# The success of biotech clusters in relation to the institutional frameworks: Are biotech clusters better off in liberal economies?

L.L. Kuhlmann

The EU needs to increasingly focus on biotechnology, since this industry forms the key to establishing a knowledge-based economy. One of the unique characteristics of this industry is its high levels of clustering and it is, therefore, interesting to investigate what makes biotech cluster successful. There is, however, little consensus on the factors that determine a cluster's success. This debate is partially about which market economies, i.e. liberal market economies (LME) or coordinated market economies (CME), can best sustain the radical and incremental segment of a successful biotech industry. Literature suggests that LMEs are better suited for radical innovation, while CMEs are better able to facilitate incremental innovation. The purpose of this paper is to test this hypothesis and to determine how successful biotech clusters look like with respect to their national institutional frameworks. From the varieties of capitalism approach three important aspects of the institutional framework are derived; how firms acquire *skilled labor*, *financial means* and *technology transfer*. Through an empirical examination of four European biotech clusters that represent either a radically or an incrementally innovative cluster in either a LME or a CME (Cambridge, Berlin, Oxford and Munich), the influence of the institutional framework on the success of biotech clusters is investigated. The results indicate that the hypothesis can be rejected since both economies are able to successfully facilitate both the radical and incremental segment of the biotech industry when circumventing the institutional disadvantages.

**Keywords**: Biotech Clusters; Innovation Strategy; Institutional Framework; Varieties of Capitalism; Patent Citations

Science and Innovation Management
Master Thesis 45 ECTS
Supervisor: Dr. A.M. Herrmann
Second reader: Drs. W.P.C. Boon
28-July-2010

# 1. Introduction

In 2000, the European leaders launched the 'Lisbon Strategy' which was aimed at making the EU the most competitive, dynamic and knowledge-based economy in the world by 2010[1] (European Parliament, 2000). Ambitious goals like achieving sustainable economic growth and driving technology transfer and innovation were set. One of the key areas of science and technology where the EU could focus on in order to become a leading knowledge-based economy is biotechnology[2] (Aho *et al*., 2006). The biotech sector is revolutionizing quickly and its new techniques, e.g. genomics and bioinformatics, unlock new possibilities in healthcare, agriculture and food production. Therefore, the European Commission (2002) regards biotechnology as "the next wave of the knowledge-based economy" (p3) and recognizes that the growth of the biotech industry can be a major contribution in achieving the Lisbon's objective of becoming the world's most knowledge-based economy.

A distinguishing feature of the biotech industry is the high level of clustering (Gertler and Vinodrai, 2009; Su and Hung, 2009). Clusters are "geographically proximate groups of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities" (Porter, 2000; p16). So, a successful biotech cluster unites biotech companies, biotech service providers, universities, hospitals, venture capitalists (VCs), highly trained personnel and related industries into a critical mass necessary for innovation. This environment ensures that entrepreneurs can acquire the necessary skills and capabilities in order to convert new inventions into businesses (Ketels *et al*., 2008; Nasto, 2008; Oxford Research, 2008) and that biotech firms are able to commercialize their scientific advances (Ketels *et al*., 2008; Laffitte *et al*., 2007). In sum, the biotech industry displays characteristically high levels of clustering and for this reason it is important, when trying to gain a better understanding of what makes the biotech *industry* successful, to grasp what makes biotech *clusters* successful.

The concept of clustering has been influential in both the academic and the political debate, visible in the presence of many academic disputes and the efforts of governments to transform the academic findings into cluster policy to increase the competitiveness of regions and nations. In the 1970s, researchers already demonstrated that "small and medium-sized enterprises specialized in the same industry, were forming a system in which both competition and cooperation relationships were taking place" (Musterd *et al*., 2007; p9). Over the past 40 years, many research has been conducted on successful clusters, e.g. the rapid economic growth in the industrial districts of the Third Italy (see Asheim, 1996), the exemplar ICT cluster in Silicon Valley (see Saxenian, 1994) as well as other examples of successful regional agglomerations (see Porter, 1998). With these studies came the understanding that clusters provide the best setting for an innovation based economy and as a result, clustering became a target for public policy. Also in the biotech sector it became apparent that clustering is essential for a highly innovative industry (Ketels *et al*., 2008) and researchers began investigating biotech clusters. At first, studies focused on describing the participants and understanding the advantages of biotech clusters (Zeller, 2001; Coenen *et al*., 2004; Malmberg and Power, 2005). But nowadays, the focus has increasingly shifted towards gaining a better understanding of the dynamics of biotech clusters, i.e. how do clusters develop and what are the key factors that

[1] On June 17th 2010, the European Council launched the successor strategy 'Europe 2020 Strategy' (EC, 2010).

[2] *Biotechnology firms* apply the most modern techniques to transform the processes of biological cells and cell components into industrially useful substances, e.g. for medical use. Biotechnology is often regarded as the discovery arm of the pharmaceutical industry.

facilitate the cluster to grow (Chiaroni and Chiesa, 2006; Su and Hung, 2009). However, despite intensive research, there remain contrasting opinions on how best to advise policy makers on the factors that determine a biotech cluster's success.

In essence, this disagreement boils down to two opposing views on the effect market economies have on the performance of firms and clusters. The proponents of both sides of the argument do agree that the type of market economy affects the national institutions which impacts how firms are financed, governed and organized, and how this consequently influences the success of firms and clusters (Casper, 2007; Herrmann, 2008). However, they differ in their opinions on the sustainability of a biotech industry in different institutional frameworks. On the one hand, Casper (2007), along with Hall and Soskice (2001), Hall and Gingerich (2004) and Whitley (2002), argue that the institutions in liberal market economies (LMEs) are most fit for radically innovative industries, e.g. the biotech industry, and that coordinated market economies (CMEs) are only suitable for incremental innovations like machinery. Thus, he proposes that only one institutional constellation can foster a successful biotech industry. On the other hand, Herrmann (2008) and Lange (2009) acknowledge that CMEs have a comparative institutional disadvantage for radical innovation, but demonstrate that there are successful biotech industries in CMEs, e.g. in Germany, because the biotech companies are able to 'defect' the national institutions. So, Herrmann states that a successful biotech industry can exist in several institutional constellations. With these two opposing views in mind it is clear that there is no univocal story about successful biotech cluster and the influence of national institutions. This study aims at contributing to this discussion by using patent citations as an indicator for a cluster's innovation strategy and is an indicator neither Herrmann nor Casper have used before. So, by using an hitherto unexplored measure for innovation strategy, this study reanalyzes which institutional arrangements are most suitable in facilitating biotech success.

In short, the research question therefore is; ***"How does a successful biotech cluster look like with respect to its national institutional framework?"***. A way to gain insight is with a side-by-side comparison of successful and unsuccessful clusters in two dissimilar market economies. This will demonstrate how biotech clusters deal with institutional (dis)advantages and it will provide policy makers, both on a EU and a national level, with new insights on how to stimulate and support biotech clusters and establish a flourishing biotech industry. This research has showed that biotech clusters can reside in both market economies by circumventing institutional disadvantages, which gives the EU useful inputs on how to optimally utilize the biotech industry's potential. This will bring the EU one step closer in realizing the Lisbon's aim of becoming the world's most knowledge-based economy.

This paper is organized as follows. Section 2 will give a theoretical background. Section 3 will explain the methodological part of this study. Then, the data is presented and analyzed in Section 4. Section 5 will interpret the results and translate the conclusions into policy implications. Lastly, the results of this research are discussed and recommendations for future research are given in Section 6.

## 2. Theoretical background

This research is embedded in the field of innovation studies and tries to establish the relation between institutional frameworks and the innovativeness of biotech clusters. Institutions can be seen as "systems of established and embedded social rules that structure social interactions" (Hodgson, 2006; p18), e.g. a trade union is an institution that makes employees and employers interact in a certain way while wage bargaining. An institutional framework refers to the set of institutions present in a region

and this impacts how firms are financed, governed and organized. In order to assess the influence of institutions on innovativeness, it is essential to understand how a firm's behavior changes in response to different institutional arrangements and consequently, how this influences the success of biotech clusters. So, a theory that gives an institutional explanation of firms' behavior is required and, therefore, the perspectives of the varieties of capitalism approach, henceforth VoC, will be adopted. The VoC approach is the most developed institutional approach today that gives insight on how institutional surroundings affect the success of biotech clusters.

### 2.1 A Relational View of the Firm

The VoC assumes that "firms are the central actors in the economy whose behavior aggregates into national economic performance" (Hall and Gingerich, 2004, p7) and this perspective adopts a relational view of the firm. It argues that for a firm to be innovative and successful it has to engage with others in many fields of the political economy, e.g. to raise finances, to regulate wages and to acquire skilled personnel. These relationships that firms establish are important because they are intangible and difficult to replicate and therefore constitute a sustainable competitive advantage (Dyer and Singh, 1998). A relational view of the firm is especially relevant for the biotech industry, since biotech innovations are the achievements of networks, rather than the virtues of individual firms (Powell, 1998). So, a (biotech) firm's success ultimately depends on its ability to establish relations with other actors in the economy. Consequently, it is important to understand how the relationships between actors are coordinated and according to Hall and Soskice (2001) there are two distinctive patterns of coordination possible. In one extreme, actors coordinate through competitive market arrangements, characterized by arms-length relations[3] and formal contracting[4], and in the other, coordination occurs via non-market relationships, where the emphasis is on collaboration, trust and relational contracting[5]. Institutional frameworks strongly influence which type of economic coordination is present and has, therefore, a strong impact on a firm's behavior in establishing relations. All in all, the VoC states that relationships are a firm's most important asset in gaining a competitive advantage and describes two distinctive patterns, influenced by the institutional context, by which coordination amongst actors can take place.

Hall and Soskice (2001) distinguish five institutional areas where coordination amongst actors needs to take place. In other words, there are five areas wherein firms must establish relationships in order to prosper and to be competitive. The first sphere is 'industrial relations' where firms must bargain over wages and working conditions with for example trade unions and employees. This is important for the firm's success since it determines wage and productivity levels, but it also impacts the whole economy by influencing unemployment and inflation rates. The second area is 'vocational training and education' where firms are concerned with establishing a suitably skilled workforce by investing in training and education for their employees. Thirdly, 'corporate governance', i.e. how firms are controlled, directly influences how firms can attract financing and how investors are assured

[3] *Arm's-length relations* are a type of business relation were both parties act like they are unrelated to each other to ensure that both act in their own self interest and conflicts of interest are avoided.

[4] *Formal contracting* refers to contracts "that must be specified *ex ante* in terms that can be verified *ex post* by a third party" (Baker *et al*., 2002; p40), in most cases a court.

[5] *Relational contracting* refers to informal agreements "based on outcomes that are observed by only the contracting parties *ex post* and also on outcomes that are prohibitively costly to specify *ex ante*. Relational contracts cannot be verified by a third party and need to be self-enforcing, i.e. the value of the future relationship must be sufficiently large that neither party wishes to renege" (Baker *et al*., 2002; p40).

of returns on their investments. The fourth sphere is 'inter-firm relations' which comprises of all the relationships a company establishes with others, e.g. with clients, suppliers and competitors, in order to secure a steady demand for its products, appropriate supplies of inputs and access to technology. The problems involved stem from the risks of sharing proprietary information. The fifth sphere is 'employees' where firms must coordinate the degree to which employees are included in the decision making process and are informed with potentially sensitive information. Problems are related to the balance between creating involved and motivated employees versus the risk of employees going to the competition, withholding information or effort from management. These five institutional spheres are not independent and exhibit interaction effects which are called institutional complementarities (Hall and Soskice, 2001; Hall and Gingerich, 2004). For example, in some countries capital is obtained through long-term bank loans with the requirements that it does not depend on short-term profits. So, firms are more inclined to enter long-term contracts of employment and invest in training and education. This means that 'corporate governance' will have an influence on how 'industrial relations' and 'training and education' are arranged and as a result, institutional complementarities occur. In sum, all five institutional spheres exhibit institutional complementarities and this makes it more difficult to determine the specific effect of each of the institutional spheres on the behavior of firms and the success of clusters.

For this reason, the current research will follow Herrmann (2008) and Casper's (2007) approach in condensing Hall and Soskice's (2001) five institutional spheres into three independent institutional fields wherein firms must establish relations in order to prosper. The three fields that the present study will incorporate are skilled labor, financial means and technology transfer and together form the institutional context, see Figure 1 for a schematic representation. These variables are the foundation upon which further analysis is based. The first variable, SKILLED LABOR, combines 'industrial relations', 'vocational training and education' and 'employees' and encompasses the problems firms face in securing adequately trained employees. Secondly, firms must obtain FINANCIAL MEANS which is influenced by 'corporate governance' and focuses on the problem of acquiring sufficient financing in order to perform research and development (R&D). The third variable TECHNOLOGY TRANSFER is Hall and Soskice's (2001) fourth sphere and deals with the problem of securing access to "the movement of know-how, technical knowledge, or technology from one organizational setting to another" (Bozeman, 2000; p3). By securing access to technology transfer, firms are able to acquire new R&D input and to develop and exploit these technological and scientific advances in order to maintain their competitive positions in the market. All in all, the national institutional surroundings determine how firms coordinate relations in the three institutional fields and

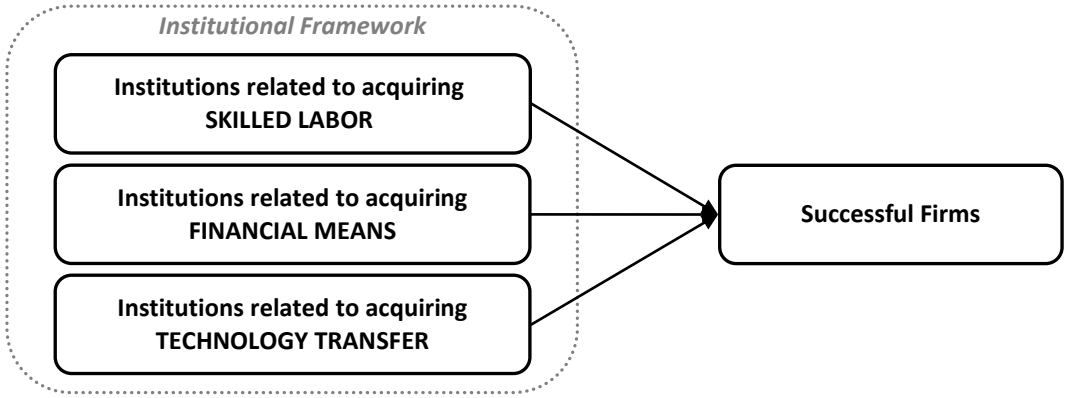


**Figure 1. Schematic representation of how a firm's success is influenced by the institutional framework, consisting of institutions related to acquiring skilled labor, financial means and technology transfer.**

this means that different institutional frameworks provide firms with different types of skilled labor, financing and technology transfer.

## 2.2 Two Idealized Market Economies

The institutional frameworks are influenced by a country's market economy and a distinction is made between liberal market economies and coordinated market economies each with its own characterizing set of institutions. In the following section, these two market economies are described and compared on the basis of the three variables identified in the previous paragraph; the institutions related to how firms acquire skilled labor, financial means and technology transfer.

