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How do pharmaceutical companies exploit and explore knowledge?

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Abstract

How do pharmaceutical companies exploit and explore knowledge? Francesca Bignami Health Innovations Research Group, MMC-LIME, Karolinska Institutet, Stockholm. Year of enrolment: 2013 Expected final date: 2017 Email address: francesca.bignami@ki.se State-of-the-art Innovation requires that firms produce new knowledge and use existing knowledge sources. In line with this concept, organization literature has distinguished between explorative and exploitative knowledge relating to whatever the knowledge involves "a pursuit of new knowledge "or "the use and development of thing already know" (March and Levinthal, 1993; March, 1991; Gupta, 2006). New knowledge of firm combines existing and/or new knowledge that doesn't only happen within a company but it also involves external organizations. Several authors, using the dichotomy by March (1991), underlined the value of collaboration with partners for the learning process of an organization by accessing new knowledge outside the firm's boundaries, as knowledge exploration, and by leveraging existing knowledge with partners, as knowledge exploitation (Beckman et al., 2004; Kim and Park, 2013; Guan and Liu, 2016). Research gap In this paper, we are interested in how the collaboration pattern differs when firms collaborate in an explorative versus an exploitation knowledge area. The main research question is: how do exploitation and exploration knowledge areas influence the collaboration pattern of companies? Previously literature has extensively investigated external collaboration patterns and factors that influence them in different sectors, countries, and sized companies and the majority of these studies has focused on different types of collaboration set ups such as alliance, joint venture, etc. Thus far, we are unaware of any systematic research that used the dichotomy of exploration and exploitation knowledge to investigate external collaboration pattern used by firms. Theoretical Arguments These types of knowledge differ considerably from each other. In the explorative knowledge area, the knowledge is both tacit and novel to the firm (Levinthal and March, 1993; March, 1991). In contrast, exploitative knowledge is likely to be explicit and entails less uncertainty because the company is experienced and has much of the required knowledge in-house (Levinthal and March, 1993; March, 1991). This distinction between knowledge exploration and exploitation can be an important factor in explaining collaboration patterns used by a company. Method The focus area of this paper is on 6 big pharmaceutical companies. The pharmaceutical industry is an ideal case for the purpose of the article because it is a knowledge-intensive industry and heavily engaged in external collaborations. First, we identified for each company the therapeutic areas of exploration and exploitation knowledge. Therapeutic areas where products already exist on the market (high sales), with ongoing clinical trials and publications, were classified as exploitation knowledge areas. In contrast, exploration knowledge can be found in therapeutic areas where there

are no current products (low sales), clinical trials in early phases and a low but growing number of publications. Second sales, clinical trial, and scientific publications were gathered for the time period (2000-2013) and classified according to therapeutic areas. Third, collaborations of the selected companies were measured through co-publications. Finally, in order to study the external collaboration patterns, we analyzed the geographical proximity ,the type of actors (e.g. universities, companies, hospitals, research institutes)and network structure for publications classified as either exploration or exploitation knowledge area. Expected results Our preliminary results show that companies have different collaboration patterns. The increase of countries involved in publications indicates the growth of network around these companies. In further analysis, we expected that companies, in exploitation knowledge area, team up with external partners closer to their competencies. As consequence, these partners are similar to the big pharmaceutical companies, for example, competitive companies, and the geographic proximity plays a marginal role. In contrast, exploration knowledge area implies that companies are active in a new therapeutic area and the exchange of knowledge is likely to be of tacit character. Further, we aim at testing how these identified collaboration networks differ in their structure. References Beckman, Christine M., Pamela R. Haunschild, and Damon J. Phillips. "Friends or strangers? Firm-specific uncertainty, market uncertainty, and network partner selection." Organization science 15.3 (2004): 259-275. Guan, Jiancheng, and Na Liu. "Exploitative and exploratory innovations in knowledge network and collaboration network: A patent analysis in the technological field of nano-energy." Research Policy 45.1 (2016): 97-112. Gupta, Anil K., Ken G. Smith, and Christina E. Shalley. "The interplay between exploration and exploitation." Academy of management journal 49.4 (2006): 693-706. Kim, Changsu, and Jong-Hun Park. "Explorative search for a high-impact innovation: the role of technological status in the global pharmaceutical industry." R&D Management 43.4 (2013): 394-406. Levinthal, Daniel A., and James G. March. "The myopia of learning." Strategic management journal 14.S2 (1993): 95-112. March, James G. "Exploration and exploitation in organizational learning." Organization science 2.1 (1991): 71-87.

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Introduction

Innovation in firms require the combination of both new and existing knowledge. New knowledge can either be obtained along the same trajectory as a firm's existing knowledge or along an entirely different trajectory (Benner & Tushman, 2003). In this regard, the organization literature distinguishes between explorative and exploitive knowledge where explorative is defined as "a pursuit of new knowledge" and exploitative as "the use and development of thing already know" (Levinthal & March, 1993; March, 1991). This study applies this distinction specifically to knowledge exchanged in external collaborations. We study the collaboration pattern of firms when they are involved in explorative knowledge areas and exploitation knowledge areas. This is relevant not only, for understanding, a firm´s knowledge acquisition strategy in terms of collaborations but also for the balance and absorption of exploration and exploitation knowledge inside a firm.

External collaborations are become an integrated part of the R&D process in many industries with the aim to reduce costs, minimize risks and combine knowledge (Matt & Wolff, 2004). Earlier literature has showed that firms collaborating externally have a much greater chance to produce more successful and economically relevant innovations (Ahuja, 2000; Stuart, 2000). Essential for the company is to find out what competences are missing and how to incorporate internal and external knowledge in order to form a sustainable company. In this regard, firms need to develop internal absorptive capacities in order to identify, integrate, transform and exploit knowledge (Cohen & Levinthal, 1990; March, 1991; Zahra & George, 2002) But there is not only one mode to do that. Several studies have confirmed that significant and persistent differences exist across firms in their ability to collaborate (West & Bogers, 2013). A firm needs to find the right pattern in order to gain the most from the collaboration (Dahlander & Gann, 2010).

