The Massachusetts Life Sciences Cluster:

A research into the performance on success factors and the cluster's level of development

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Summary

The goal of this research is to obtain an insight in the characteristics of the Massachusetts life sciences cluster. In order to achieve this goal, a theoretical framework is set up. This framework covers a wide range of cluster aspects, enabling a broad view on the cluster and its development. The cluster is first examined by using the cluster-term definition. It is then tried to identify the strengths of the cluster in terms of cluster success factors. Based on these findings, combined with findings from two specific works of earlier research, it is tried to identify the cluster's life cycle stage. In addition, an attempt is made to assess whether the Massachusetts cluster offers the typical cluster advantages as outlined by Porter.

The results as found for the Massachusetts cluster point towards the fulfilment of three success factors: 'innovation and R&D', 'human resources' and 'the ability to attract finance'. From the seven factors remaining, two were identified as being in need of improvement: the condition of the 'physical infrastructure' and the presence of a relatively low 'number of large firms'. The growth-stage was identified as the cluster's life cycle stage whereby the 2008 Life Sciences Act was found as a possible accelerator to the cluster's growth. In terms of competitive advantages, the cluster was found to realize the advantage of 'increased company productivity'.

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Chapter I Introduction

In today's world of international business, there is an ongoing trend towards the globalization of economic activity. Within this trend, the importance of particular regions has appeared to be reduced.[i1] Over the last decades, however, the exact opposite - the localization of economic activity - has become more important.[ii] The cluster concept encompasses this focus on the geographic aspect of businesses. California's Silicon Valley hereby functions as an example often referred to. Silicon Valley is, however, not the only high tech cluster within the US. In Massachusetts, and particularly in the area around Boston, a similar geographical concentration of firms can be found. Their specialization: biotechnology (or broader: life sciences).

The global trend of regional concentrated economic activity has been recognized by the Dutch government. On a domestic level, the government actively supports the development of existing clusters operating in growth sectors.[iii] Within the international arena, the government started to focus on identifying market opportunities for Dutch enterprises within foreign business clusters. In this regard, the Ministry of Foreign Affairs plays an important role. The economic departments of the many embassies and consulates around the world are assigned with exploring their areas for business opportunities. An example of one of these departments is the Netherlands Consulate General in New York.

The Netherlands Consulate General in New York

The Consulate is part of a worldwide network maintained by the Dutch Ministry of Foreign Affairs in order to promote Dutch interests abroad. One of the tasks of the Consulate is the facilitation of Dutch business activities in its area. The economic department of the Consulate takes on this challenge. For 2007, the EVD determined several key sectors to focus on. One of them was the life sciences sector. Because of this focus and the Consulate's thought of growing life sciences potential for Dutch businesses, the need for an exploration in this area developed. The Massachusetts life sciences cluster falls within the area covered by the Consulate. From there on a need for information on the life sciences cluster emanated. The research was conducted as part of an internship at the Consulate. The purpose of this research was to gather information on the Massachusetts life sciences cluster; obtain knowledge and insights in the Massachusetts based cluster in order to conclude on the level of development of the cluster. A secondary purpose of the research lies in the fact that the current research could possibly be used at a later stage to identify market opportunities within the cluster for Dutch businesses.

Why measure cluster development?

Measurement of the cluster's development can be used in several ways.[iv] In the first place, it can be used to assess whether a certain general cluster policy has been successful. It can also be used to assess the impact of a certain specific intervention. In addition, it can be used for the comparison of economic performances. Assessing a cluster's development can result in the identification of the cluster's strong and weak points. Knowledge about these key development factors can be used in order to develop the right cluster policy. The knowledge derived from the measurement can also be of help to companies or institutions willing to take on an active role in the cluster. From an academic point of view, much has

[1] This thesis makes use of endnotes in order to credit the source or reference. Information essential to the subject is placed within the main text.

been written on the cluster subject. Chapter 2 provides an overview in that regard. For this research, the report to the UK Department of Trade and Industry (the DTI report) will be of particular importance. Based on extensive literature research, the report provides an overview on how to design and measure cluster strategy. In addition, the report addresses the question what policy action to implement in order to support clusters. The various success factors identified by the DTI report are of particular importance to this research; they will be used in chapter 4 to examine the cluster's level of development.