### 2.2.1 Liberal Market Economies

In an ideal liberal market economy, firms coordinate their activities and relations mainly through market interactions, characterized by arm's length exchange of goods or services (Hall and Soskice, 2001; Hall and Gingerich, 2004). In building the firm's core competencies a firm's actions are based on rational market behavior, short-term profits and competition which can lead to free-market processes where the interaction of supply and demand determine the price-setting. However, this is accompanied by more distrust amongst companies which can lead to higher transaction costs, i.e. costs related to negotiating, monitoring and enforcing contracts. Typical LMEs are the Anglo-Saxon countries like the United States, which is almost the ideal LME (Hall and Soskice, 2001), the United Kingdom, Ireland, Canada, Australia and New-Zealand. The most prominent features of a LME are the fluid labor markets, the capital based financial markets and the way standards are set by market races in order to secure technology transfer (Hall and Soskice, 2001; Hall and Gingerich, 2004; Casper, 2007; Herrmann, 2008). The labor market is flexible since it is characterized by high employee turnover due to relatively weak trade unions, decentralized wage bargaining systems where wages are set by market forces, and because competition clauses in contracts are struck down by court. As a result of the high labor mobility, workers are more inclined to invest in general skills that they can transfer to other jobs, rather than investing in firm-specific skills, i.e. skills that are not easily transferable to other firms should the firm fail. In addition, it is very difficult for firms to establish systemized apprenticeships where firms collaborate to provide trainees with specific skills, since industry associations are weak and relations are based on competition as opposed to collaboration. Firms in a LME face large market-based financial systems with high levels of transparency and dispersed shareholding, where access to financing largely depends on publicly accessible criteria such as market value. Venture Capital (VC) can be acquired relatively easy on the condition that the capital is invested in projects promising high profits on a short-term. This is a requisite since shareholders have only limited measures of monitoring how their investments are used and, therefore, need their profit expectations fulfilled otherwise they rapidly withdraw their investments. As a result, R&D projects are financed from current earnings. In LMEs, technology transfer is accomplished by licensing and selling innovations and by the job hopping of scientists and engineers through which technical knowledge diffuses amongst companies and research institutions. Since there are few business associations capable of securing consensus on new standards and due to antitrust regulation[6] that prevents large scale firm collaborations setting common technical standards, collective standard

[6] *Antitrust regulation* is intended to "promote free competition in the marketplace by prohibiting collusive, exclusionary and monopolistic practices that restrain competition and thereby pose a danger of increased prices and reduced output, quality, and innovation" (Oxford University Press, 2004).

setting is rarely feasible. In LMEs, standard setting occurs through market races, whose winners then profit by licensing their technology to many users.

All in all, a LME is characterized by high employee turnover, a large market-based financial system and technology transfer that is accomplished through licensing and job-hopping. In contrast to the LME, the CME has entirely different institutional elements and as a result, the way firms acquire skilled labor, financial means and technology transfer is completely different from a LME.

### 2.2.2 Coordinated Market Economies

In an exemplar coordinated market economy, firms depend not solely on market interactions in constructing their core competencies, but rely more on non-market relationships (Hall and Soskice, 2001; Hall and Gingerich, 2004). This strategic interaction involves "more extensive relational or incomplete contracting, network monitoring based on the exchange of private information inside networks, and more reliance on collaborative relationships to build the competencies of the firm" (Hall and Soskice, 2001; p26). As a result, firms in a CME focus on collaboration, trust, serving the public interest, taking collective responsibility and supporting a social policy. However, profits in these countries are in general slightly lower and since relations are based on collaboration, problems like the free-rider problem[7] and the prisoner's dilemma[8] need to be overcome. According to Hall and Soskice (2001), typical CMEs are the continental countries like Germany, often regarded as the perfect CME, France, Belgium, Netherlands, Switzerland, Austria, Norway, Sweden and Denmark. The main characteristics of a CME are firm-specific skilled workers, the stakeholder system and strong networks of inter-firm collaboration (Hall and Soskice, 2001; Hall and Gingerich, 2004; Casper, 2007; Herrmann, 2008). The labor market is characterized by long-term employee careers due to strong trade unions, powerful work councils, high levels of employment protection and the courts' upholding of competition clauses in contracts. So, the labor market is rigid and this motivates employees to invest in firm-specific skills. There are collective bargaining procedures between trade unions and employers' associations for setting the relatively high and homogeneous wages, to supervise collaborative apprenticeship systems that provide employees with firm-specific skills and to assure the trainees of available positions if they invest in these specific skills. While organizing these systemized apprenticeships there is a substantial involvement from the industry and technical universities in designing the curriculum and research. In a CME, the major stakeholders of firms, e.g. banks, suppliers and employees, also tend to be major shareholders and this permits firms access to patient capital, i.e. capital for which investors are interested in long-term value maximization. As a result, R&D projects are funded from retained earnings, managers are less sensitive to current profitability, firms can maintain a skilled workforce through economic downturns and firms can invest in projects generating returns in the long run. Patient capital is obtained on the basis of reputation, rather than on market value and because a CME has a dense network of cross-shareholding and membership in influential employers' associations, shareholders are provided with private information on the progress of the firm and are aware of firms' reputations. Technology transfer in a CME cannot be accomplished by the movement of scientists and engineers across companies and, therefore, firms rely on inter-firm

[7] *Free rider's problem* refers to a situation wherein individuals or firms can use goods or services without paying for its or for its conservation.

[8] *Prisoners dilemma* refers to "a situation in which two players each have two options whose outcomes depends crucially on the other's simultaneous choice, exemplified by two prisoners separately deciding whether to confess to a crime" (Oxford University Press, 2004).

relations and government support. For example, business associations work with public officials to design publicly subsidized programs that improve firms' competencies and because there is access to private information about the company, effective policy can be designed. Moreover, due to the presence of permissive antitrust regulation that allows industry associations and firms to collaborate in setting common technical standards, the diffusion of new technologies is also facilitated and a common knowledge-base is established which helps workers from different companies to collaborate.

In sum, a CME and a LME each exhibit a very different set of institutions and this leads to different ways of coordination across actors and consequently influences how firms can establish relations in order to be successful. A summary of the differences is visible in Table 1.

**Table 1. Institutional frameworks of LMEs and CMEs**

| | LME | CME |
|---|---|---|
| **Skilled Labor**<br>*Securing adequately trained employees* | - Fluid labor markets<br>- Decentralized wage bargaining<br>- Workers with general skills<br>- No systemized apprenticeships | - Rigid labor markets<br>- Collective wage bargaining<br>- Workers with firm-specific skills<br>- Systemized apprenticeships |
| **Financial Means**<br>*Securing access to financing* | - Market-based financial system<br>- Primarily venture capital available<br>- Access to finance depends on publicly available data<br>- Activities funded from current earnings | - Bank-based financial system<br>- Primarily patient capital available<br>- Access to finance depends on reputation<br>- Activities funded from retained earnings |
| **Technology Transfer**<br>*Securing access to R&D input* | - Movement of personnel amongst firms and research institutions<br>- Licensing and sale of innovations<br>- Standards set by market races<br>- Strict antitrust regulation | - Dense network of collaboration among personnel from different firms<br>- Collective standard setting<br>- Permissive antitrust regulation |

## 2.3 The Academic Dispute

Up to this point, Herrmann (2008) and Casper (2007) have been united in their opinions on how these two market economies facilitate the coordination across actors differently in multiple institutional spheres. However, they differ in their conclusions that can be drawn from this perspective. In other words, they deviate on the issue of which market economies provide firms with the competencies needed to pursue either radical or incremental innovation strategies. Radical innovations are characterized by the development of products and processes that are entirely new to the world (Tidd *et al.*, 2005). These innovations are particularly important for high-tech industries where innovative design and rapid product development are vital for being competitive. In the case of biotechnology, the market introductions of entirely new therapeutic products and diagnostics are considered to be radical innovations. Incremental innovations, on the other hand, are defined as continuous but small scale improvements to existing products and processes, in other words "doing what we do better" (Tidd *et al*., 2005; p12). This is especially relevant in industries were capital goods are produced since the capability to develop complex cumulative knowledge is the key to a firm's success. But incremental innovation is also important in the biotech industry, e.g. the improvement of the safety and efficacy of drugs or diagnostics. In sum, for firms to pursue one of these innovation strategies, different competencies of firms are required and this is influenced by the organization of the national institutions. However, Herrmann (2008) and Casper (2007) disagree on which market economies can provide biotech firms with the necessary competencies to be successful in biotechnology.

Casper (2007), along with Hall and Soskice (2001), Hall and Gingerich (2004) and Whitley (2002), argue that key institutions in market economies provide firms with a comparative advantage in developing innovation strategies in particular technological fields, i.e. some firms perform better in LMEs and others in CMEs. LMEs are better at facilitating radical innovation strategies due to the flexible and short-term oriented way in which their institutions are organized wherein risk-taking behavior of firms and individuals is rewarded and this facilitates the rapid use of new knowledge and skills to seize radically new opportunities. On the other hand, CMEs have a comparative advantage in supporting incremental innovation strategies, since their institutional framework favors collaboration and long term commitments from managers and employees necessary for organizationally complex collaborative networks that develop competencies needed for cumulative technologies. In the case of biotechnology, Casper (2007) distinguishes between two innovation strategies; one related to developing therapeutics, with high financial and technological risks, the other to developing platform technologies[9], characterized by lower risks, lower science intensity and more technological stability. He finds that for biotech firms in Germany (CME) it is difficult to pursue radical innovation strategies, due to the comparative institutional *dis*advantages for radical innovation and underpins this with its findings that biotech firms in Germany are specialized in platform technologies and not in therapeutics. This pattern is in contrast to the specialization pattern of the UK (LME).

As a response, Herrmann (2008), but also Lange (2009), demonstrates that firms in the UK and Germany pursue the same variety in innovation strategies and, therefore, proves Casper wrong in his statement that CMEs are more focused on incremental innovation strategies. Herrmann shows that biotech firms in a CME can avoid the institutional disadvantages by 'defecting' the national institutions by relying on two functionally comparable institutions. Firms can circumvent national labor markets, dominated by firm-specific skilled workers, by hiring key scientists and managers, with general skills, from open international labor markets. Firms can also outwit national institutions by not installing work councils or not sticking to national wage bargaining agreements. Firms are then able to employ workers with the required skills by giving atypical labor contracts, e.g. hiring project collaborators for a short period of time or providing on-the-job training for general skills. In sum, Herrmann (2008) argues that firms have other options than only pursuing strategies that are in line with the national institutional advantages and, therefore, states that both coordinated and liberal market economies are able to successfully foster biotechnology. As a consequence, Herrmann's findings position her at opposite ends of Casper.

This leads to the question of how it is possible that these studies lead to such contradictory conclusions. A reason is that the studies use other measures for distinguishing the innovation strategies biotech firms pursue and the success of these biotech firms. Casper (2007) measures innovation strategy with the use of *macro*-level indicators like firm-sub sector and industry and the success of pursuing the innovation strategies was measured by the total amount of firms that pursues each strategy. Herrmann (2008) on the other hand, measures biotech success with six accounting ratios and with the frequencies with which firms in different market economies go bankrupt, merge, are acquired or continue to pursue their original strategy. On the basis of *micro*-level indicators Herrmann determines a firm's innovation strategy, e.g. on the presence of developed new chemical entities (NCE) or if the focus of firms was on midstream or upstream activities, upstream being regarded as

[9] *Platform technologies* are designed to increase the efficiency of research methods, "such as genomics, combinatorial chemistry and activities involving the rationalization of extremely complex lab procedures, such as the cloning and filtration of genetic material" (Casper and Kettler, 2001; p7).

radical. In sum, this large difference in indicators of a biotech firm's success and the type of innovation strategy it pursues leads to contrasting results[10]. The current research will continue this discussion by using patent citations as a measure for innovation strategy in order to establish which institutional arrangements are able to facilitate successful biotech clusters. Both the radically and incrementally innovative clusters will be investigated and there are two possible outcomes. On the one hand, the different indicator for innovation strategy could prove that Casper is correct in stating that a LME can only foster radical innovation, while a CME can only sustain incremental innovation. On the other hand, the indicator could also demonstrate that Herrmann is right in arguing that firms in both a LME and a CME are able to circumvent institutional disadvantages.

# 3. Method

This research tries to establish how successful biotech clusters look like in two different market economies and consequently aims to shed light on the different results obtained by Casper (2007) on the one hand and Herrmann (2008) on the other. As aforementioned, their different conclusions are the result of different measures for distinguishing the innovation strategy biotech firms pursue and the success of these biotech firms. To shed additional light on this academic dispute, it is useful to apply patent citations as an indicator for innovation strategy (Section 3.1). This will eventually lead to the selection of four biotech clusters that either pursue a radical or an incremental innovation strategy in either a LME or a CME (Section 3.2). Section 3.3 will give more insight into the measurement of the independent variables that constitute the institutional framework of the clusters.

## 3.1 Measuring Innovation Strategy

The added value of this research lies in the use of patent citations as an indicator for the innovation strategy of biotech firms. Patent citations refer to the number of times a patent is cited in other patent documents and this indicates the nature of the invention; radical or incremental. Where radical innovations have a higher than average patent citation count, incremental innovations are cited less than average. It is, however, important to take a closer look into the patent document as a legal entity and as a source of information, before turning to patent citations and their analytical value.

Patents give the owners a set of temporary exclusivity rights over their invention and this prevents others from making, using, selling or importing the patented invention for the entire duration of the patent, usually 20 years, in exchange for public disclosure of the invention. Inventions can be patented when three criteria are fulfilled; a product or process is new, involves an inventive step and is industrially applicable. A patent document encloses highly detailed information on the invention process, the inventor, the applicant, the technologic field by using International Patent Classification (IPC) subclasses and the citations to previous patents and scientific articles. Patent data is available in large numbers, both in spatial and temporal terms, and is publicly available since it is not protected by confidentiality. For all of these reasons, patents are the most frequently used data source for constructing indicators for measuring technology output in countries, regions and firms (OECD, 2009). However, patents have, just like any indicator for technological change, certain important disadvantages (Archibugi and Pianta, 1996; Hall *et al*., 2005; Dodgson and Hinze, 2005; OECD, 2009). Firstly, not all inventions are patented because firms can also rely upon alternative methods for

[10] For further reading on the topic of macro-level and micro-level indicators and the consequences for research results and conclusions, see Casper (2009) and Herrmann (2010).

protecting their inventions, e.g. secrecy. However, Hagedoorn and Cloodt (2003) have investigated the patent applications of 1200 companies in high-tech industries and conclude that although firms do not protect all their inventions with patent protection, the number of patents filed by a company is a very good indication of its technological performance. The second important disadvantage is that patents only grasp the inventive output and do not give any information on the commercial value or the innovativeness of the patent. As a consequence, there is a large variety in the innovative value of individual patents and so a simple patent count does not give any information on the commercial value of patents, on firm value or on firm performance. To resolve this issue, other patent derived indicators have been constructed, like patent citations.

Patent citations are the references to preceding inventions and are included in patent documents to demonstrate the inventive step of the invention. For analytical purposes, patent citations can either be used as backward citations, i.e. the citations to previous patent documents, to track the knowledge spillovers and the diffusion of technologies. Or patent citations can be used as forward citations, i.e. the citations subsequently received by a patent, to determine the technological impact of inventions which indicates the commercial value of patents (Hall *et al.*, 2005; OECD, 2009). Hence, the latter approach will be adopted in this research to overcome the problem of the large variety in the value of patents. A high forward citation number refers to patents that have high technologic and commercial value, but more importantly, it also gives an indication of the radicalness of the innovation. Radical innovations have a strong impact on future technology (Dahlin and Berens, 2005) and, therefore, numerous new inventions are going to be patented that cite the 'radical patent' as preceding knowledge. Thus, patents with high forward citation numbers refer to radical innovations and patents with lower forward citations to incremental innovations.