This study explores the role of exploration and exploitation knowledge in this heterogonous environment. These two types of knowledge differ considerably from each other. Explorative knowledge is tacit and novel to the firm (Levinthal & March, 1993; March, 1991). In contrast, exploitative knowledge is usually not tacit and entails less uncertainty since the company has much of the required knowledge in-house (Hausen et al, 2001). This distinction may be an important factor in explaining the different modes used by a company to collaborate externally.

Although previous research has investigated collaboration modes and factors that influences industry in different sectors, countries and sized companies (Acs, Audretsch, & Feldman, 1994; Klevorick, Levin, Nelson, & Winter, 1995; Laursen & Salter, 2004; Mohnen & Hoareau, 2003; Narula, 2004; Tijssen, 2009) we are unaware of any systematic research that used the dichotomy of exploration and exploitation knowledge to investigate external collaboration patterns used by firms. More research is needed to understand where the knowledge involved in collaboration comes from, the type of knowledge and to what extent the use of external partnering is a result of companies' collaboration strategies or/and a result of globalization.

The focus area of this study is the pharmaceutical industry. The pharmaceutical industry is an ideal case for the purpose of the article since it is a knowledge-intensive industry and heavily engaged in external collaborations. In particular, this paper adopts a longitudinal perspective (2000-2012) to study how big pharmaceutical companies explore or exploit knowledge over time with different organizations (i.e. universities, other firms, research institutes, and hospitals) focusing on factors such as geographic proximity and network structures. We reconstruct the external collaboration configurations of big pharmaceutical companies using bibliometric data.

The article is structured as follows. First, we will introduce the concept of exploration and exploitation knowledge with a focus on external collaboration. Section 3 describes the research framework and presents the hypothesis. Section 4 describes the data and the methods used and section 5 synthesizes the main findings. Finally, we draw some conclusions and suggestions for further research.

Theoretical framework

The organizational literature distinguishes between knowledge exploration and exploitation with the underlying assumption that organization´s learning capabilities is the main source of firm´s competitive advantage (Kogut & Zander, 1992). The dichotomy between exploration and exploitation was first introduced by March (1991). March defined exploration as a process of search, variation, experimentation, and discovery while in addition exploitation also includes risk taking, play, flexibility, and innovation. Since the publication of March (1991), the terms exploration and exploitation have become common in the organizational literature. First, authors have defined exploitation and exploration in different ways depending on the type of learning or on the presence or the absence of learning (Baum, Li, & Usher, 2000; Benner & Tushman, 2003; He & Wong, 2004; Rosenkopf & Nerkar, 2001; Vassolo, Anand, & Folta, 2004; Vermeulen & Barkema, 2001). Second, the definition of exploration and exploitation has differed depending on the level of analysis, whether the study is focused on the individual level, team level or a more macro organizational level (for a good overview see Gupta, Smith, & Shalley, 2006).

For the purpose of this study, we focused on the literature that uses the dichotomy of exploration and exploitation in the context of external collaboration. This literature considers external

collaboration a noteworthy vehicle for exploration and exploitation. The creation of new knowledge is a process of combining existing and/or new knowledge that doesn´t only take place within a firm but also involves external organizations. Several authors, using the dichotomy by March (1991), have underlined the value of collaboration for an organization's learning process by accessing new knowledge outside the firm´s boundaries, knowledge exploration, and by leveraging existing knowledge with partners, as knowledge exploitation (Beckman, Haunschild, & Phillips, 2004; M. Koza & Lewin, 1998; Rothaermel, 2001). More specifically, Lavie and Rosenkopf (Lavie & Rosenkopf, 2006) in their paper, clustered the literature into three separate domains of exploration and exploitation that together describe an alliance namely the function, structure or attribute domain. These three domains adopted a different definition of knowledge´s exploration and exploitation. First, the function domain literature has focused on the nature of collaboration. For example, Koza and Lewin (Koza & Lewin, 1998) defined exploration firms as firms engaging partners in the R&D innovation process, whereas firms that rely on collaboration for commercializing and using existing technologies undertook exploitation (Koza & Lewin 1998). Second, the structure domain literature has focused on the network position of a firm´s partners. In this regard, Beckman et al. (Beckman et al., 2004) treated the relation with new partners as exploration and relations with already existing partners as a form of exploitation. When a firm forms recurrent collaboration with a selected group of partners, it can rely on existing experience and routines. In contrast, when the search for collaboration goes beyond a firm´s local network it offers new opportunities and risks that can be considered a form of exploration. Finally, the attribute domain literature has studied the inter-temporal variance in the organizational attributes of a firm´s partners. March (1991) in this context, defined exploration the experimentation and variation in routines, process, technologies, applications and a deviation from a systematic pattern of alliance formation with partners that share certain organizational

attributes. In contrast, when a firm persistently forms new collaboration with partners similar to its prior partners with respect to attributes, it can apply its partnering experience in the learning process. This repetition, routines and specialization are associated with exploitation.

In this study, exploitative and exploratory knowledge has a specific meaning within the context of external collaborations that can be considered part of the function domain, exploitation means that a company strategically decides to share with external partners its core knowledge, whereas exploration means that a company decide to collaborate in a novel knowledge dimensions.

