops [7] to preserve safety and an user-centric approach. The presence of some players like advanced hospitals and healthcare organizations, often associated with universities or research institutes, can provide significant lead-user feedback and testing of new medical technologies [8] thanks to their proximity to patients.

The starting point for the analysis is the assumption that strong links between the production structure and the knowledge and institutional infrastructure in science-based industries are necessary to overcome innovation challenges: innovations could result directly from ongoing interactions among scientific, commercial, educational, and public institutions. When business segments require high levels of specialization from multiple contributors [9], clusters arise.

1. Research Problem and Research Questions

The aim of the paper is to investigate the impact of the cluster - an aggregation of different players in a localized network [10] - on innovation in the life-science setting. The work tries to enrich the line of inquiry into cluster-based innovation by analyzing which cluster configuration is the most conductive to innovation.

The cluster concept has been defined in ambiguous ways, it is rather flexible, corresponding to a large variety of spatial and organizational concrete configurations, as will be shown in the literature review section. In order to understand which of them drives to a higher cluster's innovative outcome, we address the following research question: *What is the impact of intra-cluster and inter-cluster network characteristics on the cluster's innovative performance in the life-science sector*? More specifically we analyze what network **structural** and **nodal characteristics** are best suited to maximize clusters' innovation, from an intra-cluster and an inter-cluster perspective.

The cluster we analyze involves an industrial player, an academic player and an institutional player, which, in the life-science sector, typically are comprised of pharmaceutical firms, biotech firms, universities, research centers, and healthcare organizations such as hospitals, clinics, and healthcare institutions linked through an informal or formal arrangement. Innovation is considered in terms of drug development.

2. Conceptual framework and Literature

To examine the research problem, we refer to literature on strategic alliances, networks, and clusters, on the Triple Helix model for innovation and on system innovation perspectives. These streams of research are interdependent in the context of our study given that: i) innovation arises from R&D collaborations, that tipically are strategic alliances; ii) as already mentioned, the firm's value added usually comes not from a single relation but from a network of multiplayer relations, through increased social capital; iii) clusters are a specific form of networks prominent in the Life Science sector.

Strategic alliances shorten the development time while spreading the risks and costs associated with product development [11]. One perspective explaining the benefits of strategic alliances for innovation, which is also the impetus of our contribution, is the resource dependence theory (RDT), which proposes that the key to organizational survival is the ability to acquire and maintain resources. RDT treats the environment as a source of scarce resources and therefore views the firm as dependent on other firms in the same environment. When organizations have similar objectives but different kinds of resources, the exchange of resources will often be mutually beneficial to the organizations in the pursuit of their goals. This is the reason why *partner selection* emerges as one of the most influential factors affecting an alliance's success [12]. Several contributions have built on the organizational learning literature to examine the factors that facilitate knowledge transfer among partner firms and have identified partner-specific variables, the characteristics of the collaborating firms, such as absorptive capacity, prior experience, and cultural and geographical distance [13];[14]. We will draw upon these elements to develop our propositions on the nodal characteristics of the network.

Network studies that examine the consequences of networks[2] typically follow the structuralist perspective. This focuses on the configuration of the ties, concluding that an actor's payoff is a function of network structure and of its position in the network. The literature suggests that a firm's network of relationships influences its rate of innovation and R&D, often highlighting the benefits of networking: knowledge sharing (knowledge, skills, physical assets) and knowledge flows (information conduits about technical breakthroughs and new insights) [1];[16]. Scholars supported competing school of thoughts about which network structure is the most conductive to innovation and two trade-offs are still in place: (a) between the benefits of *strong* [17] versus *weak* [15] ties (that are likely to be bridges); (b) between the benefits of *sparse* network structure [18] - facilitating the generation of ideas and hampering implementation and action - versus *dense* network structure - favoring implementation but not generation of ideas [19];[20]. The question is whether network positions associated with the highest economic return lie between or within dense regions of relationships. We will draw upon these trade-offs to develop our propositions on the network structural characteristics. Moreover, despite the considerable focus on the role of network structure in explaining firm performance outcomes, some researchers have acknowledged that a network of ties merely gives the focal firm the potential to access the resources of its contacts [21]. Contingencies need to be introduced, such as nodal heterogeneity [22], as we will do in the propositions on the nodal attributes.