1.1 Research objective and research question

The problem as identified concerns the lack of information on the Massachusetts' life sciences cluster. In order to close this information gap, the research objective was set as to acquire knowledge on the cluster's level of development and on the factors contributing to its development.

In order to conclude on the research topic a central research question has been formulated:

> *How can the cluster's performance on success factors be described and what overall level of development is reached by the Massachusetts life sciences cluster?*

The research question is divided into several sub questions:

1. *What constitutes the Massachusetts life sciences cluster?*
2. *What cluster success factors are fulfilled by the Massachusetts cluster?*
3. *At what cluster life cycle stage is the Massachusetts cluster operating?*
4. *What competitive advantages (Porter) are realized?*

The goal of the first sub-question is to provide an insight in the cluster and in the elements of which it is made of. The next step is the identification of the cluster's success factors. Identifying these factors will provide a first thought on the cluster's level of development. The classification of the cluster into a particular life cycle stage contributes to understanding the level of development the cluster has reached so far. By means of the fourth sub-question it is analyzed whether, based on the answers on the previous sub-questions, the cluster fulfils certain competitive advantages. This question was drawn in order to analyze whether the Massachusetts' cluster can be seen as developed in terms of these understandable economic parameters. The reason for this emanated from the thought that young clusters are less able to provide all the benefits suggested by literature (contrasting the ability of more mature clusters).

1.2 Research methodology

A literature review was conducted in order to form the theoretical framework. Various secondary sources have been used to compile an up-to-date overview on the cluster phenomenon. Obtaining the information needed to fill in the concepts presented by the theory was achieved by conducting two types of research. Firstly, conversations with experts active in the cluster were held to obtain first hand information. In addition, a desktop research was conducted. Various reports and articles were used to collect the information needed for this assessment.

1.3 Research structure

The research starts in chapter 2 with the presentation of the theoretical framework. It is followed by a more detailed explanation of the methodology in chapter 3. Chapter 4 presents the research findings while chapter 5 contains a conclusion and suggestions for further research.

Chapter II Theoretical Framework

Introduction

The publication of Michael Porter's book, '*The competitive advantage of nations*' triggered an immense interest for clusters that still exists today.[v] In his work, Porter highlighted the importance of regional clusters to the competitiveness of nations and regions. Since then, cluster theory has been analyzed extensively. Tracey and Monypenny (2006) document this popularity by stating that:

> *'Industrial clustering has been implemented world-wide from the United States (Waits, 2000) to Germany (Rocha and Sternberg, 2005) to Switzerland (Hollenstein, 2002) to Japan (Yamawaki, 2002). In industries ranging from biotechnology (Cooke, 2002) to information technology (Globerman, Shapiro and Vining, 2005) to the ceramic tile industry in Italy (McDonald and Vertova, 2001) and broadcasting and financial services (Pandit, Cook and Swan, 2000).'*[vi]

Many authors have contributed to the large amount of cluster literature that nowadays exists. In this regard, Mone, Menzel and Fornahl, Clar, Delgado and Morosini are important authors. Parts of their thoughts on business clusters will be included in this framework. For the purpose of this research, however, the works of three further authors, Enright, Ketels and Porter, are of even greater importance. The DTI report, containing the success factors that will be used in chapter 4 to examine the Massachusetts' cluster, refers to both Enright and Porter, underlining the importance of the contribution of these authors for this research.