Not only on the level of innovations can patent citations be applied, also on the broader level of biotech cluster are citations a useful indicator. A biotech cluster's total amount of forward citations consist of all the citations the patents, owned by firms in the cluster, have received. See Figure 2 for a schematic representation. So, on a cluster level, a high patent citation count indicates that the cluster is successfully pursuing radical innovation strategies. A lower amount of patent citations refers to clusters more capable of incremental innovation strategies. It is, however, important to take into account that information on patent citations is only meaningful when used comparatively, since there is no value measurement of patent citations. In other words, only knowing that a patent receives ten citations does not give any indication about the value of it, not until comparisons are made. So, this research will compare the forward patent citation counts of biotech clusters to assess which innovation strategy biotech clusters are pursuing and this is done with the use of the OECD/EPO patent citations database (2004).

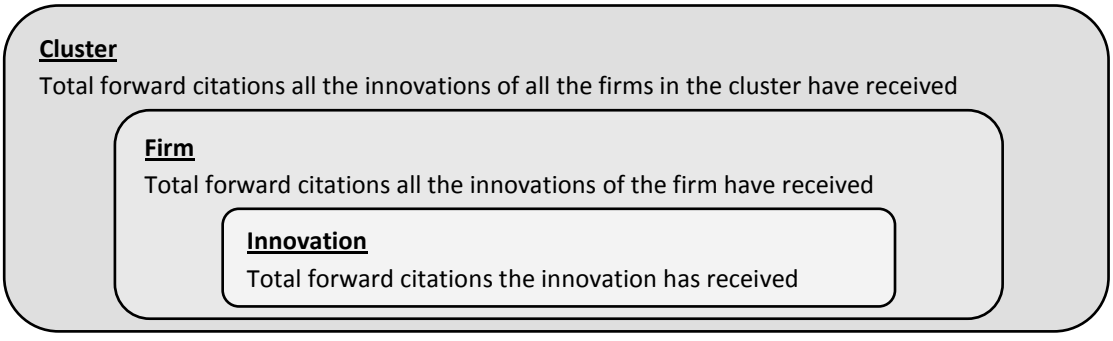


**Figure 2. Schematic representation of the relation between patent citations, innovations, firms and clusters.**

### 3.2 Case Selection

The goal of analyzing the OECD/EPO patent citation database (2004) is to get a ranking of biotech clusters in a LME and a CME, and to subsequently select clusters upon which further analysis will be based. The patent citation database includes all patent applications published on a European level, by the European Patent Office (EPO), and on an international level, under the Patent Cooperation Treaty (PCT), from January 1978 up until November 2001. In this database information on patents, applicants, inventors, IPC subclasses and citations is included and from this data it is possible to extract the amount of forward patent citations per biotech cluster, analytically defined as a city, in a LME and a CME. In order to analyze the database, three steps need to be conducted. First, patents need to be selected that have IPC subclasses that can be regarded as biotechnology (OECD, 2008), see Appendix A. The second step involves selecting only those patents whose applicants' country is the UK or Germany, since these two represent the two idealized types of market economies in the EU. The result of these two steps is a list of patents that classify as biotech and whose applicants are situated in Germany and the UK. For these patents the number of received forward citations can be extracted. In the last step of this analysis the patent citations for each city are totalized and standardized. Ideally, standardization should be performed with data that is representative for the size of the biotech cluster, e.g. number of life scientists. However, such data is only available for a few cities and is for this reason not suitable for standardizing the patent citations in all UK and German cities. Data that is available for all cities in the UK and Germany is the cities' inhabitants in 2001 (Eurostat, 2010). So, the end result of this analysis is the number of patent citations per 100.000 inhabitants for each city in the UK and Germany, see Tables B1 and B2 in Appendix B. In order to select cities that actually are successful biotech clusters it is important to take into consideration how many firms contributed to the number of forward patent citations, and therefore only those cities will be selected as cases that have a high amount of firms contributing to the patent citations. So, if the number of firms that applied for the patent citations is incorporated in the analysis it is easy to identify successful biotech clusters. In Table 2, the eight cities that have the highest firm numbers are visible. Notably, these clusters all explicitly define themselves as a biotech cluster which means that the method of cluster selection led to results that correspond to the real world and all clusters would thus be suitable for the analysis.

Since statistics on biotech clusters are very limited, a preliminary enquiry for these eight clusters is conducted to assess the availability of data. Only those clusters that have the largest collection of data available are selected as cases upon which further analysis is based. An important finding in this preliminary study was the research of Cooke (2007) whom included information on the number of life scientists for five of the eight clusters. Such data would be highly suitable for standardization since it is more representative of the size of the biotech cluster than the amount of inhabitants. Therefore, an additional standardization analysis is conducted and the results are depicted in Table 3. This demonstrates that due to more specific standardization, the ranking changes; Berlin and Cambridge have become equally successful in radical innovation, Oxford and Munich reveal to be comparable in terms of incremental innovation and Heidelberg is somewhere in the middle. So, from these refined results, four cases can be selected that represent biotech clusters successful in radical and incremental innovation in a LME and a CME. Cambridge (UK) and Berlin (DE) can be regarded as biotech clusters successfully pursuing radical innovation and Oxford (UK) and Munich (DE) can be seen as biotech clusters that are more focused on incremental innovation.

**Table 2. Eight biotech clusters present in the OECD/EPO patent citation database (2004)**

| Rank | City | Forward citations/ 100.000 inhabitants | Firms |
|---|---|---|---|
| 1 | Cambridge (UK) | 137,62 | 25 |
| 2 | Heidelberg (DE) | 69,25 | 13 |
| 3 | Oxford (UK) | 33,56 | 9 |
| 4 | Frankfurt (DE) | 18,60 | 15 |
| 5 | London (UK) | 9,84 | 59 |
| 6 | Berlin (DE) | 6,76 | 25 |
| 7 | Munich (DE) | 6,35 | 15 |
| 8 | Hamburg (DE) | 2,72 | 13 |

**Table 3. Biotech clusters standardized by the number of life scientists per cluster**

| Rank | City | Forward citations/ 1.000 life scientists |
|---|---|---|
| 1 | Berlin (DE) | 61,89 |
| 2 | Cambridge (UK) | 61,13 |
| 3 | Heidelberg (DE) | 30,62 |
| 4 | Munich (DE) | 17,27 |
| 5 | Oxford (UK) | 14,77 |
| - | Frankfurt (DE) | - |
| - | London (UK) | - |
| - | Hamburg (DE) | - |

All four clusters are in the mature stage of development (Europe INNOVA, 2007) and are, therefore, suitable for comparing the effects of institutional frameworks on the success of biotech clusters. See Table 4 for an overview of the selected clusters.

**Table 4. Cluster selection**

| Country | Market economy | City | Firms | Forward citations per 1.000 scientists | Innovation strategy |
|---|---|---|---|---|---|
| UK | LME | Cambridge | 25 | 61,13 | Radical |
| UK | LME | Oxford | 9 | 14,77 | Incremental |
| DE | CME | Berlin | 25 | 61,89 | Radical |
| DE | CME | Munich | 15 | 17,27 | Incremental |

### 3.3 Measuring the Institutional Framework

This research is thus an explanatory research where biotech clusters are analyzed within the institutional context in order to understand what makes the clusters successful. The different features of the biotech clusters are systematically compared with the use of the three variables derived from the VoC theory. With respect to how firms acquire skilled labor, this research will investigate the labor market flexibility and the presence of regional traineeships in each of the clusters. The acquisition of financial means is investigated through the amount of VC investments and subsidies that are granted to the biotech clusters. With regard to how firms establish access to technology transfer, the amount of collaboration, the presence of tech-transfer offices, the number of spin-offs and the size of the entire network are taken into account. See Table 5 for an overview of the operationalization. Data for all indicators will be collected through literature contributions, i.e. academic studies and annual reports of the cluster management and of the EU. For the variable ‘collaborations’ the author will use own calculations on the OECD/EPO patent citation database (2004) to determine how often the cities’ patents have multiple applicants. In the individual description of the case studies the data is presented in its absolute form, but when comparisons between the clusters are made, the data is transformed to a 3-point scale based on the averages of the four clusters; [+] higher than average, [+/–] average and [–] lower than average. Hence, similarities and differences between the clusters become easily visible.

All in all, with the use of the presented operationalization the four selected biotech clusters will be compared in order to determine how successful biotech clusters look like with respect to their institutional frameworks.

**Table 5. Operationalization**

| Variable | Dimension | Indicator |
|---|---|---|
| **Skilled Labor** | Labor turn-over | Labor market flexibility |
| | Training | Presence of regional training schemes |
| **Financial Means** | VC investments | VC invested in the biotech cluster |
| | Subsidies | Subsidies granted to the biotech cluster |
| **Technology Transfer** | Collaboration | Number of patents with multiple applicants |
| | Tech-transfer offices | Presence of tech-transfer offices in the region |
| | Spin-offs | Number of spin-offs in the region |
| | Network size | Embeddedness of the cluster in international networks |

# 4. Results

The four cases under investigation are the biotech clusters in Cambridge, Oxford, Berlin and Munich. They represent clusters that are successful in either radical or incremental innovation in either a LME or a CME. In order to determine in what kind of institutional framework the four successful clusters are embedded and if this corresponds to the 'ideal' frameworks for radical and incremental innovation, the clusters will be investigated using the operationalization presented in the previous chapter. In section 4.1, the radically innovative biotech clusters Cambridge and Berlin will first be described individually in order to understand how the clusters have originated and how the firms in the cluster acquire skilled labor, financing and technology transfer. Then, the institutional frameworks of Cambridge and Berlin will be compared to each other and to the 'ideal' institutional framework for radical innovation. In section 4.2, the incrementally innovative clusters in Munich and Oxford will be described and their institutional frameworks will be compared to each other and to the ideal framework for incremental innovation. All in all, this analysis will lead to a better understanding of the characteristics of the institutional environments wherein successful biotech clusters are embedded.

## 4.1 Radically Innovative Biotech Clusters

According to the VoC theory, a radical biotech cluster will be most successful if it is located in an 'ideal' institutional framework that supports the biotech firms in developing the competencies needed to be radically innovative. Such an ideal framework should be flexible, short-term oriented and rewarding risk-taking behavior of firms and individuals. The institutions present in a LME fits this profile of the 'ideal' framework best. It would thus be interesting to discover if the institutional frameworks of both radically innovative biotech clusters in Cambridge and Berlin are similar to this ideal framework or if they differ.

### 4.1.1 The Cambridge region

Cambridge has always been a region where high-tech industries have resided and initially, Cambridge was home to the electronics and computing industries. In order to attract these high-tech companies to the region, Trinity College established the Cambridge Science Park (Skentelbery, 2004) where in the early years numerous computing firms got settled. But, in the 1960s, the first biotech companies and service providers also got established on this technology park. One of them was Cambridge Consultants Ltd., a spin-off from the University of Cambridge (UoC), which tried to exploit and commercialize the scientific advances of the university and find solutions to real world problems

(Walker, 2005). Subsequently, other technology consultancies followed, e.g. the PA Consulting Group, and this marked the beginning of the biotech industry in Cambridge. Additional science and business sites were founded, e.g. Granta Park, Chesterford Research Park, Melbourne Science Park, Cambridge Research Park, Cambourne Business Park and the Wellcome Trust Genome Park (Chiaroni and Chiesa, 2006). From only one biotech firm in 1984, the cluster started to grow exponentially due to the global outburst of investments in high-tech industries to 30 in 1993, 76 in 2000 and 185 in 2006 (Cooke, 2007). These companies are primarily large companies with a high employee size (Cooke, 2001). Two third of the companies are focused on therapeutics and diagnostics, 25% on instruments and 9% on reagent and chemicals (Cooke, 2007). Within the field of therapeutics and diagnostics, Cambridge is particularly strong in the exploitation of post-genomic research (BioPartner, 2007; Cooke, 2007). All in all, the Cambridge region has always boosted high-tech industries and the biotech cluster has developed spontaneously within this climate. This biotech cluster is now one of the most successful clusters in Europe.

Besides numerous biotech companies and multinational pharma's, Cambridge is also home to a large scientific community (Rosiello and Parris, 2009). The science base consists of seven universities with life science departments, e.g. the University of Cambridge, the Cranfield University, the Trinity Hall University and Selwyn College. The Cambridge cluster also contains four medical hospitals, including the Papworth Hospital which is the world's leading hospital in cardiothoracic diseases and the Addenbrookes Hospital that houses the Laboratory of Molecular Biology (LMB). The LMB has been responsible for the development of many laboratory techniques, including the DNA sequencing method, and has delivered numerous Nobel Prize winners, e.g. Crick and Watson (Walker, 2005). Moreover, on the Wellcome Trust's Genome Campus at Hinxtron are the Sanger Centre and the European Bioinformatics Institute (EBI) located. The Sanger Centre is a global leading genomic research center and has been a major contributor in the international Human Genome Project by decoding over one third of the human genome. The EBI delivers the software necessary to process the large amounts of genetic code the Sanger Center unravels. Additionally, the Babraham Institute, the Medical Research Council (MRC) Laboratory and the MRC Centre for Protein engineering are also situated in the Cambridge biotech cluster and all institutions combined form a strong base for fundamental research. In Cambridge, the supportive industry for biotechnology has also developed rapidly which is visible by the presence of numerous technical and business service providers (Skentelbery, 2004). In sum, the large network of biotech companies, research institutions, universities and technical and business providers demonstrates the presence of a solid public infrastructure for biotechnology in Cambridge.

This successful infrastructure for biotech commercialization is also a result of the labor market facilitating two essential types of employees; managers and scientists. In Cambridge, there is a high level of entrepreneurial activity, visible in the presence of many serial entrepreneurs, i.e. entrepreneurs who set up a string of new businesses they operate until the firms become profitable. As a result, the founders of the first biotech companies in Cambridge are still active and currently work on their fifth or sixth biotech start-up and are mentoring other start-ups (DTI, 1999; Skentelbery, 2004). These serial entrepreneurs thus provide the Cambridge region with general skills. On the other hand, scientists are attracted to the cluster because of the excellent reputation universities and research institutions have in chemistry, combinatorial chemistry, combinatorial biochemistry and medicinal chemistry (Barrel, 2004). Interestingly, these key scientists are attracted to the region regardless of the problems of housing and transport. The Cambridge biotech companies thus have access to scientists,

entrepreneurs, managers and consultants all having experience in biotechnology. Another important feature of the Cambridge labor market is the recycling phenomenon which means that "nothing is redundant for very long" (Walker, 2005; p959) since workers, intellectual property (IP) and laboratory facilities and equipment are rapidly relocated in the cluster. For example, when the research facility of Millennium Pharmaceuticals closed in 2003, 90% of the 180 employees were re-employed within a few months (Casper and Karamanos, 2003). So, the fact that employees are able to find new jobs within the region indicates that there are numerous opportunities for employees to transfer from one company or research institutions to another which demonstrates the relative employment security and the fluidity of the labor market in Cambridge.

