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Dynamic Externalities, Universities and Social Capital Formation in the EU Biotechnology Industry

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Abstract. *The paper investigates the role of dynamic externalities, university-industry linkages and role of social networking in the biotechnology industry in the European Union (EU). Universities act as platforms for local knowledge spillovers and university-industry cluster development in the biotechnology field. The R&D activities at universities contribute to successful business innovations. However, the relationship between the universities and the local innovation capabilities is much more complex and therefore requires more in-depth analysis. The following study derives from the knowledge of the new economic geography, endogenous growth theory, biotechnology, as well as theories of social capital and social networks. The quantitative research elaborates contemporary literature and databases to find channels of interdependence between local university-based knowledge flows, social capital, and biotechnology cluster performance. The results of the study show that the biotechnology industry relies very much on university-business R&D partnerships and research mobility (e.g. pharmaceutical firms that performed basic research in close cooperation with academia produced more patents). In addition, social networking and informal contacts seem to be a more important for the diffusion of knowledge, especially at the beginning of R&D process, as they allow for building credibility between potential partners.*

Keywords: *industrial biotechnology, knowledge spillovers, clusters, regional development.*

Introduction

Smart specialization has been highlighted in the latest *Europe 2020 Growth Strategy* and *Cohesion Policy 2014-2020*. Both documents place smart specialization to the bottom-up entrepreneurial discovery process about a region's assets, its challenges, competitive advantages and the potential for excellence (European Commission, 2012). In this approach of priority-setting of the region`s specialization, local dynamic externalities, social networks, and university-industry collaborations play a crucial role. The role of social collaboration networks seems to be even more important in the case of such dynamic industries as biotechnology, where research is more complex and interdisciplinary. As Emanuela Todeva (2013) puts it, the smart specialization, in this context, is a function of the university-industry

interactions, and the acceleration of knowledge transfer practices, such as spin-offs, start-ups, contract research.

The following paper investigates the ways in which proximity to universities enhances social networking and informal contacts in the biotechnology industry, and thus enhances region`s innovative capabilities and smart specialization development. The research study addresses the following research questions: Where is the biotechnology industry concentrated in the EU? Which cluster (dynamic) externalities are predominant in the EU biotechnology clusters? What are the linkages between the biotechnology industry development and the university R&D labs? What is the role of social capital in the knowledge spillovers in the biotechnology industry in the EU?

The research study covers the period from 1997 up to the latest accessible data. The first section of the research papers aims to identify based on the subject literature, the theoretical linkages between the clusters, dynamic externalities and social networking. The second section of the paper focuses more specifically on the biotechnology industry drivers of development, technological externalities as well as on mapping biotechnology clusters in the EU. Finally, the last part presents the overview of the empirical studies results on the role of universities and social networking in the localized knowledge spillovers and innovation capabilities in the biotechnology industry. The research paper ends with relative conclusions and policy recommendations.

Clusters, dynamic externalities, and social networking

According to Porter's (1998) cluster-based theory of externalities, clusters, with its many competing or collaborating across related industries firms, tends to trigger innovation and learning processes. As Malmberg and Maskell (2002, p.433) point out, "in such environment, chances are greater that an individual firm will get in touch with actors that have developed or been early adapters of new technology. The flow of industry-related information and knowledge is generally more abundant, to the advantage of all firms involved". According to Van der Berg, Braun, and van Winden (2001), most definitions of the cluster share the notion of clusters as localized networks of specialized organizations (firms and institutions), whose production processes are closely linked through the exchange of goods, services and/or knowledge. In the social network studies, these actors of a cluster refer to "individuals, groups or companies tied by the relationships or flows of resources that can be material or non-material" (Wasserman & Faust, 1999,

p.4). The resources might include social support, time, information, knowledge and expertise sharing, and so on.

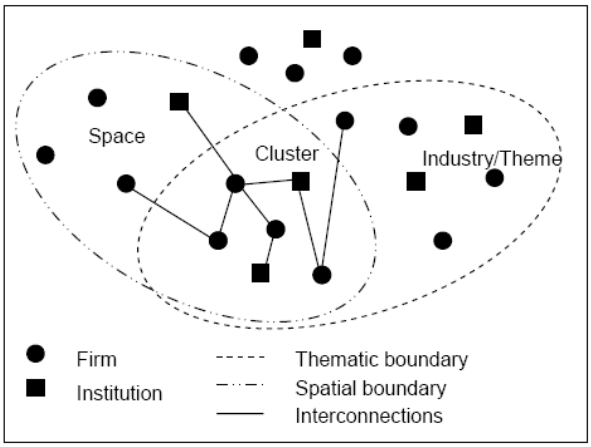


Figure 1. Interconnections between firms and institutions in a cluster (Menzel & Fornahl, 2007)

The role of social capital in linking the main cluster components: technology, humans, financing and infrastructure is represented in Figure 2.