Whatever knowledge area a company decides to specialize in it is the result of a strategic decision. However, both exploration and explorative knowledge dimensions should improve the production development and firm's should adopt a mix between exploitation and exploration activities (Gupta et al., 2006). In this regard, March (1991) underlined that the balance between exploration and exploitation is a primary factor in a firm's survival and prosperity. Firms need to be engaged in sufficient exploitation to maintain and increase short-term performance and at the same time to devote enough resources to exploration to ensure long term survival (Levinthal & March, 1993; March, 1991). An organization can learn from experience in time and space how to find a balance between exploration and exploitation activities (Levinthal & March, 1993).

So far, we have described how the literature has adopted different domains to analyze exploration and exploitation in external collaboration. We argue that these two types of knowledge differ considerably in nature, outcomes and organizational requirements in the context of external collaboration. The next section introduces the pharmaceutical industry as the unit of analysis and further explores the role of exploration and exploitation in this context.

Research framework

Knowledge is an important factor contributing to the development of medical innovations. Innovations generate new knowledge by challenging the previous set of understanding by considering new procedures or extending the scope of their applications. Several studies have described medical knowledge as cumulative combining new and existing knowledge in multiple feedback loops (Consoli & Mina, 2009). Medical innovation studies have shifted focus away from the traditional linear model framework that explains the innovation process with "scientific push" and "demand pull" approaches (Potter) and do rather consider innovations as the outcomes of an evolutionary and learning process combining elements belonging to different contexts (Barberá-Tomás & Consoli, 2012).

In accordance with the traditional view of the innovation process the drug discovery process has often been described as a linear path with different stages, from discovery, to preclinical and clinical research, development to launch. However, this linear path is a rough simplification of the process that in a more realistic way is described by a network model. Successful drug development in the networked information age requires teams involving many different actors such as basic and translational scientists, clinical service providers, policy makers, regulators, reimbursement specialists, consumers, patients, and advocates. This complex network of actors offers a process that reflects the open, collaborative and coordinated system for how drug development is taking place in the 21th century (Baxter et al., 2013; Orsenigo, Pammolli, & Riccaboni, 2001). Consequently, external collaboration has become a critical element in the innovation and R&D process of pharmaceutical companies to access external competences and knowledge (Orsenigo et al., 2001).

The network structure of the drug discovery process puts pharmaceutical companies as part of a system that develops in different modes and structures. If we focus on the R&D part of the drug discovery process, these collaborative modes and configurations can be characterized depending on if they are operating in an exploitation or exploration knowledge dimension. In the case of exploration knowledge, companies collaborate with partners to learn new technologies and to explore new therapeutic areas. The lack of in-house knowledge when it comes to certain technological areas forced companies to look for organizations in different businesses (Granovetter, 1973). Thus, firms pursuing an exploration strategy will often establish collaboration with new partners through a so-called weak tie partnership (Dittrich & Duysters, 2007). Collaboration through weak ties have a lower commitment than partnerships with strong ties (Burt, 1992). When exploring a new area, companies may want a flexible collaboration network allowing the access to a diversity of knowledge and a continuous scanning of new technological opportunities. In this type of network, the partners continuously exchange mainly tacit knowledge (Li, Vanhaverbeke, & Schoenmakers, 2008). In the case of exploitation knowledge, firms team up with partners to obtain existing, complementary know-how, or to speed up the R&D process which is of importance within the pharmaceutical industry where time-to-market is crucial. The partners are similar to the companies in respect to similar knowledge base (March, 1991). The solid in-house knowledge guarantees certainty, speed, proximity and clarity on the achievement of external collaboration goals (Hansen et al. 2001). The network is characterized by strong ties that represents long-term and intimate relationships (Krackhardt, 1992). To exploit knowledge and to make the most out of established technologies and products, intensive relations with partners are requisite. Time is needed to build up and to take benefits from these collaborations. Consequently, exploitation network will have a higher

proportion of the same partners over time than exploration networks (Kale, Singh, & Perlmutter, 2000). This type of collaboration is focused on complementarities among partners as they share explicit knowledge (Teece, 1992).

Earlier literature have focused on three different attributes that are of importance when studying exploration and exploitation in external collaboration these include type of partner, geographic proximity and network structure. First, literature has documented that pharmaceutical companies collaborate with a number of heterogeneous actors, such as universities, research institutes, and competitive large companies, and startups (Dahlander & Gann, 2010). Each type of collaboration provides different types of knowledge. Starting with exploration knowledge, drug discovery taking place in a new therapeutic area requires collaboration with partners that are more knowledgeable in the basic science of the therapeutic area (Gulati, Lavie & Singh, 2003). In this regard, academia and research institutes play an important role. There is a general belief that collaboration with universities is more focused on basic, precompetitive research (Arora & Gambardella, 1990; Mowery & Rosenberg, 1989) and that collaboration with universities is a driving force for basic research (Lewis, 1990). Tether (Tether, 2002) suggests that collaboration with universities is generally aimed at radical breakthrough innovations that may open up entire new markets or market segments. In addition to possessing a greater variety of knowledge than many other organisations universities act as knowledge brokers for firms and organizations spanning multiple industries. In contrast, in exploitation knowledge areas, companies already have internal knowledge in that therapeutic area and they look for partners involved at later stages of the innovation process. This is the case for companies that have a similar knowledge base as the focal company but also for hospitals that provide knowledge and access that is of importance for the clinical trials stage. Thus we hypothesize:

Hypothesis 1: Pharmaceutical companies collaborate with different type of actors depending on if they are in exploration or exploitation knowledge areas.

Second, geographic proximity affects the configuration of the collaboration network. The explorative knowledge is considered mainly tacit and companies therefore benefit from geographical proximity to partners (Gilsing & Nooteboom, 2006). Short distances facilitate personal interactions that are important in the exchange of tacit information for scientific collaboration (Ganesan, Malter, & Rindfleisch, 2005; Porter, 1998; Rosenfeld, 2005). Furthermore, Tijssen (2009), studied the pharmaceutical industry, observed that geographic proximity is also justified by the easy access to facilities and the ability to recruit highly skilled people from nearby universities which is crucial for the firm to get access to exploration knowledge.