The concept of a network is more general than that of **Cluster** and does not necessarily entail local embedding, a shared objective, or a specific market [23]. The cluster concept has been defined in ambiguous ways and the full range of cluster definitions are well summarized in reference [24]: an innovation cluster *"comprises an ensemble of various organizations and institutions (a) that are defined by respective geographic localizations occurring at variable spatial scales, (b) that interact formally and/or informally through inter-organizational and/or interpersonal regular or more occasional relationships and networks (c) that contribute collectively to the achievement of all kind of innovations within a given industry or domain of activity, i.e. within a domain defined by specific fields of knowledge, competences and technologies"*. The concept involves a wide range of variation and even starting from this definition, it is possible to build around the type of organizations involved, the best

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[2] A form of organized economic activity that involves a set of nodes (e.g., individuals or organizations) linked by a set of relationships [15].

spatial scale for geographical localization, the focus on a single industry or domain, and the configuration of the network. We will try to do this in developing our propositions, linking these characterizations to innovation.

As for the impact of clusters on innovation, in the life-science industry they allow access to human capital; availability of infrastructures; interactions and synergies among disciplines; development of financial conditions supporting innovation [6]. Reference [25] showed that innovative research in biomedicine has its origins in regional clusters in the United States and in European nations.

Clusters reflect the systemic character of modern interactive innovation and therefore they are related to several conceptual frameworks and models developed under the *Innovation System literature*: (a) the "Mode 3" of knowledge production, that advocates a system, consisting of innovation networks and knowledge clusters for knowledge creation, diffusion, and use [26]; (b) the "Triple Helix" (TH) Model of knowledge, developed by references [27];[28] that will be theoretically investigated in this paper. It is focused on three helices - academia, industry, and government - that intertwine through "tri-lateral networks", overlap and create synergies that result in product and process innovations in a national innovation system. The TH model is based on: (a) the internal transformation in each one of the helices; (b) the influence of one helix upon another. Universities provide advanced research and human capital; companies provide real-world problems, commercialization opportunities, and funding; and institutions provide user feedback and regulatory support. The life-science clusters are characterized by: basic biomedical research by universities and public research institutes; entrepreneurial, innovative dedicated biotechnology firms (DBFs) seeking to commercialize the results of the basic research; and funding, downstream marketing and distribution capabilities from large pharmaceuticals [8]. Strong, enterprise-supporting infrastructures complement strong, local science bases [29]. Many studies found a positive impact of university–industry relationships on innovation (e.g. [30]).

3. Propositions Development

The paper can make a theoretical contribution by filling some gaps of the previous literature mentioned above. With reference to **Cluster** literature: (a) there is still lack of clarity on the cluster concept that remains rather indefinite and chaotic [31], with no consensual views among scholars on several key issues (e.g., the spatial/geographical boundaries or the properties of the players). This lack *raises many research questions;* (b) there are *no significant contributions that analyze clusters of clusters*, meaning groups of clusters and *inter-cluster dynamics*. Inter-cluster ties are *weak ties*, and the strength of weak ties has been often advocated in the network literature. With respect to **Network** literature: (a) scholars have been *unable to agree on the form of structures most beneficial for innovation.* We try to find an intermediate solution to the fundamental tradeoff between sparse and dense structures, that are complementary, through the distinction between intra-cluster and inter-cluster dynamics and the combination of inter-firm resource pooling and cooperation [32]; (b) researchers have stressed the importance of *network structure, undervaluing other dimensions that affect knowledge sharing.* We try to overcome this limit by introducing *contingency factors*: the nodes' knowledge base (diversity of nodes) and the nodes' localization (geographic distance among nodes); (c) Scarce attention has been paid to the overall network (here cluster) performance, preferring the node's performance [33], we focus on the former.