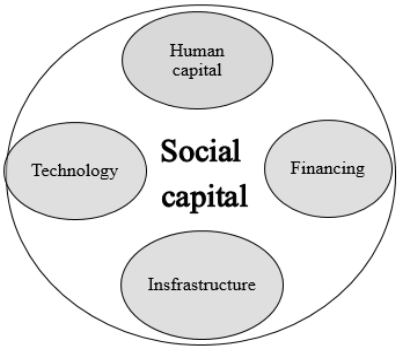


Figure 2. Social capital and main cluster components

Furthermore, as Audresch (1998) suggests the industries, in which tacit knowledge and innovative activity play an important role show a higher tendency to spatially cluster. However, there have still very few attempts to empirically investigate the role of the spatial dimension in the knowledge spillovers. The latter is mainly because tacit knowledge flows are hard to track, especially when pure technological externalities are concerned (Johansson, 2005).

Other factors and processes that influence the spatial and technological boundaries of a cluster is the ongoing process of globalization and increasing competition in knowledge-intensive sectors. Hence, important knowledge sources of the innovation of local firms stem from both local and global knowledge linkages. These linkages consist the base on which social capital is flourishing enabling all cluster participants to efficiently cooperate with one another, which leads to the increased generation of positive externalities coming from co-location and building collaborative synergy within the cluster, as well as openness for cooperation with other clusters, which leads to knowledge spillovers among them and increasing innovations (Bochniarz-Faoro, 2013). Social networks, both online and real, contribute to increasing numbers of contacts between participants sharing common interests and create the entire communities. Social networks foster the transfer, diffusion of information and knowledge (Bratianu & Orzea, 2013).

Dynamic externalities and industry life cycle

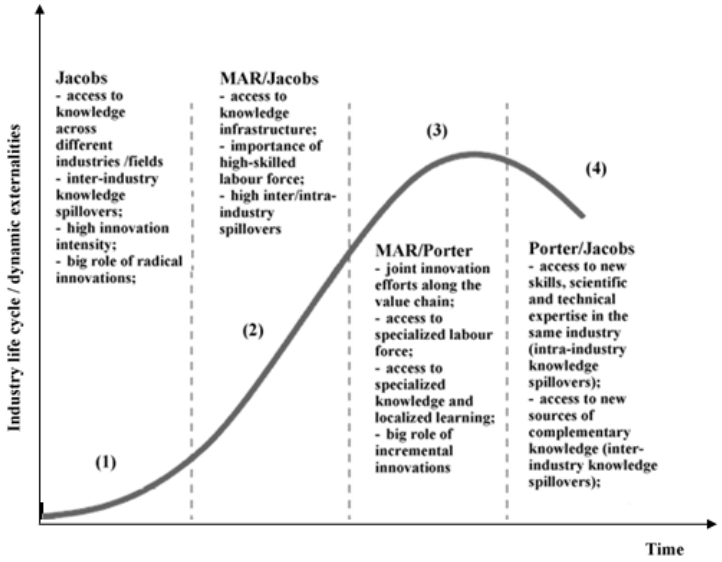
Knowledge spillovers and positive externalities from co-location play a larger role in industries that are undergoing rapid technological change or are in a growing stage of their economic life cycle. There are three types of dynamic externalities: the MAR (Marshall-Arrow-Romer), Porter's, and Jacobs`, that allow tracking the role of knowledge flows throughout industry's life cycle (Runiewicz-Wardyn, 2013). The industry life-cycle model is based on a stylized description of the evolution of an industry and follows the logistics of an S curve, starting with the introduction of new products, followed by a period of strong expansion of production, which then levels off and eventually leads to a decline. It is possible to assume that certain types of dynamic externalities assist the industry as it moves from a young to a more mature stage (Figure 3).