In contrast, exploitation knowledge rather includes codified knowledge that is more easily transferable over large distances. Therefore, hypothesis 2 is stated as follows:

Hypothesis 2: Pharmaceutical *companies'* collaboration differs in the importance of geographic proximity of partners depending on if they are in exploration or exploitation knowledge areas.

Third, exploration collaborations are characterized by short term relations and weak ties with the possibility to continuously scan for new opportunities. In contrast, exploitation is based on strong collaboration ties characterized by recurrent relations. As a consequence, the network will have a lower proportion of the same partners over time than exploitation (Kale et al., 2000; Rowley, Behrens, & Krackhardt, 2000). Therefore, we formulate the third hypothesis as follows:

Hypothesis 3: Pharmaceutical *companies'* exploration collaboration networks have a higher turnover of partners over time than exploitation network.

Methodology

We focused on the pharmaceutical industry and selected six large multinational companies: AstraZeneca, Eli Lilly, GlaxoSmithKline, Novartis, Pfizer and Takeda. These companies belong to the top-20 largest companies when it comes to both revenue and R&D expenditure. The criteria for selection included different modes of collaboration and different geographical distribution of headquarters (USA, Europe and Asia).

In the majority of pharmaceutical companies, R&D activities are organized around different therapeutic areas. Each drug or drug candidate can be assigned to one or several therapeutic areas depending on what diseases or conditions they target or at aimed at targeting. Consequently the diseases or conditions that drugs are aimed for determined the relevance of markets and the company´s investment. In addition, this organizational structure allows the company to specialize in particular areas of disease which will impact the level of interactions with clinical practices. In sum, different therapeutic areas are subject to different demands for drugs but also rely on different R&D skills (Bogner & Thomas, 1994). Important, therefore, is to analyze the knowledge of pharmaceutical company at the level of therapeutic area. Big pharmaceutical companies are engaged in several therapeutic areas at the same time. However, each firm is specialized in particular therapeutic areas characterized with "the use and development of thing already known" which can be labeled exploitation. In comparison, firms investing in new therapeutic areas with "the pursuit of new knowledge of things that might come to be known" which can be labelled exploration. The distinction between exploration and exploitation areas can

be used to develop the innovation pathway of firms. This is further influenced by strategic decisions (for example to pursue mergers and/or acquisitions), as well as by prior success in particular areas. For example, Eli Lilly has been a leader in the field of diabetic therapy for over hundred years this therapeutic area can therefore be considered a knowledge exploitation therapeutic area. Another example includes Pfizer and GlaxoSmithKline that have created a partnership, ViiV Healthcare, to develop expertise in HIV, infection that covers diseases such as HIV can therefore be considered as an exploitative knowledge area. We identified exploration and exploitation knowledge areas for each of the six selected companies using the following criteria:

- Exploitation areas are defined as therapeutic areas that belong to the core areas of a company, in which there exist in-house competences. More specifically, these are areas where the companies are active in research, clinical trials and have products on the market.

- Exploration areas are therapeutic areas that are not considered, yet, as core areas but that are explored and researched. There might be some ongoing clinical trials but over time an increasing importance of these therapeutic areas can be observed in the company´s pipeline.

Information regarding companies pipeline (including compounds clinical trials) and products were extracted from company´s annual reports. More specifically, we collected data on the R&D pipeline and R&D strategy for the years 2000-2012 and based on the number of candidates, clinical trials and products over the years we classified therapeutic areas as exploration or exploitation for each company. To validate our classification we also contacted R&D directors from each of the six selected companies, each having a broad overview of the company's

historical and ongoing pipeline. Table 1 shows which therapeutic areas that were selected as exploration and exploitation for each of the six companies.

Exploration		Exploitation	
Company	**Therapeutic Area**	**Company**	**Therapeutic Area**
AstraZeneca	Infection diseases	AstraZeneca	Cardiovascular diseases
AstraZeneca		AstraZeneca	Respiratory diseases
Eli Lilly	Musculoskeletal diseases	Eli Lilly	Endocrinology
Eli Lilly	Oncology	Eli Lilly	Cardiovascular diseases
GlaxoSmithKline	Oncology	GlaxoSmithKline	Infection diseases
GlaxoSmithKline	Immunology	GlaxoSmithKline	Respiratory diseases
Novartis	Neuroscience	Novartis	Cardiovascular diseases
Novartis	Ophthalmology	Novartis	Oncology
Pfizer	Oncology	Pfizer	Cardiovascular diseases
Pfizer	Immunology	Pfizer	Infection diseases
Takeda	Immunology	Takeda	Endocrinology
Takeda	Oncology	Takeda	Cardiovascular

Table 1: Selected therapeutic areas classified as exploration or exploitation

The external collaborations of the selected companies were identified and measured through co-publications. According to Cockburn and Henderson (1996) co-authorship can be considered an evidence of a significant, sustained, and productive interaction between researchers in different organizations. In comparison to other indicators used to map collaborations, the analysis of publications is a method that can be uniformly applied to different the companies (Tijssen, 2009, 2012). A bibliometric record includes information about the author's affiliation(s) (name of institution, country and city). Studying authors' address therefore enables to identify interactions both inside (between different R&D locations and departments) as well as outside the company.

The source of the publication data was Thomson-Reuter´s Web of Science. First, for each company, all publications that could be assigned to the selected therapeutic areas and with at least one authors affiliated with the selected company in the time period 2000-2012 were selected. The publications were assigned to a therapeutic area using keywords from the Medical Subject Heading (MeSH), the National Library of Medicine's vocabulary thesaurus. In addition, each

publication was classified as clinical or non-clinical. In table 2 the number of articles that could be classified as clinical vs. non-clinical for each of the therapeutic area is showed.