Cambridge's successful network of biotech commercialization has also been a result of the proximity to London, which is the VC capital of the EU and the UK. Venture capitalists generally use local networks to scout and obtain information about potential investee companies and to monitor and guide their investments. This has resulted in the extension of London's VC network to Cambridge and now the Cambridge cluster has the UK's second largest amount of VCs located in its cluster. The presence of specialized VCs gives biotech companies the opportunity to join global networks (Rosiello and Parris, 2009), which indicates the size of the international biotech network that Cambridge is a part of. As a result, Cambridge biotech companies can acquire financing for all the investment stages and the most important VCs are Avlar, Apax, Gateway Fund and 3I, that all together have invested €720 million in Cambridge (Rosiello and Parris, 2009). Even though there has been a difficult financial climate after the stock market bubble burst in 2001, biotech firms at all stages of development have consistently succeeded in attracting investments and in forming collaboration deals with big pharma (Walker, 2005; Library House, 2007). Conversely, the government has not been a major financial sponsor of the biotech industry and fulfills more an inspirational role than the role of investor (Barrel, 2004; Cooke, 2007). However, the government did finance the Cambridge Entrepreneurship Center in 1991 and the Cambridge-MIT Institute in 2001, since this would bring university and industry closer together. In sum, Cambridge biotech firms at all development stages have access to a capital-based financial market and finance their R&D activities from large VC investments and not from government support.

A solid public infrastructure for biotechnology commercialization is present in Cambridge. This infrastructure facilitates technology transfer in numerous ways. Firstly, Cambridge houses tech-transfer offices, e.g. ERBI[11] (East Region Biotechnology Initiative) and Cambridge Enterprise. ERBI, on the one hand, is a transfer office accessible for actors in the entire cluster and aims at establishing links between them, showcasing the region to government and to the international community. Cambridge Enterprise, on the other hand, is an example of a tech-transfer office that supports only a few actors in the cluster, i.e. it aims at transforming the research from the UoC and the Addenbrooke's Hospital to commercially successful biotech companies. Secondly, technology transfer is also accomplished through spin-offs. The research institutions have spun off biotech companies since 1980 and have been the source of more than half of the biotech companies currently present in the Cambridge region (DTI, 1999; Cooke, 2007). This means that Cambridge is an environment where firms can use university research to enter new and emerging markets (Rosiello and Parris, 2009). For example, the UoC has spun off 42 biotech companies including two of Cambridge's most successful

[11] In May 2010, ERBI and the London Biotech Network (LBN) have merged into one central networking actor; One Nucleus. (See www.onenucleus.com)

ones; Cambridge Antibody Technology and Astex. Interestingly, the major part of the spin-offs also have one founder from a technology consultant (Cooke, 2007), which indicates the presence of linkages between biotech firms, service providers and universities in the cluster. Additionally, while the local research institutions account for the establishment of half of the biotech companies, 25% of the biotech companies are spin-offs from other universities in the UK and the last 25% are industrial spin-offs, e.g. from Glaxo and SmithKlineBeecham (Casper and Karamanos, 2003). Thirdly, the biotech companies in Cambridge collaborate extensively to gain access to tacit knowledge, e.g. innovative laboratory methods, to validate methodologies and to acquire a reputation for scientific excellence (Casper and Karamanos, 2003). Additionally, the author's calculations demonstrated that Cambridge indeed has one of the highest levels of collaboration when compared to the other three clusters, see Table B3 in Appendix B. Only one third of all collaborations are with local actors and a fourth of the collaborations are with international parties, and this indicates that Cambridge is a large network with many weak ties, instead of a small network with strong ties (Casper and Karamanos, 2003). So, in Cambridge the presence of tech-transfer offices, high numbers of spin-offs and many collaboration deals make it possible for firms to get access to technology transfer.

Cambridge is thus a well networked region with a large scientific base, a supportive industry, many biotech firms, where academia and industry are successfully linked and where as a result inventions are transformed into commercially successful products. The institutional framework wherein the radical biotech innovations take place is characterized by a flexible labor market, an outstanding financial climate where VC investments run high and technology transfer is greatly present.

#### 4.1.2 The Berlin Biotech region

Berlin as a center for life sciences began in the nineteenth century with the establishment of the *Grüne Apotheke* in 1851 (now Bayer Schering Pharma) and the founding of Berlin-Chemie in 1890. Besides these two large actors, there were some 20 mid-sized companies and international corporations that marked the beginning of the pharmaceutical industry in Berlin (BioTOP, 2010). The biotech segment of the pharmaceutical industry began to develop rapidly after the Federal Ministry of Education and Research (BMBF) launched the BioRegio competition in 1995, which was aimed at stimulating the creation of biotech clusters in Germany. Berlin and 16 other bioregions were selected and stimulated to submit proposals that demonstrated "that they were able to set up a working and interacting infrastructure for the commercialization of biotechnology" (Kaiser, 2003; p846). This initiative caused high levels of networking activities in many regions in Germany where people from science, industry, VCs and politics worked together. A prerequisite of the competition was that a central networking actor needed to be created. However, Munich, Heidelberg and Cologne were selected as winning regions and Berlin failed due to the absence of public financial support for an independent intermediate organization (Kaiser, 2003). However, the Berlin cluster pursued its original proposal by establishing the missing central networking actor BioTOP in 1998 and by gathering financing, e.g. loans and research scholarships, from (state) governments (Müller, 2002). The BioRegio competition was followed up and supplemented by the BioProfile contest in 1999, which aimed at transforming the regions' competitive advantages into biotech specializations. This approach differed from the BioRegio competition by allowing regions to participate that did not have the large scientific base that was required for success in the BioRegio competition (Dohse and Staehler, 2008). This time Berlin won, along with Hannover and Stuttgart, who defined their specialization in respectively

nutrigenomics, functional genomics and regeneration biotechnology. As a reward, the BMBF invested a total of €50 million in these three winning clusters for a five year period (Dohse and Staehler, 2008). So, Berlin as a biotech cluster benefited strongly from the governmentally initiated competitions that led to networking activities from research institutions, hospitals, companies and VCs in the region (Müller, 2002). This is also visible in the growth of the cluster in terms of the number of biotech firms. Since 1997, the number of biotech companies has increased from 80 to 163 in 2009 (BMBF, 2006; BioTOP, 2010). Notably, although numerous biotech firms are present in Berlin, they have in general a relatively small employee size; 61% of the companies have 1 to 10 employees, 31% have between 11 and 50 and only 8% have more than 50 employees (Cooke, 2007; EMCC, 2008). These biotech companies are primarily focused on conducting clinical studies, because of the proximity to big and prestigious hospitals, on genomics and proteomics, due to the presence of two core institutes of the National Genome Research Network, and furthermore on DNA chips, bioinformatics and regenerative medicine (Kresse, 2006; Cooke, 2007). All in all, the strong governmental cluster policy triggered the rapid development of Berlin into a large and successful biotech cluster.

Supplementary to many biotech companies, Berlin is also home to a high concentration of research institutions and supporting companies. The scientific base consists of many important research institutions; the Free University Berlin, the Humboldt University, the Technical University Berlin, three universities of applied science, the Charité hospital which is Europe's largest teaching hospital, two Max-Planck-Institutes for Molecular Genetics and Infection Biology, a Max-Delbrück-Center for Molecular Medicine, a Protein Structure Factory and a Fraunhofer Institute for Biomedical Engineering. Moreover, most of the relevant German authorities have their headquarters in and around Berlin (EMCC, 2008), e.g. the Federal Ministry of Education and Research BMBF, the Federal Health Ministry BMG, the Robert Koch Institute which is a federal institute for disease control and prevention, and life science-related trade organizations such as the German Association of Research-Based Pharmaceutical Companies. Being close to the authorities is important for biotech companies and pharma, since this gives them the possibility to work closely with and get specialized knowledge from the different public authorities responsible for the complex and resource-demanding approval processes (EMCC, 2008). Berlin also houses more than 60 contract research organizations (CROs) and together with the Charité hospital forms a strong base for conducting clinical trials (Kresse, 2006). So, the combination of these research institutions and supportive companies form an environment that is suitable for biotech innovation.

Another essential component for biotech R&D is the presence of adequately skilled employees. The Berlin labor market is characterized by high quality education with a substantial involvement from the cluster's scientific community and this leads to 3000 science and management graduates annually (BMBF, 2006). The EMCC (2008), however, identifies a shortage of two types of employees. Due to the rigid labor market that does not facilitate general skilled workers, the cluster is in need of managers that have besides a scientific background experience in managing biotech companies. As a solution, formal training programs have been established that focus on the management side of biotech companies, e.g. the MBA BioMedTech program at the University of Potsdam. Besides a low availability of managers, there is also a shortage of lab technicians and to overcome this problem, regional apprenticeships for this type of employee are established (EMCC, 2008). However, young companies are not willing to make a three year commitment in educating lab technicians due to their lack of resources and long-term perspectives. The Berlin biotech cluster has, therefore, launched new initiatives to increase students' interests in science and technology. For

example, the government has created GenaU, a network for extracurricular science and technology learning sites at research institutions, universities and museums in Berlin. In sum, in Berlin there is a labor market that is more inclined towards rigidity than flexibility where both managers and scientists are present as a result of regional training schemes. Berlin biotech firms have thus access to a large pool of highly qualified employees to perform both research and development in biotech companies.

The availability of VC that is necessary to perform R&D has differed greatly in Berlin since 1997. In 2000, VC investments reached a peak with €150m (Cooke, 2007), but then the stock market bubble burst and financing dropped considerably. In 2002, only €25m was invested in the Berlin biotech cluster and in 2003 and 2004 financing started to increase slightly to €45m (Cooke, 2007). In 2005, €100m was invested in Berlin which is approximately the investment level of before the crisis. In 2008, there was again a global financial crisis and even though investments declined, the Berlin biotech industry has been resilient and no biotech companies had to file for insolvency (EMCC, 2008). The reason that general economic trends have little effect on the Berlin biotech industry is firstly because of a stable demand on the health and research markets. Secondly, R&D projects in the Berlin biotech companies are mainly financed by stable budgets from the government which make it possible to retain a workforce and revenues even in difficult times (BioTOP, 2010). Lastly, public funding for the biotech industry is high (Cooke, 2007). Although Berlin has great potential in becoming a successful biotech cluster, it is hampered by limited access to financing for early- and mid-stage companies (Kresse, 2006). The problem is that not Berlin but Frankfurt is the financial capital of Germany and as a result Berlin houses only few investors (Stafford, 2005; Häussler and Zademach, 2006; EMCC, 2008). Several regional initiatives have been launched to increase financing for young companies, e.g. the Go-Bio program which helps scientists that want to establish a biotech firm, or the BioChancePlus program that supports firms in the post start-up phase (EMCC, 2008). Since it has been difficult for biotech firms to get access to VC for their high risk R&D projects, a change in business strategies in the biotech sector is visible (EMCC, 2008; BioTOP, 2010). Where a lot of biotech companies previously focused on pharmaceuticals and diagnostics, they currently aim on the development of services since this entails lower risks. All in all, the biotech companies in Berlin experience difficulties in acquiring VC on a capital market, but due to government funding the biotech companies are able to run their R&D projects and remain innovative.

In Berlin, the high density of universities, research institutions, hospitals and biotech companies has great potential since they constitute a large reservoir of innovative and commercially applicable inventions (BioTOP, 2010). It is, therefore, essential to have functional systems by which commercialization can occur, e.g. through thematic networks, technology transfer offices and spin-offs. More than half of the biotech companies in Berlin have originated in research institutions (BioTOP, 2010) which have led to the creation of a network with many strong connections between various actors. This is also visible in the presence of numerous thematic networks between companies and research institutions, e.g. networks for bioinformatics, functional genomics, personalized medicine and nutrigenomics. These networks ensure close contact between science and business which leads to "effective technology transfer and speeds up the conversion of the results of basic research into wide-ranging applications" (EMCC, 2008; p9). Especially young companies benefit highly from these networks since this gives them opportunities to collaborate (EMCC, 2008). The data in Table B3 (Appendix B) indeed demonstrates that Berlin is highly successful in arranging collaboration deals since it has the highest levels of collaboration when compared to the other three clusters. Technology transfer is also accomplished by two regional initiatives, BioTOP and TSBmedici, that act at the

interface of science and business. They support a wide range of networking activities and as a result of their work the thematic networks have received major financial support from Germany's federal government (Berlin Partner, 2009). In 2009, an additional tech-transfer office was established, the Center for Molecular Diagnostics and Bioanalytics (ZMDB), which is a technology transfer platform specialized in the indication areas cancer, cardiovascular diseases, infections and immunology. All in all, technology transfer in Berlin is accomplished through tech-transfer offices, thematic networks and high inter-firm collaborations that all together form a network wherein biotechnology can be exploited.

Overall, the Berlin biotech cluster is characterized by the presence of high numbers of relatively small biotech companies, a scientific base and a supportive industry that facilitates biotech commercialization. The institutional framework wherein radical innovation takes place consists of a labor market that is more inclined towards rigidity than flexibility where both managers and scientists are present as a result of regional training schemes. Financing for biotech R&D is mainly acquired through government subsidies and not so much via the capital market. The presence of technology transfer is arranged through tech-transfer offices, thematic networks and high levels of inter-firm collaborations.

#### 4.1.3 Cambridge – Berlin Comparison

From the previous two case studies it has become clear that Cambridge and Berlin are embedded in very different institutional frameworks. Where the Cambridge labor market is characterized by high labor market flexibility, Berlin's labor market is more rigid and the pool of employees is somewhat smaller. The latter is currently being solved with regional training schemes. With respect to acquiring financial means, Cambridge and Berlin acquire financing in quite opposite ways. Where the biotech R&D in Cambridge is mainly financed with VC, Berlin's R&D is for the large part financed with government subsidies. Technology transfer in both regions is more or less comparable. That is, the inter-firm collaboration in both regions is equally high and both possess technology transfer offices. However, it needs to be mentioned that BioTOP plays a more important role in the cluster development than ERBI does. A reason could be that BioTOP was established as a means to get the cluster growing, while ERBI was put in place long after the successful start of the Cambridge cluster. Furthermore, the amount of spin-offs that derive from the research institutions are approximately the same in both regions. One particularly interesting difference is that Cambridge is part of a large international network for both collaborating and financing with numerous weak ties, while Berlin is embedded in a much smaller network where there are fewer but stronger ties. For a simplified schematic representation of the differences between the institutional frameworks of Cambridge and Berlin, see Table 6. For a more elaborate comparison, see Table 8.

Two radically innovative biotech clusters can thus be embedded in very different institutional frameworks wherein biotech firms are supported differently in developing the competencies they need to pursue radical innovation. The institutional constellation in Cambridge is in line with the 'ideal' framework wherein radical innovation should take place and also corresponds to the national institutional framework of a LME. So, the findings of this research confirm that Cambridge's institutions are in accordance to the theoretical expectations. On the other hand, Berlin's institutional framework is not comparable with the 'ideal' radical innovation framework but is in line with the national institutions of a CME. However, the theory presupposes that the institutions in a CME should

**Table 6. Simplified representation of the differences in the institutional frameworks of the radically innovative biotech clusters in Cambridge and Berlin**

| Institutional Framework | | Cambridge | Berlin |
|---|---|---|---|
| **Skilled Labor** | Labor market flexibility | + | – |
| | Regional training schemes | – | + |
| **Financial Means** | VC investments | + | – |
| | Subsidies | – | + |
| **Technology Transfer** | Collaboration | + | + |
| | Tech-transfer offices | +/– | + |
| | Spin-offs | + | + |
| | Network size | + | – |

favor incremental innovation and not radical innovation. This research thus rejects the assumption that a CME cannot successfully foster radically innovative firms. However, this subsequently raises the question how Berlin biotech firms can be radically innovative while being in a non 'ideal' framework. From the case studies it has become clear that Cambridge has originated spontaneously which suggests that there initially was a more favorable environment for radical biotech innovation when compared to Berlin. However, German government has found a successful way to create a framework wherein radical biotech innovation can take place and does so by not trying to mimic the frameworks of a LME, but by exploiting its own characteristics. That is, the radically innovative Berlin biotech cluster is based upon a CMEs characteristic that is in theory least suitable for radical innovation and uses it to its advantage. It is often assumed that since CMEs are too coordinated radical innovation cannot exist, but it is particularly this coordination in the form of government initiatives that have made Berlin as successful as it currently is. This government support includes both BioRegio and BioProfile competitions, the establishment of BioTOP, granting subsidies for R&D and facilitating the establishment of regional trainee programs to acquire the required skilled labor. However, it would be interesting to see what happens when government support stops; will the Berlin biotech cluster be able to maintain its strength or will it collapse. Based on the findings of this report, the latter seems the most likely outcome. Since the government has such a strong influence on all three aspects of the institutional framework it will be likely that if this support is withdrawn the cluster will fail. All in all, radical innovation can take place in two very different institutional frameworks; in the ideal LME, but also in a CME where the key to success is incorporating a strong cluster policy.