Furthermore, new industries – or industries at the introductory stage of their development – benefit mostly from diverse knowledge infrastructure and inter-industry knowledge spillovers. Therefore, Jacobs' externalities will be more important at this stage. The birth of a new industry typically follows radical innovations, which may originate outside of the particular industry or sector. Innovation intensity is high, as there are many unexplored technological opportunities (Neffke et al., 2009).

At the growth stage of industry development, production becomes more standardized, which opens up possibilities for firms to exploit their divisions of labor and economies of scale, companies produce more or less similar products and get increasingly involved in price competition. This leads

typically to a sharp drop in prices and a growth in production volumes. Both MAR's and Jacobs's externalities may be important at this stage.

At the stage of maturity, firms typically face vigorous price competition. Profit margins are reduced and technological opportunities are exhausted. In terms of innovation, longer jumps in technology are less likely and innovations are more of Arrow's nature (radical innovations are all but infeasible, as the industry has invested heavily in machinery and skill development that would become obsolete by dramatic discontinuities in technology). The R&D efforts require very specialized, industry-specific knowledge and skills. Such expertise is often of a strong tacit nature and is best acquired through processes of learning by doing and imitation. The role of local possibilities to tailor education, training systems and access to the university R&D output increases. Both tendencies lead to a lowering of Jacobs' and an increase of MAR/Porter's externalities.



Note: *from (1) introductory, (2) growth, (3) maturity and (4) decline phase of industry life cycle

Figure 3. Industry life cycles* and dynamic externalities

The overview of the literature on industrial life cycle and dynamic externalities imply that social networks may be determined by the above-demonstrated interrelationships between the industry`s maturity process and cluster dynamic externalities. Similarly, some mutual linkages between the actors within the social network may exhibit more stability than others, yet others may transcend cluster boundaries (local networks) and access to communication and potential links with other nodes within national, international and global value chain networks. Thus, in order to comprehend better the interdependencies between clusters, dynamic externalities and

social networking the specific industry and its regional contexts must be considered. The next section is going to focus on the case of the biotechnology industry in the selected EU regions.

Biotechnology industry life cycles and drivers of development

The biotechnology industry represents technological evolutions in the biopharmaceutical industry, as a whole. The opportunities in the biotechnology industry largely mirror those in the pharmaceutical industry[1]. The key difference between the two industries is that biotechnology firms are much more focused on research activities because they are still developing their initial products. Thus, biotechnology is a relatively young branch of bioscience, developed in the late 2000s. According to the literature, the biotechnology industry started to form its shape in the early 1980s. when improved the regulatory and patenting and licensing systems and launch government-lead research initiatives, especially in the US. The innovation process shows that there is not just one S-curve but a succession of S-curves from organic chemistry/pharmacology to biochemistry and molecular biology (Figure 4). It can be seen that the waves of molecular biology overlap the waves of biochemistry and are about to leap upwards.

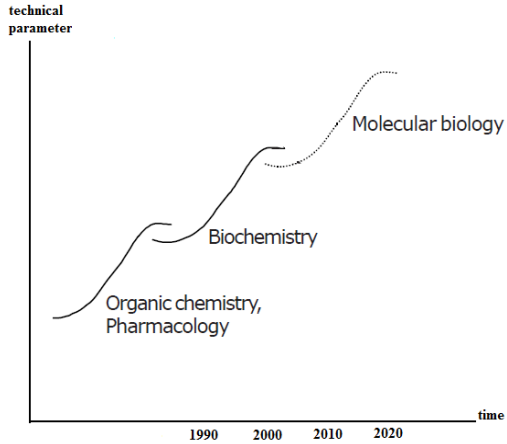


Figure 4. Industry life cycle maturity and technology diffusion in high-tech industries (Runiewicz-Wardyn, 2013)

Currently, scientists and researchers are attempting to exploit basic molecular research to identify new drugs, the production of which will be