Exploration				Exploitation			
Company Therapeutic area	**C**	**NC**	**Total**	**Company Therapeutic area**	**C**	**NC**	**Total**
AstraZeneca	125	394	519	**AstraZeneca**	1056	1878	2934
Infection diseases	125	394	519	Respiratory diseases	261	574	835
				Cardiovascular disease	795	1304	2099
Eli Lilly	1032	1155	2187	**Eli Lilly**	1081	1546	2627
Musculoskeletal diseases	434	596	1030	Cardiovascular diseases	458	646	1104
Oncology	598	559	1157	Endocrinology diseases	623	900	1523
GlaxoSmithKline	1198	2526	3724	**GlaxoSmithKline**	967	2323	3290
Immunology	676	1516	2192	Infection diseases	685	1444	2129
Oncology	522	1010	1532	Respiratory diseases	282	879	1161
Novartis	807	1805	2612	**Novartis**	1381	2669	4050
Nervous System Diseases	693	1605	2298	Oncology	732	1547	2279
Ophthalmology	114	200	314	Cardiovascular diseases	649	1122	1771
Pfizer	1184	2285	3469	**Pfizer**	1191	2172	3363
Immunology	586	1218	1804	Infection diseases	397	964	1361
Oncology	598	1067	1665	Cardiovascular diseases	794	1208	2002
Takeda	113	413	526	**Takeda**	281	502	783
Immunology	53	224	277	Cardiovascular diseases	148	258	406
Oncology	60	189	249	Endocrinology diseases	133	244	377
TOT	**4459**	**8578**	**13037**	**TOT**	**5957**	**11090**	**17047**

Table 2: Publication within exploration or exploitation knowledge therapeutic area. C=Clinical publications, NC= Non-clinical publications.

In order to study the different modes of collaboration, we used three measures: type of publication (clinical/non-clinical), type of partner and geographic proximity. All author addresses were cleaned to eliminate spelling variations and a single standardized name was assigned for

each organization. Each organization was classified according to type of sector: industry, hospital, university, agency, and other. Table 3 explains the classification of each sector.

Type	Definition
University	University and centres where the priority is education and research
Hospital	Hospital, Clinic, Medical centres where the priority is patient care
Industry	Private companies (Inc, Spa, Ltd, GmbH, etc) and CROs
Institute	Institute with the main focus in research
Other	Associations and societies that represent different stakeholders from industry, academia, professions or other institutions; Governmental agencies; Funding bodies

Table 3: Sector classification.

In Table 3 some key indicators for each of the companies are presented.

Selected Companies	Hearth quarter	Revenues 2012 (USD millions)	R&D expenses 2012 (USD millions)	No. publications 2000-2012	% of in-house publication 2000-2012
Pfizer	New York, US	58986	7870	12325	26,3
GlaxoSmithKline	Brentford, UK	26400	3474	11163	22,3
Novartis	Basel, CH	56673	9116	11388	19,9
AstraZeneca	London, UK	27973	5243	8930	18,3
Takeda	Osaka, JP	18401	3437	1498	21,3
Eli Lilly	Indianapolis, US	22603	5278	5389	30,8

Table 4: Company statistics. Ranking is based on the total revenue for 2012.

Results

Descriptive analysis

Based on bibliometric data we analyzed the external collaboration patterns of big pharmaceutical companies. This section provides some preliminary descriptive results. Similar data will be used to carry out a regression analysis in order to test the hypothesis. The regression analysis is still in the process but section 5 describes the expected results.

Balance between exploration and exploitation

The total number of publications published between 2000 and 2012 was 13037 for exploration areas and 17047 for exploitation areas. This very similar trend might be indicative of a balance between exploration and exploitation research in the companies studied. Figure 1 shows the trend of total number of publication, in-house publication (no other organizations mentioned in the address field) and collaborative publications (with at least one external organizations) in the time period 2000-2012. The number of total publications increased between 2000-2012 both in exploration and exploitation areas. The increase in collaboration could be seen as a result of the increasing interest and R&D investments targeting external collaboration.