2.1 Cluster dimensions

Defining the cluster term

Both entrepreneurs and policy makers have been eager to learn about cluster theory since the advantages seemed to be straight forward. As a starting point in this framework it is useful to define the term 'cluster'. Within literature and policymaking, the term is used to describe a variety of phenomena.vii The term 'regional clustering', for example, has been used to 'describe industrial districts of small crafts firms, high technology centres, agglomeration of financial and business service firms in cities, company towns, and large branch plants and their supply chains'.[viii] Within the many cluster-definitions available, Press (2006) states that they all share a common denominator by referring to clusters as 'non-random spatial concentrations of economic activity that exist due to the effects of agglomeration externalities'.[ix] Agglomeration externalities are hereby defined as 'the specialization and concentration externalities and economic and social diversity externalities that arise from the spatial concentration of economic agents'.[x] The emergence of clusters is hereby usually a result of a combination of 'historic accident' and 'industry-specific factors', both facilitating the likelihood of obtaining 'first-order proximity benefits'.[xi]

Enright (1998) mentions that, due to the high amount of cluster-literature available, cluster terminology seems highly embedded, wherefore it is difficult to sharply define or even redefine the term.[xii] Nonetheless, Perry (2005) defines clusters in a neutral way by referring to them as 'spatial concentrations in which firms have potential to gain from their mutual presence but which does not automatically denote advantage actually arises'.[xiii] The point made by Perry is that the mere existence of a cluster does not necessarily means that advantages will be gained by its participants.[xiv] As one of the most recent definitions available, Porter (2008) defines a cluster as 'a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities (external economies)'.[xv] This definition incorporates four key elements of the cluster concept which are listed in table 1.[xvi]

Table 1. *The cluster definition examined* (based on Porter and Clar et al. (2008)).

Cluster element	Meaning
Geographical concentration	*Physical proximity as an important characteristic for effective cooperation, thereby also enhancing learning and the level of innovation.*
Specialization	*Specialization of the firms in a particular field as a precondition for realizing cluster benefits. Focusing on related technologies, markets and processes bring about cluster advantages.*
The presence of companies together with other institutions	*The business environment of a cluster encompasses a broad range of actors besides firms, which are important to the overall cluster performance.*
The connectivity in line with the cooperative competition	*Within clusters, firms are able to compete and cooperate at the same time. While competing for market share, firms can benefit from joint action in a particular field to increase overall performance.*

Cluster dimensions

In order to develop cluster policies, Enright (1998) characterizes clusters along different dimensions. To start with, a cluster's geographic scope refers to 'the territorial extent of the firms, customers, suppliers, support services, and institutions' which are part of the relationships within the cluster.xvii Clusters can either be localized – 'tight groupings in small geographic area' – or dispersed; 'spread across wider geographies'.[xviii] A cluster's density refers to the number and economic weight of the firms in the cluster. A cluster can be dense – consisting of hundreds or thousands of firms, or sparse – where the economic weight of the cluster is not as high, either caused by consisting of fewer firms or fewer powerful firms.[xix] In terms of breadth of clusters, a cluster can be narrow or broad. In a narrow cluster, the range of horizontally related industries within the cluster is low, containing a few industries and their supply chain.[xx] Broad clusters consist of more interconnected industries. The depth of a cluster refers to the amount of vertically related industries within the cluster. A deep cluster is a cluster that contains of a nearly complete supply chain, from raw material to end product, whereas a shallow cluster consists of one or a few related industries which are input-dependent on firms outside the cluster. A cluster's activity base can either be rich or poor. In activity-rich clusters, most of the value adding activities are carried out within the cluster. The setting of the firm's main strategy, marketing plans and R&D are examples of such value adding activities. A cluster contains a poor activity base where it contains only one or a few activities within an industry. The demand for products and services supplied by the cluster, combined with the cluster's competitive position delineates the cluster's growth potential. A cluster's competitive position should be classified relative to that of outside competitors and includes the ability of the cluster to obtain the resources necessary for growth. Enright classifies clusters into sunrise, noonday and sunset clusters combined with the firm's relative competitiveness, resulting for example in sunrise/competitive or sunrise/non-competitive clusters. A cluster's innovative capacity refers to the cluster's ability to innovate in terms of products, processes, designs, marketing, logistics and management needed for competitive advantage in the particular industries. Knowledge of these factors, including knowledge of governance structures, can be useful in determining cluster policy in order to bring about the most efficient use of scarce resources.[xxi]