[1] *The major difference between biotechnology products and pharmaceuticals is that in case of the former drugs are produced in living organisms such as bacteria, yeast and mammalian cells, whereas in case of the latter they are produced through a series of chemical synthesis.*

based on recent advances in genomics technology. Scientific breakthroughs such as genetic engineering, the ability to create monoclonal antibodies, and the mapping of the human genome have opened up new areas of research, and the pace of discovery in basic biomedical science has accelerated dramatically over the past few decades. The emergence of biotechnology is changing the pharmaceutical industry in terms of requiring a convergence of science and technologies and a multi-disciplinary approach to producing new technological discoveries (biological sciences, chemical engineering, bioprocess engineering, information technology, and biorobotics). The latter explains the fact that many cluster agglomerations; where biotechnology is co-located involve the interaction of such actors as science-based universities, global multinationals, health care facilities as well as other related industries (chemical, instrumentation, medical, and health research). Increasing competition drives the specialization of firms in specific products; however, so far this has been somewhat limited due to the few experts in the specific biotechnology fields, e.g. cancer diseases. Biotechnology is firmly rooted in the growth stage, with heavy reliance on science and R&D investments, however, industrial biotechnology is still in its relatively early stage of growth, and many potential products are not yet on the market.

Patenting has increased sharply over the past few decades, with biotechnology patenting applications far outpacing the general rise in patenting applications. The biggest number of patents in biotechnology grew from the late 90s up to early 2000. For example, in 1977, there were only 12 biotechnology patents filed globally under the PCT. By 2009, this number had increased up to 9,339 patents (this is substantially more than a 77% increase). Almost 70% of these patents were filed by an inventor resident in either the EU-27 or US (OECD, 2012).

The level of activity in the biotechnology industry among the EU countries depends largely on the research field. For example, Europe's competitive edge lies mainly in healthcare applications and in industrial biotechnology, including the chemical industry. Some Member States have developed advanced biotech sectors whereas others have stayed behind (Denmark, Germany, UK). New Member States of the EU are generally the early movers in the biotechnology sector. Thus, the identification of the stage of life cycle of the biotechnology industry must be treated with necessary caution.

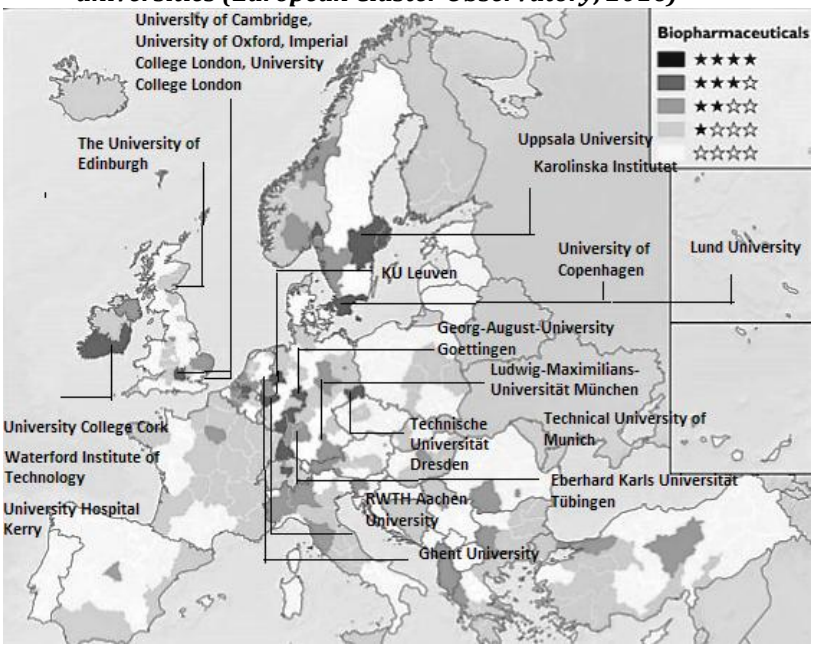
However, while the biotechnology sector shows a strong growth stage, the degree of diffusion and adoption of biotechnology products and processes has been slowed down for several reasons. Mainly, the substitution of traditional techniques for producing products with the use of biotechnology relates to the costs of the transformation of existing production processes,

e.g. substituting diesel extracted from petroleum with biodiesel made from feedstock or canola oil (McNiven, 2007). Moreover, in the present case of biopharmaceuticals, the demand side is largely influenced by regulations. It is strongly regulated and therefore excludes many inventions due to morality (European Patent Office, 2016).