### 4.2 Incrementally Innovative Biotech Clusters

A biotech cluster specifically aimed at incremental innovation would ideally be in an environment that supports the biotech firms in developing the competencies needed for incremental innovation. Such an environment should favor collaboration, trust and long term commitments from managers and employees, since that is necessary to develop organizationally complex collaborative networks needed for cumulative technologies. This ideal environment is most comparable to the institutional framework of a CME. It would, therefore, be interesting to see if the institutional frameworks of both Munich and Oxford are organized in line with the 'ideal framework' for incremental innovation or if they possess a different set of institutions. Additionally, this section will investigate why these clusters are not as successful at radical innovation as their counterparts.

### 4.2.1 BioTech Region Munich

The biotech cluster in Munich started in the mid nineties when firms such as MediGene, Micromet and MorphoSys were founded. Notably, all companies are spin-offs from major research institutions, respectively the Munich Gene Center, the Ludwigs-Maximilians-Universität (LMU) and the Max-Planck-Institute. In this period, the growth of Munich's biotech industry was moderate, but the start of the BioRegio competition in 1995 initiated the rapid transformation of Munich into a biotech cluster (Lechner and Downling, 1999). In 1996, Munich was selected as one of three winners of this competition and as a reward was funded with €25 million (BMBF, 2006), for supporting start-ups in the life sciences. In addition to these investments, "the most important factor that this BioRegio competition created was the establishment of a network structure between private and public actors" (Kaiser, 2003, p847). As a part of the BioRegio competition, Bio$^{M}$ AG was founded in 1997 which aims at transforming Munich into a center of biotech excellence and does so by guiding start-ups, by showcasing the region, by creating a real estate market for laboratories, jobs and lab devices and by serving as a seed and VC funder. Bio$^{M}$ is now often regarded as a driving force behind Munich's success (Kaiser and Liecke, 2008). After winning the BioRegio competition, the number of biotech firms in Munich began to increase rapidly from 36 in 1996 to 120 in 2001 (Kaiser, 2003), with around 17 start-ups per year (Bio$^{M}$, 2007). However, after this initial period of growth, the number of annual start-ups decreased to six per year and in 2008 Munich had 150 biotech companies (Bio$^{M}$, 2008). Munich has thus "entered a phase of consolidation in which growth mostly exists within the already established companies" (Kaiser and Liecke, 2008; p7). Interestingly, the Munich biotech industry is dominated by companies that have a relatively small employee size (Cooke, 2007); 95% of the companies have less than 100 employees and only 5% has more than 100 and there are no companies with more than 250 employees (IHK, 2005). These biotech companies are for the largest part (52%) active in the area of pharmaceuticals and diagnostics, 26% in equipment and reagents, 15% in biotech service providing and 7% in bioinformatics (Zeller, 2001; IHK, 2005; Bio$^{M}$, 2008). Within the area of pharmaceuticals, the focus is on oncology (Kresse, 2006) since two universities and the Max-Planck-Institutes are highly active in developing new cancer treatments and because Hoffmann-La Roche, formerly known as Boerhinger Mannheim, has a large R&D facility near Munich where ideas from the biotech cluster in the field of oncology are further developed. In sum, the strong governmental cluster policy in the form of a funded competition triggered the rapid development of Munich into a large and successful biotech cluster.

In addition to biotech companies, Munich houses many research institutions and has a large industry for support services (BMBF, 2006). Munich's scientific base consists of eight research institutions, namely the Ludwigs-Maximilians-University (LMU), the Technical University Munich (TUM), three biologically oriented Max-Planck-Institutes for Neurobiology, Biochemistry and Psychiatry, the National Research Center for Environment and Health (GSF), which coordinates the German share of the international Human Genome Project, and two colleges of applied science, i.e. the Fachhochschule München and the Fachhochschule Weihenstephan. Furthermore, there is an extensive network of consultants, suppliers and buyers that serve the biotech industry (IHK, 2005), e.g. CROs, strategic advisors and marketing specialists for life sciences or laboratory equipments. Munich also houses both the German - and the European Patent Office which leads to the presence of specialized knowledge of intellectual property rights which is important for the commercialization process (Zeller, 2001). There are also many supporting (semi) public agencies such as Bayern International, Bayern Innovativ, Invest-in-Bavaria, the Munich Business Plan competition, the Federal Ministry for

Economy and Technology (BMWi) and the Chamber of Commerce. In sum, after the start of the BioRegio Competition Munich has developed into an extensive network where biotech companies, important research institutions, a large supporting industry and many public agencies are linked into a critical mass necessary for innovation.

This dense network of actors in Munich is also supplemented by a strong labor market. The job market is quite rigid where the presence of good education facilities and high education standards leads to a pool of readily available highly qualified scientists and technicians (Kresse, 2006). This is also visible in the fact that in 2005 there were 2950 employees working in biotech of which more than the half had an academic degree (IHK, 2005). On the other hand, the labor market is shaped by the most important employers in biotechnology, i.e. by the research institutions, e.g. the Max-Planck-Institute and the Gene Center, and by long existing firms like Hoffmann-La Roche which has the largest production location for biopharmaceuticals in the world located in Munich (Zeller, 2001; IHK, 2005; Bio$^{M}$, 2008). This influence has led to the emergence of a critical mass of researchers in molecular biology and biotechnology (IHK, 2005), which means that there is an abundance of scientists in the region. So, biotech firms can thus acquire workers from a large pool of qualified staff that is mainly active in molecular biology and biotechnology and the Munich labor market is more rigid than flexible.

In order to perform biotech R&D, acquiring investment deals is important. The availability of financing in the Munich biotech cluster has varied considerably since 1997. After winning the BioRegio competition, the availability of financing began to increase rapidly from €100m in 1998 to €500m in 2000 (Bio$^{M}$, 2008). However, due to the general capital market crisis in 2000, far less VC was invested in the high risk business models of biotechnology in 2002 (€95m) and 2003 (€80m) (IHK, 2005; Kresse, 2006). For example, TBG and BayernKapital invested €30m into the biotech cluster in 2000, but only €0,7m in 2003 (Kaiser and Liecke, 2008). Consequently, several biotech companies collapsed (IHK, 2005). At the end of 2004, the financial climate became somewhat better and companies were able to raise funds and in 2005 €220m was invested (IHK, 2005). But since then Munich, and entire Germany, has seen a decline in financing (Bio$^{M}$, 2008). However, Munich biotech firms have found additional ways of financing, i.e. some companies are financed through the capital market by enlisting on the stock market, and others have without the stock market established collaborations to acquire long-term financial commitments. Although, there is an unfavorable financial climate in all of Germany, Munich has one of the highest concentrations of VCs of Germany and is therefore able to attract capital (IKH, 2005; Kresse, 2006; Häussler and Zademach, 2006). This tight network consists of over 35 venture capital firms, e.g. ATLAS Venture GmbH, Techno Venture Management GmbH and Apax Partners & Co. The federal government has established investment firms such as Bayerische Kapital Risikobeteiligungs- GmbH and the Bay BG. But eventually, the German government and EU give little financial support to the Munich biotech cluster since they consider the region to be highly developed (Kresse, 2006). In this active VC landscape, the early- and mid-stage companies find it difficult to acquire investments since VCs still prefer to fund the established and late-stage companies (Kresse, 2006; Bio$^{M}$, 2008). Overall, the established biotech firms in Munich find itself in a tight financing net, but the early- and mid-stage firms have more difficulty with attracting financing, which constitutes a large disadvantage for the Munich region.

Due to the very early involvement of the research institutions in the process of building the biotech cluster, technology transfer has been actively promoted (Kresse, 2006). That is, the technology transfer offices of the university and the Garching Innovation GmbH, the technology transfer center

for the Max-Planck-Institutes, are highly active in the region. By 2005, the research institutions had already spun off more than 60 life science companies (IHK, 2005; Kaiser and Liecke, 2008). These spin-offs and other young companies benefit from the close contacts with the research institutions (BMBF, 2006) and the dense network of inter-firm collaborations, since "this provides them with access to the newest technological developments and allows them to pool their strengths and to enter new markets" (IHK, 2005; p13). In 2006, companies with headquarters in Munich were engaged in 120 development collaborations with biotech companies and pharma, 60% of these collaborations entailed international partners especially in Europe and the US and they licensed out 66 and licensed in 23 products or technologies (Kresse, 2006). Besides product development collaborations, there were also 141 sales and distribution collaborations in 2005 in the Munich biotech cluster (IHK, 2005). The author's calculations demonstrated that when comparing Munich to the other three clusters, Munich collaborates slightly more than Oxford but less than Cambridge and Berlin, see Table B3 in Appendix B. So, in the Munich biotech region, biotech firms have access to technology transfer through successful technology transfer offices, inter-firm collaborations and the licensing of new products and technologies.

Overall, Munich can be regarded as a highly successful biotech cluster in terms of the number of biotech firms, research institutions and supporting companies. The institutional framework of Munich is characterized by a rigid labor market with high levels of scientists, by a relatively successful financial climate where R&D is mainly financed through capital markets and not from government subsidies. Technology transfer is accomplished by out licensing new products and technologies and through tech-transfer offices. This raises the question why Munich is not as successful in radical innovation as its Berlin counterpart. Both clusters are comparable because they are governmentally induced, but they differ in terms of size, financing and employees. Berlin has 10% more biotech firms than Munich and Berlin firms have access to a more varied pool of employees with both managers and scientists present, where in Munich scientists are the dominant type of workers. Berlin is also more aware of this and has therefore organized regional training schemes in order to keep increasing and renewing the pool of workers. Berlin is also able to acquire higher investments for their R&D than Munich can. Lastly, in Berlin firms collaborate more and the research facilities spun off 20% more companies than in the Munich cluster. For a summary of the similarities and differences between Munich and Berlin, see Table 8. In sum, Munich has the potential to become radically innovative but needs to grow on the previously mentioned aspects.

#### 4.2.2 Oxfordshire Bioscience Network

The biotech industry in Oxford has, just like in Cambridge, developed spontaneously over the years and so a clear beginning of the cluster is therefore hard to distinguish. Oxfords' first biotech companies were established in the 1980s and include British Biotechnology Ltd. (now OCI), Oxford Glycosciences (now UCB), which is a leader in proteomics, and Oxford Molecular (now Accelrys Ltd.), which is specialized in cheminformatics, i.e. chemical information management and decision-support software. Cooke (2007) demonstrates that these core companies formed the basis for the biotech cluster by attracting numerous other biotech companies. The biotech cluster grew rapidly to 60 companies in 2001, 111 in 2005 and 142 in 2008 (Cooke, 2001; OBN, 2008). Since 2005, growth not only resulted from new company formations, but also from the relocation of established companies to Oxford (OBN, 2008). The biotech companies in Oxford are in general small to medium-sized since 54% of the companies have 1-10 employees, 29% has 11-50 employees and 17% of the companies has

more than 50 employees (Hendry and Brown, 2006; OBN, 2008). The Oxford cluster used to be mostly involved with therapeutics, but since 2005 the cluster's activities have become more varied. Nowadays, 24% of the companies are in therapeutics, 21% in diagnostics, 21% in biotech service providing, 21% in instruments and 7% in bioinformatics (OBN, 2008; BioPartner, 2007). The main therapeutic focus is on oncology and the central nervous system. All in all, the Oxford region has developed spontaneously around core biotech firms and has now reached a stage of maturity.

Besides numerous biotech companies, the Oxford biotech region is also home to universities and research institutions that form a strong scientific base. There are two universities present, the University of Oxford and the Oxford Brookes University. There are 18 science and business parks in the city and almost half of Oxford's biotech and healthcare companies are located on Milton Park and Oxford Science Park (OBN, 2005), since they provide start-up and follow-on facilities. Although the rents in these parks are very high, firms are willing to pay since they highly value the localized knowledge spillovers on these parks (Cooke, 2007). In Oxford, there are three leading hospitals involved in biotech research and development, including the John Radcliffe Hospital and the Churchill Hospital. They offer clinical research facilities and host commercial clinical trials as well as NHS trials. Other research institutions that are present in Oxford are the MRC Radiobiology Institute, the Wellcome Trust Human Genetics Centre and the Nuffield Department of Clinical Medicine, which is Europe's leading center in functional genomics. Oxford houses a great variety of research institutions involved in equally diverse activities which subsequently attracts an equally varied supporting industry to the region (Kasabov and Delbridge, 2008). These companies support the biotech firms by providing intermediate goods and services and are for example suppliers, distributors, manufacturers and consultants with expertise in therapeutics (Hendry and Brown, 2006; OBN, 2008). Another example of a supporting company is the Oxfordshire Bioscience Network Ltd. (OBN), a spin-off from the Brookes University, which aims at stimulating the rapid growth and development of the Oxford biotech cluster. It supplies a range of facilities related to establishing links between actors in the cluster, group purchasing and promoting the region to investors and government. All in all, the Oxford region has a strong infrastructure for biotechnology due to the presence of a well-balanced variety of organizations, resources and competencies in the areas of drug R&D.

The Oxford labor market and in particular the availability of highly qualified human capital, is one of the most important factors for biotech firms to settle in the Oxford region (OBN, 2005; Cooke, 2007). Moreover, employees are attracted to the region due to the high number of biotech companies since this gives them relative employment security and provides possibilities for workers to hop from one job to the other (DTI, 1999) which demonstrates that the labor market is more inclined towards flexibility. Employees are thus attracted to the region because of the firms and firms are attracted to the region because of employees and this interplay keeps reinforcing the success of the cluster. A further important aspect of the Oxford labor market is the presence of serial entrepreneurs that keep reusing their capital, general skills and experience to start-up new businesses (OBN, 2008). The majority of the firms did not have any difficulty in recruiting managers and scientists which according to OBN (2005) is highly promising at a time when firms experience difficulties in attracting high quality management. However, companies have found it difficult to recruit scientists and, therefore, OBN has launched the Oxford Life Sciences Recruitment Fair through which scientific enrollment can take place (OBN, 2008). So, the biotech companies have access to managers and the shortage of scientists is currently being overcome by OBN initiatives and the employees face a fluid labor market that makes it a suitable environment for innovation.

Biotech companies need to have access to financing to run their R&D projects. The region therefore hosts three VCs; Oxford Technology VCTs who invest €150.000 to €370.000 in start-up and early-stage companies, Oxford Capital Partners who invest up to a maximum of €1.5m in high-tech companies and Seven Spires Investments also invests €1.5m in high-tech start-ups. These local VCs help to attract late-stage investors from both national and international markets to the region. Such financing deals are mainly acquired on the basis of publicly available data, e.g. the quality of the management teams, the science and the IP portfolio (OBN, 2005). Moreover, numerous public companies are listed on the LSE, NASDAQ and NYSE which also indicates the international orientation of the cluster and its capability in attracting international companies and investments to the region (OBN, 2008). This has led to investments of €213m in 2005, €135m in 2006 and €257m in 2007 (OBN, 2008). The government has been reluctant to invest in the region and their support has been more mental and inspirational rather than financing (Cooke, 2007; Rosiello and Parris, 2008). All in all, Oxford's financial system is characterized by high VC and big pharma investments and the role of the government on the field of financial support is quite modest.