Table 2. *Cluster dimensions (Based on Enright 1998).*

Dimension	***Types***	***Measurement***
Geographic scope	Localized Dispersed	*Number of cluster actors within a concise area*
Density	Dense Sparse	*Number of cluster actors*
Breadth	Broad Narrow	*Range of horizontally related industries; number of different business sectors present in the cluster*
Depth	Deep Shallow	*Amount of vertically related industries; number of supply chain actors present in the cluster*
Activity base	Activity-rich Activity-poor	*Level of value-adding activities within the cluster; number of major activities carried through by cluster participants (e.g. strategy setting versus mere administrative tasks).*
Growth potential	Sunrise/(un)competitive Noonday/(un) competitive Sunset/ (un)competitive	*Ability to attract the resources necessary for growth*
Innovative capacity	High innovation Low innovation	*R&D-rates, number of start-ups.*

In bringing the abovementioned cluster dimensions together, Enright concludes that localized, dense, deep and activity-rich clusters have ‘a greater chance of fostering close inter-firm communication and interaction that can be a source of competitive advantage’. In addition, these clusters are also more likely to rank high in terms of innovation, benefiting from globalized economic activity.[xxii] On the other hand, clusters identified as being dispersed, sparse, shallow and activity-poor are ‘less embedded into the local economic and social systems and are less likely to be sources of self-sustaining growth’, wherefore the cluster’s level of innovation is more likely to be low.