Mapping biotechnology clusters in the EU

The major share of the biotechnology firms is concentrated in "biotechnology clusters" mostly located in western and northern European regions or countries with a long tradition of life sciences and biotechnology research and activities in industries such as pharmaceutical, chemical, agro-production and medical technology. Biopharmaceutical employ over 2 million people in the EU. It is among the largest sectors supported by cluster organizations. These clusters are often located around research institutions and universities. These organizations form a highly attractive infrastructure both for scientists and for specialized suppliers of materials, equipment, and services. The reason for being part of these networks is the diversification of costs and risks of developing new technologies and the innovative environment. Investments and acquisitions of university biotech spin-offs accelerate the location advantages of some clusters and regions, generating a positive dynamic for growth (Todeva & Rakhmatullin, 2016).

Map 1. The EU regions specializing in biopharmaceuticals and their leading universities (European Cluster Observatory, 2016)



Map 1 shows the EU locations specializing in biopharmaceuticals and their leading universities. These regions were much more successful in providing a "critical mass" for encouraging research and enhancing networking between business, higher education institutions, research centers, and technology parks. As a result, they follow the virtuous circle of growth – innovations and technological change is fueling economic growth, which is being fed back into higher earnings and greater investment in education and R&D.

Dynamic externalities in the biotechnology industry

The analysis of the growth stage of biotechnology shows that the industry is still in the initial stage of growth in its life cycle. This requires huge amounts of R&D funding, whereas R&D projects often involve a high risk of failure. Biotech firms that are active in the biopharmaceutical sector and do not have alliances with large pharmaceutical firms, tend to rely more heavily on domestic sources in their innovative activities, including universities and public research organizations. Thus, in order to stimulate positive technological externalities in the biotechnology industry, the local productive structure must be determined by the presence of diversified local technological capability centers (clustered near universities).

Furthermore, the rate of innovation in biotechnology depends on the strong interaction with science-based university research and on the presence of other industries, such as pharmaceutical, chemical, healthcare, food, etc. Furthermore, because most European companies specializing in biotechnology are small or medium-sized enterprises (SMEs). Therefore, the rivalry is extremely intense. High research costs, the need to fully exploit patent protections before they expire, and the expenses of costly marketing induce close alliances and co-operation among biotech firms and R&D institutions. In fact, the study by Runiewicz-Wardyn (2013) shows that both agglomeration economies and the proximity to a qualified labor pool as well as other biotechnology firms have a positive and significant impact on biotechnology patents. Other researchers have reached a similar conclusion. For example, Prevenzer (1997) shows that in biotechnology firms tend to cluster together in just a handful of locations. The above arguments suggest the existence of earlier described Porter externalities in the EU biotechnology clusters.

Furthermore, the results of Runiewicz-Wardyn's (2013) study indicate that diversity across complementary economic activities is very conducive to

innovation in the biotechnology industry. Biotechnology companies especially those whose success depends on staying on top of new technologies and processes, increasingly want to be where new, hot ideas are percolating. This suggests patenting in biotechnology requires combining innovative specialization with industry diversity. The latter could also suggest Jacobs's (1969) externalities. Except for the fact that Jacobs (1969) and Porter (1998) argue the opposite, Porter (1998) considers that competition is more conducive to knowledge externalities than a local monopoly would be. It should be emphasized that by local competition, Jacobs (1969) refers to the competition for new ideas embodied in economic agents. An increased number of firms provide greater competition for new ideas, but greater competition across firms facilitates the entry of new firms specializing in some new product niche. This is because the necessary complementary inputs and services are likely to be available from small, specialist niche-oriented firms but not necessarily from large, vertically integrated producers. Large firms play a pivotal role also in driving innovation, but share this role with small technology and service firms, which sometimes operate under the radar (Todeva & Rakhmatullin, 2016).

In sum, the rate of innovation in biotechnology depends on to a large extent on specialization and cooperation among large pharmaceutical firms and small, research-intensive institutions, biotechnology enterprises. Agglomeration externalities in the sense of Jacobs's resulting from inter-industry knowledge spillovers turned out to be especially important in the biotechnology industry in its early growth phase. Further on, the innovative activity of biotechnology firms is determined by a combination of both innovative specialization, industry diversity and competition externalities.

Local knowledge spillovers and universities-industry collaborations

It`s been already pointed out in the previous section of the paper that different agglomeration externalities are needed in various stages of biotechnology industry life-cycle. Even though the dynamic externalities approach seems to be very useful in explaining cluster development, some scholars link the emergence of high-tech clusters rather to spin-off activities than agglomeration externalities (Boschma, 2014).