Therefore we will investigate network structure and the nodes' characteristics focusing on intra-cluster and inter-cluster (i.e., cluster of clusters) dynamics. In this analysis, contrasting perspectives and concepts are useful: the perspectives of *learning* (theory of knowledge and innovation) and *governance* (Transaction Costs Economics) [34] and the concepts of *exploration* (discovery of novel ideas) and *exploitation* (implementation of ideas discovered through exploration) [35], both needed for the innovation outcome. From a learning perspective, a fundamental prerequisite for innovation is cognitive diversity, that can be summarized in three dimensions: the number of cognitive entities involved in the learning process (size) and connections (density) and the cognitive distances among the nodes, here expressed by partner vertical diversity and geographical distance [36].

3.1. Structural Characteristics

The first aim of the paper is to investigate what structural characteristics of the cluster maximize the cluster's innovations, from an intra-cluster as well as an inter-cluster perspective. We focus on size and density/spanning of structural holes.

3.1.1 Size

Size (number of nodes) is the basic structural feature of networks [23], it determines the amount of knowledge circulating and spilling over between firms in a cluster. In a RDT view, this can be an important predictor of firm performance, thanks to: (a) reliance on a wider pool of product and process technologies, (b) increased specialization and division of labor leading to more focused expertise development [37], (c) scale effect (increases in inputs are rewarded with more than proportionate increases in output), affecting the transformation function f of the innovation function, and (c) leverage effect, given that each node in a cluster is part of other networks.

As shown in reference [38], there is a positive relationship between the number of contacts of a node and a node's knowledge, if the innovative performance of each node increases, the overall cluster innovative performance will increase too. Therefore, we can formulate the following proposition.

P1*: The larger the size of the life-science cluster, the higher the cluster's innovative performance.*

3.1.2 Density/Structural Holes

The effects of network density (the number of the effective ties divided by the number of possible ties)[3] on innovation remains ambiguous.

A dense innovative cluster provides benefits both from the learning perspective (intense interaction, coordinated action, triangulation, transfer of tacit knowledge) [39] and from the governance perspective (lower transaction costs, opportunism, risks), favoring the *exploitation* component of innovation.

However over time, the knowledge overlap between cluster organizations will increase [40], the only way to compensate for this trend is to increase the cluster firms' knowledge exchanges with outside entities. The presence of structural holes spanned between a cluster and other clusters (configuration based on semi-isolated subgroups) determines the extent to which the cluster's knowledge base is continuously

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[3] The absence of density results in the presence of many structural holes. A structural hole exists between the brokered actors, two nodes in a network, if the nodes share a tie with ego but are not connected to each other [18].

rejuvenated through knowledge inputs from outside the cluster [41] and novel combination of ideas. This allows the detection of new ideas from remote parts of the network, favoring the *exploration* component of innovation.

To strike the **the balance of exploration and exploitation**, we can refer to network structure. Combining the organizational learning arguments [42] with the *small-world networks concept* [4][43], [44]; we can conclude that networks that have both clustering and some amount of linking between them - cluster-spanning bridges - spur each cluster innovation. Dense and sparse configurations co-exist at different scales and levels of the network, in a multi-scaled cluster, where at the same time the logic of exploitation and exploration may prevail at some spatial scale [24]. The bridging ties with other clusters allow for outside exploration, while the high density of clusters allows for effective exploitation and inside cluster exploration (that is a "finalized exploration process", occurring in a "prearranged systemic way", similar to exploitation for certain characteristics).

Since we are focusing on the single cluster's innovation outcome, a concern may arise: cross-cluster connections are able to engender an outflow of knowledge and a competition to appropriate the innovation outcomes. However this is irrelevant: at the exploration stage, the possibilities of exact imitation are reduced; the firm would have to know the exact way to implement the idea, which is difficult; the implementation process is very long and complex, and there would certainly be a first-mover problem.

The interaction of the two effects (density and spanning of structural holes) will have the greatest effect on innovation considering that, as stated by reference [45], closure can be a significant factor in realizing the value buried in a structural hole: catching new ideas from outside and effectively implementing them inside the cluster. We can formulate three propositions on intra-cluster and inter-cluster characteristics:

- Intra-cluster characteristic

P2a): The higher the density in the life-science cluster, the higher the cluster's innovative performance.