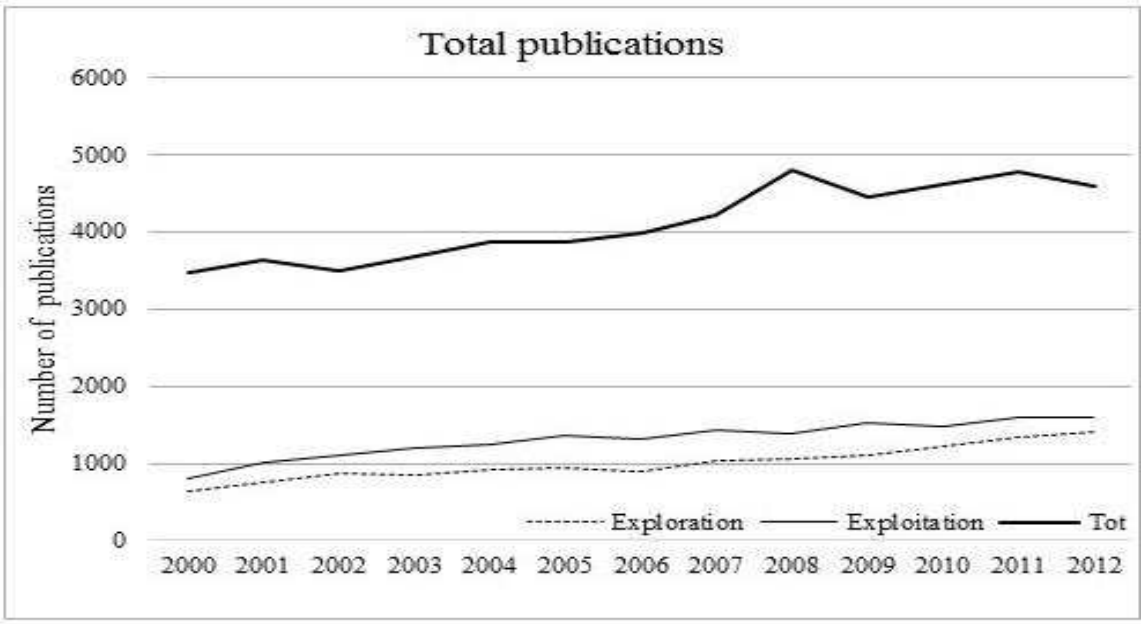

Figure 1: Number of publications over the time period 2000-2012.

3379 papers (26%) are intra-collaboration within exploration areas and 3901 papers (23%) are intra-collaborations for exploitation areas. The majority of publications in both areas are published in collaboration with external partner. As can be seen from figure 2 no clear difference in exploration and exploitation trends can be observed. A small difference in the proportion of collaborative publications for exploration knowledge areas in comparison to exploitation knowledge areas can be seen.

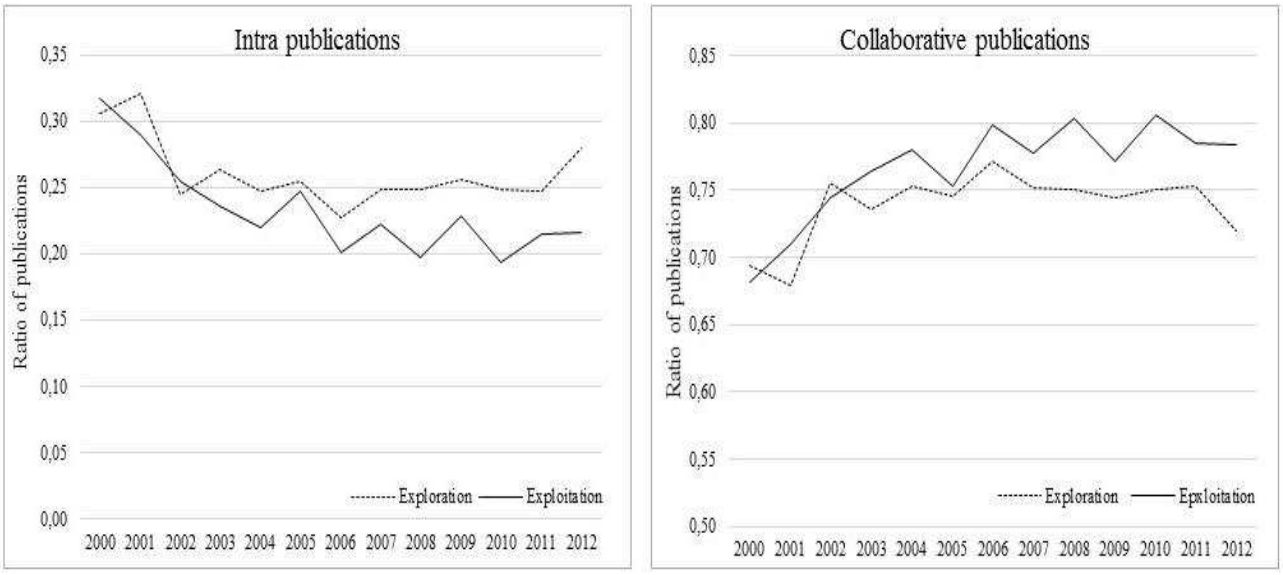

Figure 2: Intra-collaboration and collaborative publication trends.

The mean number of external organizations per paper is presented in table 5. This analysis is a first indicator of the network structure (density) of external collaboration. The mean number of organizations increased from 2,7 in 2000 to 4,9 in 2012 for exploration areas. For exploitation areas, the trend is not as obvious with an increase from 3,0 organizations per paper to 4,4. Exploration areas are characterized by a lower ratio of collaborative publications but with a higher number of external organizations per paper in comparison to exploitation areas.

	Mean number of institutions/paper	
Year	**Exploration**	**Exploitation**
2000	2,7	3,0
2001	2,8	3,0
2002	2,8	3,0
2003	2,9	3,3
2004	3,1	3,1
2005	3,2	3,8
2006	3,6	3,5
2007	3,5	3,7
2008	3,6	3,8
2009	4,3	4,0
2010	4,3	4,3
2011	4,7	4,5
2012	4,9	4,4

Table 5: Mean number of institutions per paper.

Clinical and non-clinical publications

We distinguished between clinical and non-clinical publications in order to study the importance of the different clinical phases within the drug discovery and development process. We defined exploitation areas as therapeutic areas with many ongoing clinical trials. In contrast, exploration areas were characterized as areas with few ongoing clinical trials. This distinction can't be observed in our data. The share of clinical and non-clinical publications in exploration and exploitation knowledge areas are very similar, see table 6. However, we need to consider that the clinical publications include both clinical trials and pre-clinical research. This results might

indicate that companies in exploration areas are active in the pre-clinical phase of the drug and discovery process.

	Tot	Clinical	Non-clinical
Exploration	13037	4459 (34%)	8578 (66%)
Exploitation	17047	5957 (35%)	11090 (65%)

Table 6: Percentage of clinical and non-clinical publications.

Type of partners: Sector analysis

Table 7 shows the percentage of collaborative papers corresponding to four different types of external organization collaborations: (i) university (where at least one affiliation is a university), (ii) hospital (where at least one affiliation is a hospital) (iii) industry (where at least one affiliation is an industry) and (iiii) institute (where at least one affiliation is a research institute).