In this region, technology transfer is accomplished in a few ways. First, Oxford has an entrepreneurial culture, visible in the fact that the first spin-offs date back to the 1980s. The University of Oxford has established its own tech-transfer office ISIS Innovation which has generated a steady rate of 72 spin-offs, e.g. Oxford Glycosciences and Oxagen Ltd., and offered 70 licensing opportunities (BioPartner, 2007; OBN, 2008). The Brookes University has also spun off numerous new companies, e.g. Oxford Expression Technologies Ltd., Wildkey and OBN, and also out-licenses technologies. Academic spin-offs are also beneficial to its founder, e.g. the University of Oxford spin-off Oxford Asymmetry still invests in its parent company to support their research (DTI, 1999). Second, Oxford houses very diverse organizations that are all positioned at different phases of the research supply chain of biotechnology and life sciences (Kasabov and Delbridge, 2008). This variety is important for successful commercialization, technology transfer and the positioning of the Oxford cluster in national and international innovation networks. Third, biotech firms collaborate with universities, research institutions and other biotech companies to extend their R&D capabilities, to raise finances and attract investors. In 2005, 92% of the Oxford biotech companies collaborated with the university, mainly for consulting services, 51% with R&D companies, 40% with manufacturing companies, 40% with sales and 38% with distribution companies (OBN, 2008). However, although these figures indicate that there is a high level of collaboration, the author's calculations demonstrate that Oxford is the region with the least amount of collaboration when compared to the other three biotech clusters, see Table B3 in Appendix B. Regarding the size of the network Oxford is embedded in; 55% of the collaborations are with local partners and only 11% with international partners and this demonstrates that collaboration mainly takes place on a regional level (Kasabov and Delbridge, 2006; OBN, 2008). All in all, the mature Oxford cluster creates technology transfer by labor turnover, spinning off companies and by out-licensing technologies.

All in all, the Oxford institutional setting is characterized by a fluid labor market with primarily managers and a shortage of scientists, by a financial system through which large VC and big pharma investments are available for R&D, and by technology transfer that is accomplished through labor mobility, spin-offs and licensing. This description leads to the question why Oxford differs from Cambridge in their innovativeness. Both clusters are comparable in their spontaneous origin, but differ in terms of size, financing and collaboration. Cambridge has 30% more biotech companies and employees than Oxford. Moreover, Cambridge has a more diversified pool of employees to its

disposal where both managers and scientists are present, where Oxford only possesses managers. Both regions are not supported with government funding and therefore rely on VC investments to run their R&D projects. However, Cambridge is able to attract higher amounts of VC than Oxford. Also, firms in the Cambridge cluster collaborate far more than their Oxford counterparts. Cambridge is also embedded in a large international network both for acquiring collaboration deals and financing, where Oxford is only part of a regional network. For a summary of the similarities and differences between Oxford and Cambridge, see Table 8. All in all, Oxford is the smaller version of Cambridge and the large difference in innovativeness can be attributed to this factor.

#### 4.2.3 Oxford – Munich Comparison

From the previous case studies it has become clear that these two incrementally innovative biotech clusters are embedded in slightly different institutional frameworks, but the differences between them are not as large as in the Cambridge – Berlin comparison. Where the Oxford labor market is flexible but with a shortage of scientists, Munich has a more rigid labor market where scientists are abundantly present. With respect to acquiring financial means, Oxford and Munich attract finances in a similar way, i.e. the clusters run their R&D projects with VC investments and not with government subsidies, since the latter has been difficult to attract for both regions. The transfer of technology does however takes place in different ways in both clusters, because the Oxford firms collaborate far less than the Munich firms do. Both clusters have tech-transfer offices in place, but Bio$^{M}$ has a far more active role in managing the cluster development than OBN does. Moreover, the amount of spin-offs that derive from the research institutions is around 20% higher in Oxford than in Munich. With regard to the size of the network, both regions are comparable since they are embedded in regional networks and not in international ones, with the difference that Munich has fewer but stronger ties while Oxford has more but weaker relations. For a simplified schematic representation of the similarities and differences between the institutional frameworks of Oxford and Munich, see Table 7. For an elaborate comparison, see Table 8.

So, two incrementally innovative biotech clusters can thus be embedded in different institutional frameworks wherein biotech firms are supported in different ways in developing the competencies they need to pursue incremental innovation. The institutional framework of Oxford deviates a little from the ideal framework for incremental innovation, but it also differs slightly from its national institutional framework. That is, from the theory it would be expected that the environment suitable for incremental innovation needs to have a rigid labor market in place where firm-specific

**Table 7. Simplified representation of the differences in the institutional frameworks of the incrementally innovative biotech clusters in Oxford and Munich**

| Institutional Framework | | Oxford | Munich |
|---|---|---|---|
| **Skilled Labor** | Labor market flexibility | + | – |
| | Regional training schemes | – | – |
| **Financial Means** | VC investments | +/– | +/– |
| | Subsidies | – | – |
| **Technology Transfer** | Collaboration | – | +/– |
| | Tech-transfer offices | +/– | + |
| | Spin-offs | + | +/– |
| | Network size | +/– | – |

skills are developed that are necessary for incremental innovation. Also, theory suggests that for incremental innovation there need to be high collaboration levels, since technology transfer cannot be accomplished through labor turnover. However, Oxford is characterized by both a flexible labor market and low collaboration levels while still being incrementally innovative. So, the findings of this research demonstrate that Oxford's institutions are not in line with the theoretical expectations. This subsequently raises the question how Oxford biotech firms can be incrementally innovative while being in a non 'ideal' framework. It seems that the absence of collaboration is overcome by the flexible labor market, where the job-hopping of workers ensures technology transfer. Moreover, it appears that within the flexible labor market specific-skilled workers can be developed that are needed for developing cumulative knowledge necessary for incremental innovation. For example, the firms can offer long-term contracts which make employees more inclined to invest in the firm-specific skills. So, even though these institutions are not in line with the ideal framework, Oxford has found a way to circumvent them and still be successful in incremental innovation. It can thus be concluded that a LME can successfully foster an incrementally innovative biotech cluster.

On the other hand, Munich's institutional arrangements are for a large part comparable to the 'ideal' framework for incremental innovation and to its national institutional framework. However, the theory suggests that government subsidies in a CME are very important for financing the R&D of incremental innovation projects, yet the Munich cluster has not been able to attract large amounts of subsidies. Moreover, Munich firms collaborate only averagely, while it is assumed that for incremental innovation a dense network of collaboration should be present since this will lead to the development of complex cumulative technologies. It can thus be concluded that incremental innovation can also take place in an institutional framework that is comparable, but not identical to the ideal framework. This then leads to the question how Munich biotech firms can be incrementally innovative despite not being in the 'ideal' framework. From the case study it has become clear that although Munich is not able to finance their R&D projects with government support, they have been successful in attracting VC investments and therefore, the low amount of government investments is compensated. Moreover, even if Munich firms do not collaborate that extensively, technology transfer is arranged due to highly active other institutions related to technology transfer, e.g. the active involvement of $Bio^{M}$ in networking activities. In this way access to new know-how and technologies can still be accomplished. It can thus be assumed that the cluster's present institutions compensate for the absent ones and as a result make it possible for firms to develop complex cumulative products.

All in all, incremental innovation can take place in both a LME and a CME; where clusters in a LME need to circumvent certain institutional disadvantages and where clusters in a CME need to compensate the absent institutions with highly successful functionally equivalent institutions.

Another interesting question already mentioned is why the incremental clusters are not as successful in radical innovation as their counterparts are. From this research a pattern can be distinguished that gives some indications on the differences between radically and incrementally innovative biotech clusters, see Table 8. It seems that incremental clusters are smaller in terms of the number of biotech firms, have arranged fewer collaboration deals and have attracted a somewhat lower amount of investments (both subsidies and VC) than the radical innovative clusters.

**Table 8. Overview of institutional frameworks of the biotech clusters in Cambridge, Berlin, Oxford and Munich**

| Institutional Framework | | Radically innovative biotech clusters | | Incrementally innovative biotech clusters | |
|---|---|---|---|---|---|
| | | **Cambridge** | **Berlin** | **Oxford** | **Munich** |
| **General** | **Origin** | Spontaneous | Government induced | Spontaneous | Government induced |
| | **Number of firms** | 195 (2008) | 165 (2008) | 142 (2008) | 150 (2008) |
| | **Firm employee size** | High | Low | Average | Low |
| **Skilled Labor** | **Labor market flexibility** | High | Low | High | Low |
| | **Employee type** | Managers and scientists | Managers and scientists | Managers, shortage of scientists | Scientists |
| | **Regional training schemes** | Not necessary | Present (to increase both management and science skills) | Necessary, but not present | Not necessary |
| **Financial Means** | **VC investments** | High | Low (especially for early- and mid-stage companies) | Average | Average (especially for early- and mid-stage companies) |
| | **Subsidies** | Low | High | Low | Low |
| **Technology Transfer** | **Collaboration** | High (e.g. 3,8% of patents have multiple applicants) | High (4,1% of patents have multiple applicants) | Low (e.g. 0,6% of patents have multiple applicants) | Average (1,7% of patents have multiple applicants) |
| | **Tech-transfer offices** | Present (ERBI and Cambridge Enterprise) | Present (BioTOP, TSBmedici, ZMDB) | Present (OBN and ISIS innovation) | Present ($Bio^M$ and Garching Innovation) |
| | **Spin-offs** | >50% of all companies | 50% of all companies | 50% of all companies | 40% of all companies |
| | **Network size** | Large international network with many weak connections | Small regional network with strong connections | Large regional network with many weak connections | Small regional network with strong connections |

# 5. Conclusion

The EU launched the Lisbon Treaty in 2000 with the goal of making the EU the world's most competitive, dynamic and knowledge-based economy in the world by 2010. One of the areas where the EU needs to focus on is the biotechnology industry, since growth of this industry could be a major contribution to the Lisbon's objective. The biotech industry is characterized by high levels of clustering and it is, therefore, important to understand what makes biotech clusters successful in order to increase the successfulness of the biotech industry as a whole. Interestingly, there have been many discussions about which factors determine a cluster's success and the current research has put itself in the middle of one of these academic disputes. Herrmann (2008) and Casper (2007) are disagreeing on which national institutional framework(s) can best sustain a radical biotech industry and consequently biotech clusters. Where Casper argues that only a LME is able to foster a successful radical biotech industry, Herrmann states that radical biotechnology can be sustained in both a CME and a LME. This study, therefore, tries to shed light on the different results obtained by Casper and Herrmann. Additionally, this research has also included incrementally innovative clusters in the analysis in order to determine if the opposite is true, i.e. are CMEs the only institutional framework wherein incremental innovation can take place. Overall, the current study tries to establish how successful biotech clusters look like with respect to its institutional framework.

By using patent citations as an indicator for innovation strategy four biotech clusters were selected; the radically innovative biotech clusters Cambridge (LME) and Berlin (CME) and the incrementally innovative clusters Oxford (LME) and Munich (CME). These cases are analyzed with the use of variables derived from the varieties of capitalism approach and for each of the four clusters the following institutional spheres are investigated; how firms acquire 'skilled labor', 'financial means' and 'technology transfer'.

From the patent citation analysis it already becomes clear that radical and incremental clusters can reside in both types of market economy, but this leaves the question of how their institutional framework are organized. From the case studies it has become apparent that the *radically* innovative biotech clusters can reside in two institutional arrangements; in the ideal LME, but also in a CME if the government incorporates a strong cluster policy to compensate for institutional disadvantages. The *incrementally* innovative biotech clusters can also be located in both a LME and a CME; but clusters in a LME need to circumvent certain institutional disadvantages, e.g. by arranging the development of specific-skilled workers. Clusters in a CME need to compensate for the absent institutions for technology transfer by establishing highly successful other ones. In sum, both types of innovation strategy can be sustained in both institutional frameworks. Additionally, the analyses have demonstrated that the differences between radically and incrementally innovative clusters are related to size, collaboration and VC investments. That is, radical biotech clusters are in general larger in terms of the number of biotech firms, collaborate more and attract higher amounts of investments (either from subsidies or VC) than incrementally innovative cluster.

From these analyses multiple conclusions can be drawn. Firstly, the analysis of the patent citation database has demonstrated that radical biotechnology in Germany is just as successful as in the UK and the same can be concluded with respect to incremental biotech cluster in both countries. It thus seems that Casper has overlooked that there is a radical biotech industry present in Germany which means that his assumption that only one institutional constellation is suitable for biotechnology is not supported by the findings of this research. On the other hand, the findings of this research do

support Herrmann's assumption that firms can circumvent comparative institutional disadvantages and that multiple institutional constellations are able to facilitate radical biotech innovation. The analyses have showed that Oxford (the incremental cluster in a LME) uses circumvention as a mechanism to avoid institutional disadvantages, but Berlin (the radical cluster in a CME) uses a strong cluster policy to compensate for its institutional disadvantages. Lastly, it has also become apparent that Casper's definitions of radical and incremental innovation are not supported by this research. When defining radical innovation as new to the world, also platform technologies (which Casper sees as an exemplar incremental innovation) are included in the definition as long as they are entirely new. Conversely, when defining incremental innovation as doing what we do better, the development of therapeutics (which Casper sees as an exemplar radical innovation) can also be incremental when only the administration form has changed. This research would therefore advice Casper to incorporate improved definitions for radical and incremental innovation.

These new insights on the success of biotech clusters in relation to their national institutional frameworks can also be transformed into policy implications. That is, if the EU wants to increase the successfulness of its biotechnology industry, they have to focus on supporting the development of the biotech clusters and have to take two characteristics of the biotech clusters into account; 1) the nature of the predominant innovation strategy within the cluster, i.e. radical or incremental, and 2) the national institutional surroundings of the cluster. Radically innovative clusters located in a LME do not require government support since biotech clusters will develop spontaneously in this environment due to the favorable national institutions for radical innovation. For radical clusters in a CME the opposite is true, because governmental support is highly essential for the success of these clusters. Such support programs include initiating competitions that aim at increasing networking activities, giving subsidies, organizing trainee programs and launching financing programs for entrepreneurs and early-start ups. These government initiatives are necessary to overcome the CMEs institutional disadvantages and consequently can facilitate the growth of successful radically innovative biotech clusters. For the incrementally innovative biotech clusters it is not so clear how government influence can facilitate the growth of the clusters. It seems that in a LME the biotech firms of an incrementally innovative cluster are able to circumvent institutional disadvantages on their own, which means that policy is not essential for the growth of the cluster. Incrementally innovative biotech clusters in a CME also seem to develop spontaneously due to the favorable climate for incremental innovation, which means that government support is unnecessary. In sum, biotechnology can take place in different economies which means that there are multiple models for successful biotech clusters. Hence, policy measures should be custom made for each cluster when taking into account the cluster's innovation strategy and the cluster's national institutional framework.