- Inter-cluster characteristic

P2b): The more the nodes in the life-science cluster span structural holes between the cluster and other clusters, the higher the cluster's innovative performance.

- Intra-cluster and Inter-cluster characteristics

P2c): ***The more the nodes in the life-science cluster span structural holes between the cluster and other clusters, the higher will be the positive impact of density in the life-science cluster on the cluster's innovative performance.***

3.2. Nodes' Characteristics

The second aim of the paper is to investigate what characteristics of the nodes in a cluster maximize the cluster's innovations, from an intra-cluster and an inter-cluster perspective. We focus on vertical and sectoral heterogeneity and geographical distance.

3.2.1 Nodal vertical heterogeneity

Vertical diversity means cognitive distance and differences in alliance partners' operational contexts in the value chain, it implies the distinction among three

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[4] Community of actors structured into well-defined clusters, only sparsely connected to each other.

categories: horizontal, upstream, or downstream [46]. In the life-science cluster, the players that occupy the different roles from downstream to upstream are: pharmaceutical firms, biotech firms, universities, research institutes, institutions. For instance a biotech and a pharmaceutical firms are diverse and two pharmaceutical firms are equal. This kind of diversity seems to be a quite comprehensive measure, since in most cases it implies also resource-based diversity, industry-based diversity, technological diversity, and strategic fit.

Referring to the *learning* and the *governance* theoretical perspectives, cognitive distance can represent both an opportunity (i.e., novelty value), favoring *knowledge development*, and a problem (i.e., reduced absorptive capacity, higher transaction costs), disfavoring *knowledge transfer* [23]. Looking at the empirical works, few studies reject the notion that there can be benefits associated with diversity but these come with a cost; in any case, the findings are mixed. We analyze the effect of diversity in the intra-cluster and inter-cluster context[5].

In the **intra-cluster setting**, with reference to the context drawn in proposition **P2a**, vertical diversity in the cluster has a positive moderation effect. It enhances the *internal exploration* process, favoring Schumpeterian "novel combinations," while the problem of the absorptive capacity is counterbalanced by the presence of high connectivity in the cluster. Vertical diversity also allows the effectiveness of the *exploitation process* that in the life-science industry requires complementary skills and division of labor. Moreover, redundancy in a dense network discourages idea generation; this redundancy will be reduced in the presence of nodes' vertical diversity. As for the **specificities of the life-science industry**, we can point out some important remarks: vertical diversity (a) is important to answer the *regulatory requirements* and to allow *feedback loops* and a *trial-and-error process*; (b) it means also *complementarity*, leading to greater innovation results [47]; (c) it means *related knowledge background*: players act in subsequent phases of the same macro-process, and own the same background in terms of basic skills and shared language [48], reducing the concern of absence of absorptive capacity. We can formulate the following proposition:

- Intra-cluster characteristic

P3a): The partners' vertical diversity in the life-science cluster positively moderates the impact of size and density on the cluster's innovative performance.

The higher the level of partners' vertical diversity in the cluster, the higher the positive impact of size and density on the cluster's innovative performance.

In the **Inter-cluster setting,** with reference to proposition **P2b**, the link connecting cluster to cluster (spanning a structural hole) should be a weak tie, in a sparse configuration, and **the problem of absorptive capacity between the two extreme nodes is higher than in the intra-cluster case**. If learning performance from interaction is the mathematical product of novelty value and understandability, the result is an inverted-U shaped relation with cognitive distance. Beyond a point there will be decreasing returns to learning [35]. Optimal cognitive distance lies at the maximum of the curve [23], where there is a sustainable level of transaction costs and competition and a good level of complementarity and absorptive capacity. A moderate

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[5] In the proposition formulation, by the level of vertical diversity in **the intra-cluster setting** (diversity at the network level), we mean the range of diverse partners inside the cluster, whereas in the **inter-cluster setting**, diversity is measured for pairs of nodes (the two extremes of the structural hole) and not in a network.

level of partner diversity (e.g., between biotech and pharmaceutical firms) is ideal: it contributes more to firm innovation than does a very low level of diversity (with redundancy in resources [18], inter-firm rivalry, risk of negative spillovers) or very high level of diversity (with low absorptive capacity and high costs of sharing and transferring knowledge [49]). Therefore we can formulate the following proposition.