	Exploration	Exploitation
Hospital	49,0%	59,5%
Industry	29,0%	30,6%
Institute	27,3%	25,1%
University	83,8%	78,5%

Table 7: Percentage of clinical and non-clinical publications.

The importance of university collaborations can be observed in both knowledge areas. However, exploration knowledge areas have a higher percentage of collaborative paper involving a university (83,8%). On the other hand, it clearly emerges from table 6 that hospitals are more involved in papers classified as exploitation areas. They are partners in almost 60% of the collaborative papers. This indicates that pharmaceutical companies look for knowledge from the hospital especially when they operate in exploitation knowledge area. This result might indicate

that pharmaceutical companies collaborate with different type of actors depending on if they are in exploration or exploitation knowledge areas (Hypothesis 1).

Taking a closer look at hospital and university collaborations for clinical and non-clinical publications, some interesting insights emerge, see figure 3.

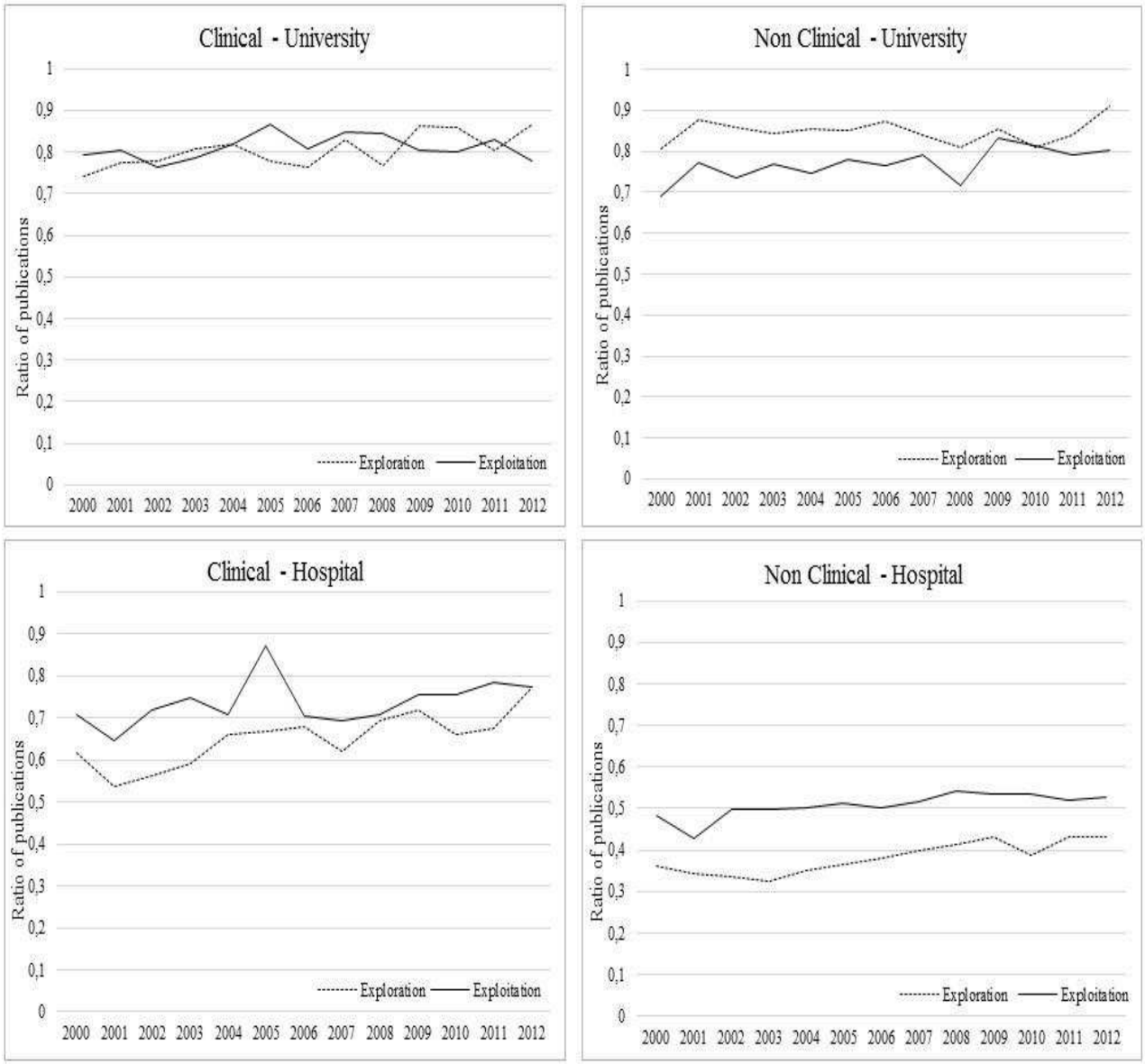

Figure 3: Hospital and university collaborations classified as clinical and non-clinical publications.

Within both exploitation and exploration knowledge areas, clinical and non-clinical publications have a relatively stable trend over the years. However, for non-clinical publications companies involve hospitals in 38,5% of exploration publications compared to 51,1% when they operate in exploitation knowledge areas. Furthermore, 84,9% of publication classified as exploration knowledge areas and 73,3% in exploitation knowledge areas of non-clinical publications included at least one university. In exploration knowledge areas, companies team up with partners that are more knowledgeable in the therapeutic area for example with universities that often have a strong basic science knowledge base. In exploitation areas, hospitals are considered an important source of knowledge also for non-clinical publications.

Next we calculated, for the non-clinical publications, the duration of the collaborations with hospitals and universities. Figure 4 shows that within exploitation areas collaboration have a longer duration. This is specifically true for collaboration taking place with hospitals. This preliminary result might indicate that pharmaceutical companies collaborations network in exploration have more turnover of partners over time than exploitation network (Hypothesis 3).