## 6. Discussion

This study has demonstrated that innovation strategies can be developed in all market economies, i.e. LMEs are also able to foster incremental innovation and CMEs can also be successful in radical innovation. These results are, as aforementioned, in line with the findings of Herrmann (2008) and Lange (2009) who already demonstrated that firms can circumvent institutional disadvantages. But also the research of Akkermans *et al.* (2009) highlighted that both LMEs and CMEs constitute the same variety of innovation strategies. The results are, however, not in line with Hall and Soskice (2001), Whitley (2002), Hall and Gingerich (2004) and Casper (2007) who argue that institutional

disadvantages cannot be overcome. Perhaps the findings of the current research will stimulate them into conducting further research to bring this debate to a next level.

As all research, this study has some limitations. The first limitation is related to the limited amounts of public data that is available for the four cases. While Munich and Cambridge have been adequately studied in the literature, Oxford and especially Berlin remain somewhat under researched and are therefore not as well understood in academia. This study is therefore an explanatory research that leads to the identification of certain patterns that then need to be further investigated. Additional studies are thus required that use the current research's findings as a stepping stone to demonstrate how biotech clusters are embedded in institutional frameworks and how they deal with comparative institutional disadvantages. For example, both interviews and questionnaire survey on a firm sample of the biotech clusters could be conducted in order to develop a more in-depth and comprehensive understanding of the relation between market economy and innovation strategy. Another limitation is related to the focus on the four cases. It might be that Cambridge, Berlin, Oxford and Munich may not be the only or the best representatives for each innovation strategy. Therefore, additional research is required that would systematically compare numerous biotech clusters in order to confirm the findings of this research. These large biotechnology benchmarking studies have so far only been adopted on the national level (see EuropaBio, 2006; Beuzekom and Arundel, 2009). Future research should thus try to organize such a benchmarking approach on a cluster level since this would lead to a more thorough understanding of the factors that drive or hamper the successfulness of the biotech clusters.

Multiple other directions for future research can be derived from this study. For example, the current research has been one of the first studies were patent citations are incorporated as an indicator for innovation strategy. It would, therefore, be interesting to compare multiple indicators for innovation strategy to patent citations, e.g. number of NCEs, midstream or upstream focus of firms, profits, number of FDA approvals. In this way the quality of patent citations as an indicator for innovation strategy can be confirmed. Another interesting issue is related to the role cluster management organizations play in developing the success of the biotech cluster. This research has demonstrated that German cluster organizations have a far more active role in the cluster development than UK organizations do. Currently, ERBI has merged with the London Biotech Network and it would be interesting to see how the new organization OneNucleus will influence the entire biotech cluster of London and Cambridge. Moreover, this research has demonstrated that some clusters are policy induced while others have originated spontaneously. These findings correspond to the research of Su and Hung (2009) and Chiaroni and Chiesa (2006). It would, however, be interesting to expand this field of research by investigating what happens when government support stops; will Berlin still be as successful as it nowadays is without government support present. In sum, this research has delivered some very interesting results with respect to innovation strategy and institutional frameworks and showed that biotech clusters are not better off in liberal market economies.

## References

AHO, E., CORNU, J., GEORGHIOU, L. AND SUBIRÁ, A., 2006. Creating an Innovative Europe. *European Commission*. Available on: http://ec.europa.eu/invest-in-research/pdf/download_en/aho_report.pdf.

AKKERMANS, D., CASTALDI, C. AND LOS, B., 2009. Do 'Liberal Market Economies' Really Innovate More Radically Than 'Coordinated Market Economies'?. Hall and Soskice Reconsidered. *Research Policy*, 38 (1), pp.181-191.

ARCHIBUGI, D. AND PIANTA, M., 1996. Measuring Technological Change Through Patents and Innovation Surveys. *Technovation*, 16 (9), pp. 451-468.

ASHEIM, B.T., 1996. Industrial Districts as 'Learning Regions': A Condition for Prosperity? *European Planning Studies*, 4, pp. 379-400.

BAKER, G., GIBBONS, R. AND MURPHY, K.J., 2002. Relational Contracts and the Theory of the Firm. *The Quarterly Jounal of Economics*, 117 (1), pp. 39-84.

BARREL, A., 2004. Innovation Champions Network: The Cambridge Cluster Description. *Library House*. Available on: http://www.insme.org/documents/cambridgeStruct.pdf.

BERLIN PARTNER, 2009. Life sciences in the Berlin-Brandenburg Capital Region, *Berlin Partner GmbH*. Available on: http://www.berlin.de/imperia/md/content/sen-wirtschaft/publikationen/life_sciences_en.pdf?start&ts=1278582441&file=life_sciences_en.pdf.

BEUZEKOM, VAN, B. AND ARUNDEL, A., 2009. *OECD Biotechnology Statistics 2009*. Available on: http://www.oecd.org/dataoecd/4/23/42833898.pdf.

BIO$^{M}$, 2007. *Biotechnology in Bavaria – 2007*. Available on: http://www.bio-m.org/_resources/dynamic/hauptbereich/presse_download/report_2007_cluster_biotech_bayern_final.pdf.

BIO$^{M}$, 2008. *Biotechnology and Pharmaceuticals 2008 in the European Metropolitan Region Munich (EMM)*. Available on: http://www.bio-m.org/_resources/dynamic/hauptbereich/unternehmen/muenchner_biotechnologie_report_2008_biomihkeng.pdf.

BIOPARTNER, 2007. Biotechnology Clusters – supporting the UK as Europe's No1 in Bioscience. *Life Science Clusters*, 1 (1), pp. 36-38. Available on: http://www.biopartner.co.uk/documents/clustersarticle.pdf.

BIOTOP, 2010. BioTOP-Report 2010. Journal of Biotechnology in Berlin-Brandenburg, 40, pp. 1-76. Available on: http://www.biotop.de/data/files/biotopics/BioTOPReport2010.pdf.

BOZEMAN, B., 2000. Technology Transfer and Public Policy: A Review of Research and Theory. *Research Policy*, 29 (4-5), pp. 627-655.

CASPER, S. AND KARAMANOS, A., 2003. Commercializing science in Europe: The Cambridge Biotechnology Cluster, *European Planning Studies*, 11 (7), pp. 805-822.

CASPER, S. AND KETTLER, H., 2001. National Institutional Frameworks and the Hybridization of Entrepreneurial Business Models: The German and UK Biotechnology Sectors. *Industry and Innovation*, 8 (1), pp. 5-30.

CASPER, S., 2007. *Creating Silicon Valley in Europe: Public Policy Towards New Technology Industries*. New York, Oxford University Press.

CASPER, S., 2009. Can New Technology Firms Succeed in Coordinated Market Economies? A response to Herrmann and Lange. *Socio Economic Review*, 7 (2), pp. 209-215.

CHIARONI, D. AND CHIESA, V., 2006. Forms of creation of industrial clusters in biotechnology. *Technovation*, 26 (9), pp. 1064-1076.

COENEN, L., MOODYSSON, J. AND ASHEIM, B.T., 2004. Nodes, networks and proximities: On the knowledge dynamica of the Medicon Valley biotech cluster. *European Planning Studies*, 12 (7), pp. 1003-1018.

COOKE, P.N., 2001. Biotechnology Clusters in the U.K.: Lessons from Localisation in the Commercialization of Science. *Small Business Economics*, 17 (1-2), pp. 43-59.

COOKE, P.N., 2007. European Asymmetries: A Comparative Analysis of German and UK Biotechnology Clusters. *Science and Public Policy*, 34 (7), pp. 454-474.

DAHLIN, K. B. AND BERENS, D.M., 2005. When is an Invention Really Radical? Defining and Measuring Technological Radicalness. *Research Policy*, 34 (5), pp. 717-737.

DODGSON, M. AND HINZE, S., 2000. Indicators Used to Measure the Innovation Process: Defects and Possible Remedies. *Research Evaluation*, 9 (2), pp. 101-114.

DOHSE, D. AND STAEHLER, T., 2008. BioRegio, BioProfile and the Rise of the German Biotech Industry. Working Paper Kiel Institute for the World Economy. Available on: http://www.econstor.eu/bitstream/10419/24850/1/58214230X.pdf.

DTI, 1999. Biotechnology Clusters, *Department of Trade and Industry*. Available on: www.bis.gov.uk/files/file28706.pdf.

DYER, J. H. AND SINGH, H., 1998. The Relational View: Cooperative Strategy and Sources of Interorganizational Competitive Advantage. *The Academy of Management Review*, 23 (4), pp. 660-679.

EC, 2010. EuCo 13/10. Conclusions – 17 June 2010. Available on: http://ec.europe.eu/eu2020/pdf/115346.pdf.

EMCC, 2008. Biomedical healthcare sector: Berlin-Brandenburg Cluster, Germany. *European Monitoring Center on Change*. Available on: http://www.eurofound.europa.eu/pubdocs/2007/1113/en/1/ef071113en.pdf.

EUROPABIO, 2006. *Biotechnology in Europe: 2006 Comparative study*, Brussels, European Commission, available at: http://www.europabio.org/CriticalI2006/Critical2006.pdf.

EUROPE INNOVA, 2007. Biotech Cluster Development: Constraints and Good Practices Affecting Companies and Clusters in their Development. Available on: http://archive.europe-innova.eu/servlet/Doc?cid=8692&lg=EN.

EUROPEAN COMMISSION, 2002. Life Sciences and Biotechnology – A Strategy for Europe. Available on: http://ec.europa.eu/biotechnology/pdf/com2002-27_en.pdf.

EUROPEAN PARLIAMENT, 2000. Lisbon European Council 23 and 24 March 2000 – Presidency Conclusions. Available on: http://www.europarl.europa.eu/summits/lis1_en.htm.

EUROSTAT, 2010. City Population in UK and DE. Available on: http://epp.eurostat.ec.europa.eu/.

GERTLER, M.S. AND VINODRAI, T., 2009. Life Sciences and Regional Innovation: One Path or Many? *European Planning Studies*, 17 (2), pp. 235-261.

HAGEDOORN, J. AND CLOODT, M., 2003. Measuring Innovative Performance. Is there an Advantage in Using Multiple Indicators? *Research Policy*, 32 (8), pp. 1365-1379.

HALL, B. H., JAFFE, A. AND TRAJTENBERG M., 2005. Market Value and Patent Citations. *RAND Journal of Economics*, 36 (1), pp. 16-38.

HALL, P.A. AND GINGERICH, D.W., 2004. Varieties of Capitalism and Institutional Complementarities in the Macroeconomy: an Empirical Analysis. *Berliner Journal fur Sociologie*, 14 (1), pp. 5-43.

HALL, P.A. AND SOSKICE, D., 2001. An Introduction to Varieties of Capitalism. In: Hall, P.A. and Soskice, D. (Eds.), Varieties of Capitalism; The Institutional Foundations of Comparative Advantage. Oxford, Oxford University Press, pp. 1-68.

HÄUSSLER, C. AND ZADEMACH, H.M., 2006. Cluster Performance Reconsidered: Structure, Linkages and Paths in the German Biotechnology Industry. Available at: http://ssrn.com/abstract=907475.

HENDRY, C. AND BROWN, J., 2006. Organizational Networking in UK Biotechnology Clusters. *British Journal of Management*, 17 (1), pp. 55-73.

HERRMANN, A.M., 2008. *One Political Economy, One Competitive Strategy? Comparing Pharmaceutical Firms in Germany, Italy and the UK*. New York, Oxford University Press, first edition.

HERRMANN, A.M., 2010. How Macro-Level Sampling Affects Micro-level Arguments: A Rejoinder to Steven Casper. *Socio Economic Review*, 8(2), pp. 333-339.

HODGSON, G.M., 2006. What are Institutions? *Journal of Economic Issues*, XL (1), pp. 1-25.

IHK, 2005. Biotech and Pharmaceuticals Region Munich 2005. Industrie – und Handelskammer für München und Oberbayern. Available on: http://www.muenchen.ihk.de/mike/presse/Anhaenge/BioTech_Region.pdf.

KAISER, R. AND LIECKE, M., 2008. Sub-National Capabilities to Perform a Strategic Innovation-Policy, the Example of Biotech in Munich. *DRUID* Working Paper No. 08-21. Available on: http://www3.druid.dk/wp/20080021.pdf.

KAISER, R., 2003. Multi-level Science Policy and Regional Innovation: The Case of the Munich Cluster for Pharmaceutical Biotechnology. *European Planning Studies*, 11 (7), pp. 841-858.

KASABOV, E. AND DELBRIDGE, R., 2006. Biotech Clusters in the UK – Challenges and Opportunities. *Advanced institute of management research*. Available on: http://www.aimresearch.org/uploads/file/Publications/EBs/Biotech%20Clusters%20in%20the%20UK.pdf.

KASABOV, E. AND DELBRIDGE, R., 2008. Innovation Embeddedness and Policy: Evidence from Life Sciences in Three UK Regions. *Technology Analysis and Strategic Management*, 20 (2), pp. 185-200.

KETELS, C., SÖLVELL, Ö., DUCH, E., SAGRARIO, I., FOLKESSON, T. AND LINDQVIST, G., 2008. Innovation Clusters in 10 New Member States of the European Union. *Europe INNOVA*. Available on: http://www.europe-innova.eu/c/document_library/get_file?folderId=148901&name=DLFE-6120.pdf.

KRESSE, H., 2006. The German Biotechnology Sector 2006 – Analysis and Opportunities for UK Engagement. *University of Cambridge, Institute of Biotechnology*. Available on: http://www.erbi.co.uk/SITE/UPLOAD/DOCUMENT/ukti%20reports/Germany_2006.pdf.

LAFFITTE, P., AHO, E., DANNEELS, L., EVRARD, J., MEIER ZU KOCKER, G., MINGASSON, J.P. AND MONKS, G., 2007. The European Cluster Memorandum. Promoting European Innovation through clusters: an Agenda for Policy Action. *Europe INNOVA*. Available on: http://www.clusterobservatory.eu/upload/European_Cluster_Memorandum.pdf.

LANGE, K., 2009. Institutional Embeddedness and the Strategic Leeway of Actors: The Case of the German Therapeutical Biotech Industry. *Socio Economic Review*, 7, pp.181-207.

LECHNER, C. AND DOWLING, M., 1999. The Evolution of Industrial Districts and Regional Networks: The Case of the Biotechnology Region Munich/ Martinsried. *Journal of Management & Governance*, 3 (4), pp. 309-338.

LIBRARY HOUSE, 2007. Looking Inwards, Reaching Outwards. The Cambridge Cluster Report – 2007. Available on: http://www.ifm.eng.cam.ac.uk/ctm/teg/documents/2007-11LibraryHouse-CambridgeClusterReport.pdf

MALMBERG, A. AND POWER, D., 2005. (How) do (Firms in) clusters create knowledge? *Industry and Innovation*, 12 (4), pp. 409-431.

MÜLLER, C., 2002. The Evolution of the Biotechnology Industry in Germany. *Trends in Biotechnology*, 20 (7), pp. 287-290.

MUSTERD, S., BONTJE, M., CHAPAIN, C., KOVÁCS, Z. AND MURIE, A., 2007. Accommodating Creative Knowledge – A Literature Review from a European Perspective. *ACRE report 1*. Available on: http://www2.fmg.uva.nl/ACRE/results/documents/WP1StateoftheArtversion15mrt2007.pdf.

NASTO, B., 2008. Chasing Biotech Across Europe. *Nature Biotechnology*, 26, pp. 283-288

NIH, 2000. NIH Working Definition of Bioinformatics and Computational Biology. Available on: http://www.bisti.nih.gov/docs/compubiodef.pdf.

OBN, 2005. Oxfordshire Bioscience Cluster Report 2005. *Oxfordshire Bioscience Network*. Available on: www.obn.org.uk/seeb/images/publications/oxford_biotech_cluster.pdf.