- Inter-cluster characteristic

P3b): The vertical diversity between the two nodes spanning an inter-cluster structural hole moderates the impact of the inter-cluster structural hole on the cluster's innovative performance with an inverted U-shaped pattern.

A too-low level and a too-high level of vertical diversity between the two nodes spanning the inter-cluster structural hole reduce the positive impact of the inter-cluster structural hole on the cluster's innovative performance.

A moderate level of vertical diversity between the two nodes spanning the inter-cluster structural hole enhances the positive impact of the inter-cluster structural hole on the cluster's innovative performance.

3.2.2 Sectoral difference

The definitions of "cluster" in the literature do not establish whether the concept of cluster refers to a single or multiple industries:*"a concentration of interdependent firms within the same or adjacent industrial sectors*" [50]. In the last two propositions, we referred to the concept of partner vertical diversity that already include *inter-industry difference* (according to our definition). However it could be interesting to focus directly on inter-industry difference to compare the impact of *cross-industrial clusters* and *single industry clusters* on cluster's innovation. Firms in single-industry clusters face mutual competition, they are likely to be reluctant to exchange knowledge freely and disclose their advancements, this will reduce the opportunities for innovation. On the contrary, inter-industry differences have the positive effect of protecting from knowledge spillovers and spur innovation. An argument related to absorptive capacity has been posed against inter-industry differences, however, here this is solved by the sharing of a common knowledge base. We can formulate the following propositions.

- Intra-cluster characteristic

P4a): Inter-industry difference in the life-science cluster positively moderates the impact of size and density on the cluster's innovative performance.

The inter-industry difference in the cluster enhances the positive impact of size and density on the cluster's innovative performance.

- Inter-cluster characteristic

P4b): Inter-industry difference between the two nodes spanning an inter-cluster structural hole positively moderates the impact of the inter-cluster structural hole on the cluster's innovative performance.

The inter-industry difference between the two nodes spanning an inter-cluster structural hole, enhances the positive impact of the inter-cluster structural hole on the cluster's innovative performance.

3.2.3 Geographical distance

There is still a lack of clarity on whether geographical proximity should be retained as a defining characteristic of clusters. We investigate whether geography matters for a cluster's innovation process, trying to define the optimal boundaries of a cluster.

In the literature some elements support localization and proximity for innovation, others a wider geographical extension, all related to the *learning or governance* approach. Factors supporting **geographical proximity** are: (a) transaction costs reduction and development of relational dimensions; (b) location-specific drug development for epidemiological reasons; (c) location-specific regulatory framework; (d) tacit knowledge transfer, frequency of interaction, trust [23]; (e) location-specific assets (agglomeration economies, pool of skilled labor; scientific, technical, commercial spillovers) in positive "externality arenas" [7]; (f) the theory of proximity in the network theory, that identifies proximity as the main facilitator of knowledge flow [51]. Factors supporting **geographical distance** are: (a) need of an escape from local embedding for innovation (cognitive distance) [52]; (b) embedding in virtual communities, with internet use reducing transaction costs; (c) substitutive role of frequent meetings [23]; (d) avoidance of lock-in effect (social legitimacy; location-specific investments; institutional embedding: local obligations of conformity); (g) tension toward trans-local, disembedded clusters, in the real world (e.g. according to the European Cluster Observatory the bio-pharmaceutical clusters show a high degree of international openness) and in the institutional recommendations (e.g. European Commission) to enhance competitiveness. This is especially true for some industries, as the life-sciences, where the relevant knowledge base is strongly internationalized; (h) arbitrage opportunities with respect to regulatory framework.

Finally while co-location in firm-to-firm collaboration is not found to be an important factor, for universities' and firms' agreements, it is the opposite [53].

Considering what explained, a better solution for innovation would be a balance between local and non-local players inside the cluster, as well as in the inter-cluster connections (a moderate level of geographical distance): the shared context of a local circuit and of remote cooperation will be complementary resources [10], favoring the combination of *exploration* and *exploitation.* We formulate the following propositions:

- Intra-cluster characteristic

P5a): The geographical distance between the nodes in the life-science cluster moderates the impact of size and density on the cluster's innovative performance with an inverted U-shaped pattern.