The role of the university was already acknowledged in Michael Porter`s cluster diamond model, mapping four interactive dimensions that impact cluster competitiveness. The latter are the factor conditions, demand conditions, firm strategy and rivalry, and supporting industries. Universities are one such factor. On the one hand, universities also influence other dimensions of cluster competitiveness, e.g. increasing the quality of inputs,

upgrading human capital, disseminating knowledge and generating new technological opportunities. In fact, many platform technologies for the new biotechnology companies have been started with basic research programs run in the university labs.

In fact, universities and their research centers play a "catalytic role" in the process of regional development and thus influence knowledge-based economic development (Ketikidis et al., 2016). Most of the knowledge universities produce may flow and spill over to the local economy by means of university-industry transfer projects, university spin-offs, and the mobility of university graduates and researchers to industry and social networks. Trained science and technology (S&T) graduates look for their first jobs in an area of the university. In fact, Bekkers and Freitas (2008) conclude that labor mobility is very important for the transfer of academic technological 'breakthroughs' into the biotechnology industry in Dutch universities (PhDs and academic staff). Zucker, Darby and Armstrong (2002) report that biotechnology firms that collaborate with 'star' scientists are more likely to be productive in terms of a number of patents. On the one hand, doctoral S&T graduates of pharmaceutical or engineering industries employ their academic knowledge in industry; on the other hand, they learn from their training in laboratories in large corporations.

Audretsch and Stephan (1996) points that the discovering scientists ('superstars') tend to enter into contractual arrangements with existing firms (contract or ownership) or start their own firm in order to extract the supra-normal returns from the fruits of their intellectual human capital. Moreover, the scientist works with or create a new firm within commuting distance of home or university (where they tend to retain affiliation) thus creating localized effects of university research. Similarly, in terms of R&D collaborations and knowledge networking in the biotechnology, local knowledge spillovers and nationally based R&D institutions and business entities seem to play a significant role and thus confirms the general features of a strong spatial concentration of the biotechnology industry.

Aharonson, Baum, and Feldman (2004) emphasize consistently that proximity to universities and/or other local sources of knowledge is important for the circulation of tacit knowledge and that personal acquaintance with the scientists, continuous monitoring of companies are fundamental aspects of venture capital and this knowledge is much easier to be acquired at the local level. The discovering scientists ('superstars') tend to enter into contractual arrangements with local firms (contract or ownership) or start their own firm in order to extract the supra-normal returns from the fruits of their intellectual human capital. Moreover, the scientist works with

or create a new firm within commuting distance of home or university (where they tend to retain affiliation) thus creating localized knowledge spillovers. Access and ability to use (and integrate) external knowledge becomes increasingly important for growth and diversification (Corelleur, Carrere, & Mangematin, 2003; Lemariè, Mangematin, & Torre, 2001).

In other terms of a secrecy of knowledge sharing localized effects of university and industry research are most likely to result primarily from a combination of tacit non-replicable knowledge and low geographical as well as organizational mobility of researchers (Breschi & Lissoni, 2001). Furthermore, the interviews with EU biotechnology field experts in 2011 conducted by Runiewicz-Wardyn (2013) have shown the importance of IP protection and secrecy in R&D projects. They emphasized the importance to publish all the R&D output, prior to discussing them in public or in an informal way. Some knowledge tends to remain sticky and limited in its circulation. Naturally, excludable and rivalries knowledge do not spill over, it is rather people embodying knowledge move (locally) across organizations in order to exploit the value of their knowledge.

The role of local research base and spin-offs in the EU biotechnology industry – the overview of the empirical studies results

The following two sections present the research conclusions based on the review of over 30 different research papers and articles, aiming to identify the knowledge spillovers, the role of networks and collaborations and dynamic externalities in the biotechnology clusters in the EU. The method applied by the authors included both case study and/or econometric analysis.

The study results by Prevezer (2003), Aharonson et al. (2004), Corelleur at al. (2003) and Swann and Prevezer (1996) show that access and ability to use (and integrate) external and local knowledge becomes increasingly important for growth and diversification in biotechnology clusters. Similarly, Pammolli and Riccaboni (2001) conclude, in their analysis of the European biotechnology clusters, that clustering derives to a large extent by the availability of a strong, heterogeneous but integrated research base that facilitates the transfer and the integration of knowledge, as well as the development of skilled labor, the mobility of such labor and – presumably – also the development of other supporting institutions like venture capital (Table 2).