OBN, 2008. Biocluster Report 2008: Resurgence. The Definitive Guide. *Oxfordshire Bioscience Network*. Available on: http://www.obn.org.uk/seeb/images/documents/OBN%20BioCluster%20Report%202008%20-%20Definitive%20Guide%20and%20South%20East%20Bioscience%20Companies%20Review%20web%20version.pdf.

OECD, 2009. *OECD Patent Statistics Manual*. Available on: www.sourceoecd.org/scienceIT/9789264054127.

OECD/ EPO PATENT CITATIONS DATABASE, 2004. Information on: http://www.oecd.org/document/41/0,3343,en_2649_34451_40813225_1_1_1_1,00.html.

OXFORD RESEARCH, 2008. Cluster Policy in Europe. A brief summary of cluster policies in 31 European countries. *Europe INNOVA Cluster Mapping*. Available on: http://www.clusterobservatory.eu/upload/Synthesis_report_cluster_mapping.pdf.

OXFORD UNIVERSITY PRESS, 2004. Oxford University Press, Editors: Catherine Soanes, Angus Stevenson.

PORTER, M.E., 1998. Clusters and the Economics of Competition. *Harvard Business Review*, 76 (6), pp. 70-90.

PORTER, M.E., 2000. Location, Competition, and Economic Development: Local Clusters in a Global Economy. *Economic Development Quarterly*, 14 (1), pp. 15-34.

POWELL, W.W., 1998. Learning from Collaboration: Knowledge and Networks in the Biotechnology and Pharmaceutical Industries. *California Management Review*, 40 (3), pp. 228-240.

ROSIELLO, A. AND PARRIS, S., 2009. The Patterns of Venture Capital Investments in the UK Bio-Healthcare Sector: The Role of Proximity, Cumulative Learning and Specialization. *Venture Capital*, 11 (3), pp. 185-211.

SAXENIAN, A., 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, Massachusetts: Harvard University Press.

SKENTELBERY, C., 2004. Eastern Promise. *Chemistry World*, 1 (2), pp. 24-27. Available on: http://www.rsc.org/chemistryworld/restricted/2004/February/promise.asp.

STAFFORD, N., 2005. Focus on Berlin. *Scientists*, 19 (6), pp. 45-48. Available on: http://www.the-scientist.com/article/display/15352/.

SU, Y.S. AND HUNG, L.C., 2009. Spontaneous vs. Policy-Driven: The Origin and Evolution of the Biotechnology Cluster. *Technological Forecasting & Social Change*, 76 (5), pp. 608-619.

TIDD, J., BESSANT, J. AND PAVITT K., 2005. *Integrating Technological, Market and Organizational Change*. West Sussex, England, John Wiley and Sons Ltd, third edition.

WALKER, J., 2005. Cambridge: Europe's Leading Location for Biotechnology. *Drug Discovery Today*, 10 (14), pp. 956-959.

WHITLEY, R., 2002. Developing Innovative Competences: The Role of Institutional Frameworks. *Industrial and Corporate Change*, 11 (3), pp. 497-528.

ZELLER, C., 2001. Clustering Biotech: A Recipe for Success? Spatial Patterns of Growth of Biotechnology in Munich, Rhineland and Hamburg. *Small Business Economics*, 17, pp. 123-141.

## Appendix A: IPC subclasses of biotechnology patents

| IPC Code | Definition |
|---|---|
| A01H 1/00 | Processes for modifying genotypes |
| A01H 4/00 | Plant reproduction by tissue culture techniques |
| A61K 38/00 | Medicinal preparations containing peptides |
| A61K 39/00 | Medicinal preparations containing antigens or antibodies |
| A61K 48/00 | Medicinal preparations containing genetic material which is inserted into cells of the living body to treat genetic diseases; Gene therapy |
| C02F 3/34 | Biological treatment of water, waste water, or sewage; characterized by the micro-organisms used |
| C07G 11/00 | Compounds of unknown constitution; Antibiotics |
| C07G 13/00 | Compounds of unknown constitution; Vitamins |
| C07G 15/00 | Compounds of unknown constitution; Hormones |
| C07K 4/00 | Peptides having up to 20 amino acids in an undefined or partially defined sequence |
| C07K 14/00 | Peptides having more than 20 amino acids |
| C07K 16/00 | Immunoglobulins, e.g. monoclonal or polyclonal antibodies |
| C07K 17/00 | Carrier-bound or immobilized peptides |
| C07K 19/00 | Hybrid peptides (hybrid immunoglobulins composed solely of immunoglobulins |
| C12M | Apparatus for enzymology or microbiology |
| C12N | Micro-organisms or enzymes; compositions thereof propagating, preserving, or maintaining micro-organisms; mutation or genetic engineering; culture media |
| C12P | Fermentation or enzyme-using processes to synthesis a desired chemical compound or composition or to separate optical isomers from a racemic mixture |
| C12Q | Measuring or testing processes involving enzymes or micro-organisms; compositions or test papers therefore; processes of preparing such compositions; condition-responsive control in microbiological or enzymological processes |
| C12S | Processes using enzymes or micro-organisms to liberate, separate or purify a pre-existing compound or composition; processes using enzymes or micro-organisms to treat textiles or to clean solid surfaces of materials |
| G01N27/327 | Investigating or analyzing materials by the use of electric, electro-chemical or magnetic means: biochemical electrodes |
| G01N33/53* | Investigating or analyzing materials by specific methods not covered by preceding groups: immunoassay; biospecific binding assay; materials therefore |
| G01N33/54* | … double or second antibody: with steric inhibition or signal modification: with an insoluble carrier for immobilising immunochemicals: the carrier being organic: synthetic resin: as water suspendable particles: with antigen or antibody attached to the carrier via a bridging agent: Carbohydrates: with antigen or antibody entrapped within the carrier |
| G01N33/55* | … the carrier being inorganic: Glass or silica: Metal or metal coated: the carrier being a biological cell or cell fragment: Red blood cell: Fixed or stabilised red blood cell: using kinetic measurement: using diffusion or migration of antigen or antibody: through a gel |
| G01N33/57* | … for venereal disease: for enzymes or isoenzymes: for cancer: for hepatitis: involving |
| G01N33/68 | … involving proteins, peptides or amino acidsmonoclonal antibodies: involving limulus lysategroups: |
| G01N33/74 | … involving hormones |
| G01N33/76 | … human chorionic gonadotropin |
| G01N33/78 | … thyroid gland hormones |
| G01N33/88 | … involving prostaglandins |
| G01N33/92 | … involving lipids, e.g. cholesterol |

These IPC subclasses refer to technological areas that are regarded as biotechnology (OECD, 2008) and except for A01H 4/00 and C02F 3/34, who do not reflect biotechnology related to health care, are all included in the analysis of OECD/EPO patent citations database (2004).

# Appendix B: Additional Tables

**Table B1. Number of forward patent citations for German cities**

| Germany | | |
|---|---|---|
| City | # forward citations per 100.000 inhabitants | # firms |
| Marburg | 260,457 | 5 |
| Mannheim | 236,393 | 3 |
| Göttingen | 100,951 | 6 |
| Darmstadt | 70,780 | 5 |
| Heidelberg | 69,254 | 13 |
| Düsseldorf | 46,429 | 7 |
| Frankfurt | 18,596 | 15 |
| Köln | 18,596 | 9 |
| Freiburg | 12,002 | 7 |
| Würzburg | 10,776 | 6 |
| Tübingen | 9,704 | 3 |
| Jena | 7,908 | 5 |
| Berlin | 6,758 | 25 |
| München | 6,354 | 15 |
| Giessen | 4,093 | 3 |
| Hannover | 4,066 | 5 |
| Regensburg | 3,931 | 3 |
| Hamburg | 2,722 | 13 |
| Leipzig | 1,825 | 4 |

**Table B2. Number of forward patent citations for UK cities**

| United Kingdom | | |
|---|---|---|
| City | # forward citations per 100.000 inhabitants | # firms |
| Cambridge | 137,618 | 25 |
| Slough | 81,567 | 4 |
| Oxford | 33,563 | 9 |
| Nottingham | 11,619 | 5 |
| London | 9,844 | 59 |
| Cardiff | 5,819 | 5 |
| Norwich | 4,022 | 3 |
| Leeds | 3,610 | 3 |
| Manchester | 3,297 | 6 |
| Leicester | 2,420 | 3 |
| Edinburgh | 2,325 | 4 |
| Glasgow | 2,065 | 5 |
| Sheffield | 1,364 | 3 |

**Table B3. The level of collaboration in the four clusters**

| Cluster | Double applicants / 100 patents |
|---|---|
| Cambridge | 3,78 |
| Berlin | 4,10 |
| Oxford | 0,63 |
| Munich | 1,71 |

## Appendix C: Abbreviations and Definitions

| | |
|---|---|
| **BMBF** | *Bundesministerium für Bildung und Forschung*, Federal Ministry of Education and Research (Berlin, DE) |
| **BMG** | *Bundesministerium für Gesundheit*, Federal Ministry of Health (Berlin, DE) |
| **BMWi** | *Bundesministerium für Wirtschaft und Technologie*, Federal Ministry of Economy and Technology (Munich, DE) |
| **CME** | Coordinated Market Economy |
| **CRO(s)** | Contract Research Organization(s) |
| **EBI** | European Bioinformatics Institute (Cambridge, UK) |
| **EPO** | European Patent Office |
| **ERBI** | East Regional Biotechnology Initiative (Cambridge, UK) |
| **GSF** | *Forschungszentrum für Umwelt und Gesundheit*, National Research Center for Environment and Health (Munich, DE) |
| **IP** | Intellectual Property |
| **IPC** | International Patent Classification |
| **LBN** | London Biotech Network (London, UK) |
| **LMB** | Laboratory of Molecular Biology (Cambridge, UK) |
| **LME** | Liberal Market Economy |
| **LSE** | London Stock Exchange (London, UK) |
| **NCE** | New Chemical Entity |
| **LMU** | *Ludwigs-Maximilians-Universität*, Ludwigs-Maximilians-University (Munich, DE) |
| **MRC** | Medical Research Council (Cambridge, UK) |
| **NASDAQ** | National Association of Securities Dealers Automated Quotations |
| **NCE** | New Chemical Entity |
| **NHS** | National Health Service |
| **NPL** | Non Patent Literature |
| **NYSE** | New York Stock Excange |
| **OECD** | Organization for Economic Cooperation and Development |
| **R&D** | Research and Development |
| **SME(s)** | Small- and Medium-sized Enterprise(s) |
| **TUM** | *Technische Universität München*, Technical University Munich (Munich, DE) |
| **UoC** | University of Cambridge (Cambridge, UK) |
| **USPTO** | US Patent Trademark Office |
| **VCs** | Venture capitalists |
| **WIPO** | World Intellectual Property Organization |
| **ZMDB** | *Zentrum für Molekulare Diagnostik und Bioanalytik*, Center for Molecular Diagnostics and Bioanalytics |

| | |
|---|---|
| **Antitrust regulation** | … is intended to "promote free competition in the marketplace by prohibiting collusive, exclusionary, and monopolistic practices that restrain competition and thereby pose a danger of increased prices and reduced output, quality, and innovation" (Oxford University Press, 2004). |
| **Arm's length relations** | … are a type of business relation were both parties act like they are unrelated to each other to ensure that both act in their own self interest and conflicts of interest are avoided, e.g. when a firm wants to get a bank loan, any agreement will reflect market value and commercially reasonable terms and conditions. However, a loan between parents and child is more inclined to be provided on much more favorable terms and conditions. The first example is considered to be an arm's length relation, the second is not. |
| **Bioinformatics** | … is the "research, development, or application of computational tools and approaches for expanding the use of biological, medical, behavioral or health data, including those to acquire, store, organize, archive, analyze, or visualize such data" (NIH, 2000). |
| **Biotechnology firms** | … apply the most modern techniques to transform the processes of biological cells and cell components into industrially useful substances, e.g. for medical use. |
| **Business associations** | … are organizations of businesses that promote the interests of its members and in particular those activities that are expensive and time-consuming for a firm alone, e.g. lobbying, information gathering, research and setting technology standards. |
| **Employers' associations** | … are organizations of employers in some sector of the economy that for example conduct collective bargaining with trade unions on behalf of their members. |
| **Firm-specific skills** | … are skills that workers cannot easily transfer to other firms should a company fail. Antonym: general skills. |
| **Formal contract** | … "must be specified ex ante in terms that can be verified ex post by a third party, e.g. a court" (Baker *et al*., 2002; p40). |
| **Free-rider problem** | … refers to a situation wherein individuals or firms can use goods or services without paying for its or for its conservation. |
| **General skills** | … are skills that workers can use in other firms. Antonym: firm-specific skills. |
| **Incremental innovations** | … are continuous but small scale improvements to existing products and processes. Antonym: radical innovation. |
| **Innovation** | … is "the process of turning inventions into widely used practice" (Tidd *et al*., 2005; p66). |
| **Invention** | … is the occurrence of an idea for a new product or process. |
| **Institutions** | … are "systems of established and embedded social rules that structure social interactions" (Hodgson, 2006; p18). |
| **Patent citations** | … are the references to preceding knowledge that applicants include in patent documents to establish a patent's patentability and particularly to show the inventive step of their idea. |
| **Patentability** | … refers to the ability of requiring patent protection over an invention and depends on three criteria; "a product or process is new, involves |

| | |
|---|---|
| | an inventive step and is susceptible of industrial application" (OECD, 2009; p18). |
| **Patient capital** | … is capital for which investors are interested in long-term value maximization. |
| **Platform technologies** | … are designed to increase the efficiency of research methods, "such as genomics, combinatorial chemistry and activities involving the rationalization of extremely complex lab procedures, such as the cloning and filtration of genetic material" (Casper and Kettler, 2001; p7). |
| **Prisoner's dilemma** | … refers to "a situation in which two players each have two options whose outcome depends crucially on the other's simultaneous choice, exemplified by two prisoners separately deciding whether to confess to a crime" (Oxford University Press, 2004). |
| **Radical innovations** | … are the development of products and processes that are entirely new to the world (Tidd *et al*., 2005). Antonym: incremental innovations. |
| **Relational contract** | … "is based on outcomes that are observed by only the contracting parties *ex post* and also on outcomes that are prohibitively costly to specify *ex ante*. Relational contracts cannot be verified by a third party and need to be self-enforcing, i.e. the value of the future relationship must be sufficiently large that neither party wishes to renege" (Baker *et al*., 2002; p40). |
| **Spin-off** | … is a new company created from an existing part of another firm. |
| **Technology transfer** | … is "the movement of know-how, technical knowledge, or technology from one organizational setting to another" (Bozeman, 2000; p3). |
| **Therapeutics** | … is "the branch of medicine concerned with the treatment of disease and the action of remedial agents" (Oxford University Press, 2004). |
| **Trade union** | … is an "organized association of employees in a trade, group of trades, or profession, formed to protect and further their rights and interests" (Oxford University Press, 2004). In Dutch: *vakbonden*. Antonym: Employers associations. |
| **Transaction costs** | … are the costs incurred during buying or selling of products and services, e.g. broker commissions, and are strongly related to trust. The more distrust amongst actors, the higher the expectation that the other will engage in opportunistic behavior during the transaction making, so costs need to be made to negotiate, monitor and enforce the contract/ exchange. |
| **Venture capital** | … is "capital invested in a project in which there is a substantial element of risk" (Oxford University Press, 2004). |
| **Works council** | …is "a group of employees representing a workforce in discussions with their employers" (Oxford University Press, 2004). In Dutch: *ondernemingsraad*. |