A too-low level and a too-high level of geographic distance between the nodes in the life-science cluster reduce the positive impact of size and density on the cluster's innovative performance.

A moderate level of geographic distance between the nodes in the life-science cluster enhances the positive impact of size and density on the cluster's innovative performance

- Inter-cluster characteristic

P5b): The geographical distance between the two nodes spanning an inter-cluster structural hole moderates the impact of the inter-cluster structural hole on the cluster's innovative performance with an inverted U-shaped pattern.

A too-low level and a too-high level of geographic distance between two nodes spanning an inter-cluster structural hole reduce the positive impact of the inter-cluster structural hole on the cluster's innovative performance

A moderate level of geographic distance between two nodes spanning an inter-cluster structural hole enhances the positive impact of the inter-cluster structural hole on the cluster's innovative performance.

4. Discussion and Conclusions

Clusters have become a prevalent form of industrial organization and their innovativeness is considered to be a key source of regional and national competitive advantage. The primary contribution of the study is a framework that suggests an understanding of the factors that give rise to differential innovative outcomes across different clusters. Other contributions have been explained at the beginning of the "Proposition development" section. We tried to identify the impact of cluster's structural as well as nodal characteristics on the cluster's innovative performance. The potential moderation effect of contingency factors on the relations between network structure and cluster innovative performance have been underlined. More importantly we tried to distinguish between intra-cluster and inter-cluster dynamics in line with the OECD [54] conception of cluster as mainly open and reticular. To the extent that cluster may be thought of as a specific type of inter-firm network, some conceptual categories offered here may be considered valid also for a general theory of network innovativeness, contributing to the literature on alliances and inter-firm networks.

The study has some limits, too. Firstly, we have to mention the scope conditions of our predictions. The propositions are valid for a specific context that is a highly regulated setting, such as the life science industry, having some specificities: a process involving different, strict stages that must follow definite rules, as in clinical trials, and to which the contribution of diverse players - healthcare organizations or governmental organizations such as the technical and scientific public bodies of the National Health Service - are fundamental. Despite the numerous contributions on topic of alliances, the effects of alliances on highly regulated settings, are unexplored; this can open a novel research path. Secondly, in the present paper we focused on drug development as clusters' aim. However the cluster will produce a general improvement of the health condition in a given area and the innovation can also consist in: improvements in diagnostic-therapeutic paths or in risk management. These other applications of the topic could be further investigated. Thirdly, this paper has developed a conceptual framework, that can have empirical spillovers. It could be the basis for an original empirical quantitative study, enriching research on cluster-based innovation by using Social Network Analysis (SNA) methods. In fact the use of constructs and concepts derived from social network analysis in the clusters’ actual operationalization is only occasional [41]. It would be possible to test the THM (Triple Helix Model) with empirical evidence coming from fieldwork, adopting statistical and quantitative methods. The five propositions could be converted into hypotheses and statistically tested.

Despite the aforementioned limits, the paper's topic is relevant and grounded in reality because the cooperative options are widespread[6] given that trends of growing systemic complexity, increased specialization, enhanced regulatory hurdles, advent of molecular biology and genetic engineering, yielded a profound transformation of the life-science industry. They induced a division of labour requiring a new organizational form made up of new networks of scientists, specialized new entrants and large pharma

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[6] Cases of common knowledge are the UK, where there are 56 innovative clusters but particularly important are those of Cambridge (with 28 colleges, 370 hi-tech firms) and Edinburgh; Route 128 in Boston around MIT; Silicon Valley. Clusters diffusion is above the average in Finland, Germany, Sweden, Uk, US, Japan. The historical data on inter-firm R&D partnering in the life science industry reveal an overall growth pattern in the number of newly established R&D partnerships since the mid-1970s.

firms. The conclusions of the work could be significant for the world of the practice in that they could drive the choice of the best structural configuration and the best partners' mix, thus increasing the managerial capabilities with reference to clusters' formation.

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