Table 2. The overview of the research studies results on cluster development in biopharmaceutical sector in the EU based on the literature (for the period 1997-2013)

EU biotechnology industry	
Role of university spin-offs	**Local research base**
1) many new biotechnology firms in the EU15 are university spin-offs (which are at the initial stage of development in the New EU Member states). 2) successful clusters exhibit high rates of internal firm's formation, whereas weaker clusters are characterized by lower domestic productivity and higher propensity to migrate. 3) process of a spinoff from local institutions originates and sustains the cluster. 4) spinoffs and startups tend to locate close to their "parents" and region-specific practices/ways of doing things.	1) local sources of knowledge appear to be fundamental in the early stages of cluster development and for new, highly specialized firms. 2) access to external and inter- regional knowledge becomes important for growth and diversification. 3) firms collaborate with 'star' scientists, PhDs and academic staff, especially in the case of very specific, narrow fields. 4) strong, heterogeneous but integrated research base facilitates knowledge/technology transfer. 5) pharmaceutical firms, which perform basic research in close cooperation with academia produce more patents.

Many new biotechnology firms in the EU15 are university spin-offs, in the New Member states spin-offs are at the initial stage of development. Consequently, successful clusters continue to exhibit high rates of internal firm's formation, whereas weaker clusters are characterized by both lower domestic productivity and higher propensity to migrate. Moreover, spinoffs and startups tend to locate close to their "parents, therefore the process of a spinoff from local institutions originates and sustains the cluster.

Furthermore, local sources of knowledge appear to be especially important in the early stages of the development of a cluster and for new, highly specialized firms. Whereas access and ability to use (and integrate) external/pan-European/global knowledge become increasingly important for growth and diversification (Corelleur et al., 2003; Lemariè et al., 2001; Prevezer, 2003; Swann & Prevezer, 1996).

Networks and collaborations in the EU biotechnology industry - the overview of the empirical studies results

A number of authors have commented upon the growing importance of social networks and collaboration in achieving innovation capacity (Mowery, 1988). Less understood are the mechanisms by which such networks emerge. In terms of the character of networks, the case studies based on the EU clusters (Van Egeraat & Curran, 2010) show that both the formal networks, connected through patents, and the informal networks, connected

through directorship do exist. However, the formal network is noticeably less clustered than the informal network, which suggests knowledge in the formal network will flow and diffuse in a different, slower manner. The complex and interdisciplinary nature of relevant knowledge bases in pharmaceutical R&D tends to make technological innovations the outcome of interactions and cooperation among different types of agents commanding complementary resources and competencies. The formal network is noticeably less clustered than the informal network, which suggests that the informal networks are far more conducive to knowledge flow than the formal networks.

Owen-Smith, Riccaboni, Pammolli and Powell (2002) compare the structure of the American and European networks in biomedical research. They show that the US network is characterized by extensive relationships between U.S. public research organizations and firms located in dense regional clusters that span therapeutic areas, across multiple stages of the development process, and involve diverse collaborators. In contrast, European innovative networks are characterized by sparser, more specialized and upstream relationships among a more limited set of organizational participants located in national clusters (Table 3). Both U.S. and European networks are geographically clustered, then, but in quite different manners.

Table 3. The overview of the research studies results on knowledge spillovers and networks in the EU biotechnology industry (for the period 1997-2013)

Knowledge spillovers	Networks and collaborations		
	Character of networks	**Degree of diversity**	**Geographical dimension of networks**
1) proximity to universities is important for tacit knowledge, sharing R&D opportunities and personal acquaintance. 2) superstars enter into contractual arrangements with existing firms (contract or ownership) or start their own firm (to gain supra-normal returns); 3)scientist work with or create a new firm within commuting distance of home or university (of affiliation) creating	1) cooperation among different types of agents of complementary resources and competencies. 2) links between distinct clusters in the network. 3) networking and informal contacts more important at the early stage of R&D process whereas further knowledge sharing is determined by the importance of IP protection and secrecy. 4) formal network is	1)networks are characterized by sparser, more specialized and upstream relationships among a limited set of organizational participants located in national clusters.	1) strong geographical dimension spanning well beyond the boundaries of the location. 2) openness to geographical distant nodes: increasing number of collaborations and a decreasing proportion of local connections. 3) better-performing and growing firms rely less on local sources of knowledge. 4) inter-organizational collaboration follows the

localized effects of research.	noticeably less clustered than the informal network.		accumulative advantage based on the overlapping specialization, and multi-connectivity. 5) network tends to consolidate around a rather stable core of companies, composed by large incumbents and early entrants in the network.