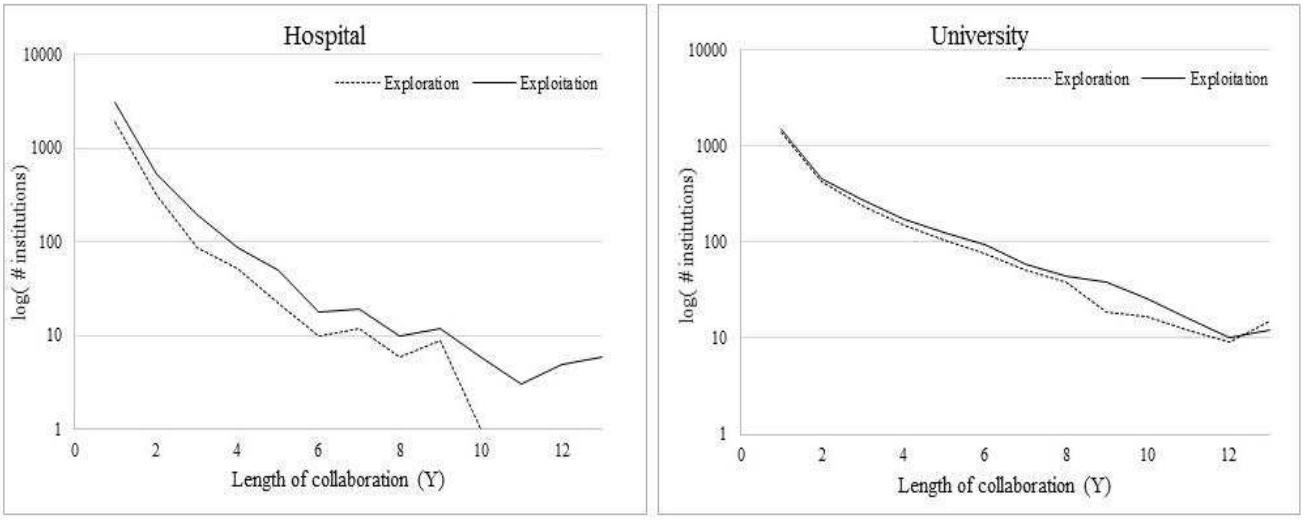

Figure 4: Length of collaboration with hospitals and universities for non-clinical publications.

Geographic proximity: Country level

Focusing on geographic proximity, in this preliminary analysis, we looked at the distribution of countries in exploration and exploitation areas between 2000 and 2012. The most interest result emerge from non-clinical publications (Figure 5).

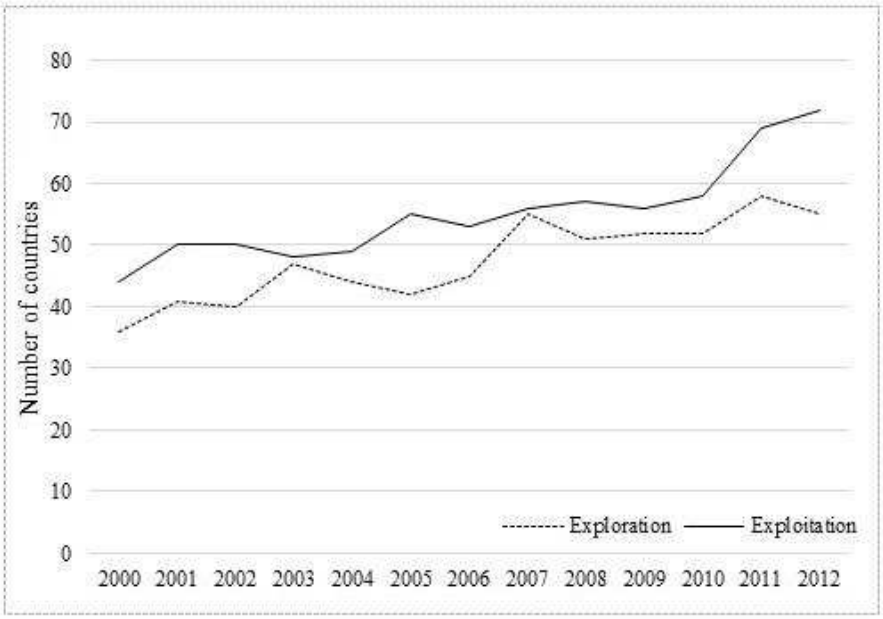

Figure 5: Number of countries in non-clinical publications between 2000 and 2012.

In Figure 5 the total number of different countries involved in publications for each year is illustrated. The results show that companies published with a growing number of researchers from different countries between 2000 and 2012 in both knowledge areas. More specifically, in exploration areas companies are less multi-national than exploitation. This observation might indicate that the network in exploitation area is more geographically spread compare to exploration areas.

Regression Analysis (to be done)

In sum, the preliminary analysis indicates that pharmaceutical' collaborations partly differ depending on the exploration or exploitation knowledge area. More specifically, the results show some important factors that will be used for further analysis: density of external collaboration network, collaborations with hospital and university, turnover of partner´s collaborations and geographic spread of collaborations.

To be able to take a closer look at the effects exploration and exploitation knowledge might have on external collaborations pattern, we will estimate a regression model on the publication rates in the two knowledge dimensions. The independent variables will be collaboration rate with hospitals and universities, geographic proximity (as the distance from R&D company heart quarter) and duration of collaborations. We will control for additional variables to consider potential heterogeneity at firm, network, sector and geographic level. These controls include clinical and non-clinical publications, firm name, firm´s R&D intensity, therapeutic areas, M&A strategy of the companies, countries of companies R&D location and year.

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