Networks span well beyond the boundaries of the geographical location, but the performance of the individual nodes within the network is strongly associated with high degrees of openness to geographical distant nodes (Owen-Smith et al. 2002; Pammolli & Riccaboni, 2001). Moreover, in a dynamic perspective, the growth of geographical networks and the tendency towards clustering is accompanied by a parallel process of increasing openness of the original clusters. In Europe, recent trends suggest a combination of an increasing number of collaborations and a decreasing proportion of local connections (Pammolli & Riccaboni, 2001). Similarly, in the USA biotechnology clusters rely increasingly less on local sources of knowledge (Corelleur et al., 2004). In a similar way, Powell, Porter and Whittington (2005) conclude that biotechnology clusters in the EU follow the accumulative advantage based on the overlapping specialization and multi-connectivity. For example, international cluster networks can help setting up cluster initiatives by transferring the experience of more mature clusters to emerging ones. An example can be drawn from the Connecting Energy Clusters across Europe project (CENCE). The CENCE consortium played a vital role in the development of a new Bioenergy Innovation Cluster in Northern Hungary. Embedded in international co-operation, local clusters receive practical advice and support in structuring and managing the new cluster organization from the start.

Summary and conclusions

The main research questions addressed in this paper concerns the role of dynamic externalities, university-industry linkages and role of social networking in facilitating the development of the EU biotechnology industry. For this purpose, the author adopted contributions from the industry life-cycle theory, theory clusters, and dynamic externalities as well as the social capital literature. Globally these research results contribute to on-going debates in the area of high-tech clusters formation and development, social

networks and university-industry linkages, both at the methodological and empirical levels. The results obtained, although still exploratory, already provide some indications concerning a preferable condition for the EU biotechnology industry to develop and prosper. The development of biotechnology industry in the EU is attributed to both agglomeration externalities and the presence of leading universities and research laboratories. The results of the study show that the interaction and collaboration are of particular importance to the EU biotechnology industry, especially for the SMEs, for securing financial resource, business platforms, and infrastructure required for biotechnology research or business development. The EU biotechnology industry relies very much on university-business R&D partnerships and research mobility as knowledge-diffusion channels. The research further supports the view of Todeva and Rakhmatullin (2016) that building an effective triple helix of proactive public authorities, universities and business enterprises is a prerequisite for the development and implementation of smart specialization strategies through interregional cooperation at European level.

The results confirm the general features of a strong spatial concentration of the biotechnology industry. Social networking and informal contacts seem to be a more important at the early stage of R&D process, whereas in terms of further knowledge sharing experts emphasized the importance of IP protection and secrecy in R&D process; and therefore the importance to publish all the results, prior discussing them in public or in an informal way. The R&D collaborations and knowledge networking in the home region and nationally based R&D institutions and business entities seem to play a more significant role for the newer EU member states. For many R&D units, EU ERA-NET-based R&D funding plays only a secondary role. The latter fact shows that the actual ability of regional R&D units to participate and take advantage of knowledge networks (locally or/and globally) depends largely on their own stock of knowledge and absorptive capacities.

In terms of the further research, several questions should be considered. For example, what regional local externalities favor job mobility in the biotechnology industry or how do social networks fit into the larger debate around the development of biotechnology technology clusters? Furthermore, if cluster development depends on the formation of social networks that have primary origins through shared career experiences, then what could be the role for government institutions in favoring such networks? These questions are important and should be further developed in the research.

In terms of policy recommendations, it is essential to encourage the EU Member States to consider the role of universities and social capital in their

regional/ local innovation systems, especially when drafting smart specialization strategies. Furthermore, analysis how universities are being involved in smart specializations, including sharing experiences and best practices of university-regional engagement across the EU, match the technical and academic profiles of local universities with the economic priorities of the region as well as study the existing relationships between the university, individual academics and other regional actors to 'nourish' the partnerships. Last, but not least, understand the specific obstacles and challenges that inhibit a greater level of engagement of local universities in the region.

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