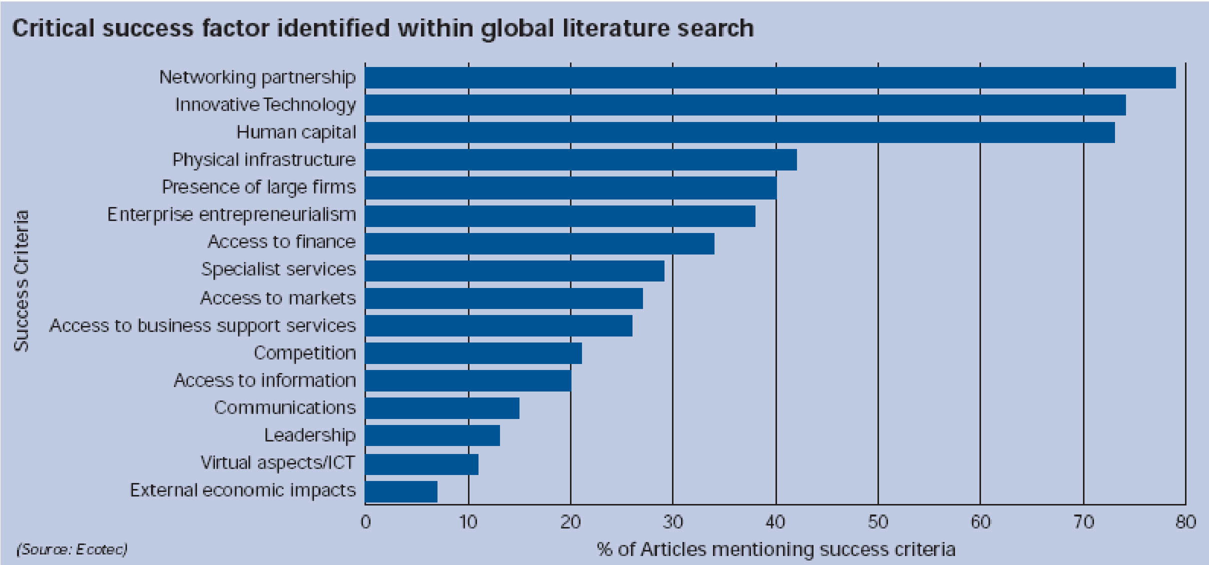
2.2 Cluster success factors

Porter identified several factors that influence competition, providing benefits for cluster firms and, in that way, influence the general cluster development. It goes without saying that there exists no general formula of factors applicable to every cluster. The factors determining a cluster’s development will always vary according to the specific circumstances. It is, however, possible to identify some general, underlying factors that lie at the heart of most successful clusters. These factors, called success factors, have been subject to extensive literature research in the past. Mone (2000) for example, distinguishes 8 factors that are more critical to a cluster’s success than others, see Table 3 (Appendix 1).[xxiii] Clar (2008) also elaborates on success factors of cluster development. Seven points are mentioned, determining specific aspects of development. A fairly complete overview of cluster success factors is presented in the report to the UK Department of Trade and Investment (DTI report).[xxiv] This report includes the factors mentioned by Mone (2000) and Clar (2008) but classifies them into more general factors containing specific elements.[xxv] This facilitates not only the measurement of the factors; it also contributes to an increased understanding of the findings.

DTI Report

The report is based on extensive literature search, aiming at bringing together the material published on cluster development. The report identifies three decisive factors for successful cluster development: critical success factors, contributing success factors and complementary success factors.[xxvi] Figure 1 shows a graphic overview of these decisive factors, listed on number of appearance in global literature.

Figure 1. *Critical success factors according to DTI 2004 (DTI, 2004).*



The first three criteria stand out from the rest, and are therefore labeled as 'critical success' factors.[xxvii] The next group of factors is called 'contributing success factors'.[xxviii] The report mentions that the findings did not present a causal relationship between these factors and the development of successful clusters. What was found was the presence of these factors, each to a certain degree, in successful clusters. Table 4 presents an overview of the success factors identified, each with a short explanation.

Table 4. *Critical and Contributing success factors by DTI (DTI 2004).*

Critical success factors	
1. The presence of functioning networks and partnerships and the knowledge flow between actors	*Strong professional, social and informal networks are fundamental to the effectiveness of a cluster. Such networks may naturally develop within a cluster or be facilitated and promoted by intermediaries such as local associations, technology clubs or governmental agencies.*
2. A strong innovation base with supporting R&D activities	*Universities and research institutions are often the hubs for new ideas and basic research in the growing clusters.*
3. The existence of a strong skills base	*A highly skilled and mobile workforce ensures flow of information and development of new ideas.*
Contributing success factors	
4. A sufficient physical infrastructure	*Important for attracting companies to a cluster as well as facilitating interactions among companies*
5. The presence of large firms	*Large firms act as anchors creating a viable economic base for the cluster to evolve.*
6. A strong entrepreneurial culture	*Clusters grow with the creation of new businesses. A culture of entrepreneurship and risk taking encourages start ups and investment in R&D.*
7. Access to sources of finance	*New technology start ups often can not survive without external sources of funding. Presence and willingness of VC's to invest in new start ups in a cluster is essential to the market success of new ideas and new entrepreneurs. Government policies often play a significant role in facilitating and providing financial support to new start ups in such clusters*

Next to identifying general success factors, it is also possible to identify general factors that negatively influence a cluster's development. These factors are called failure factors, or simply risks. Clar et al. distinguishes six risks to cluster development.[xxix] Table 5 presents an overview of these factors, see Appendix 2. As seen from the table most cluster risks are related to the assumption that clusters are less able to adjust to changing circumstances.[xxx] Specialization, established practices, cluster size, cooperation and satisfaction are hereby mentioned as underlying reasons. In order to reduce these risks it is essential that a cluster remains having an open attitude towards outside influences on the cluster.[xxxi] This research focuses on success factors rather than on failure factors. Therefore, a more detailed examination of the latter is left aside.

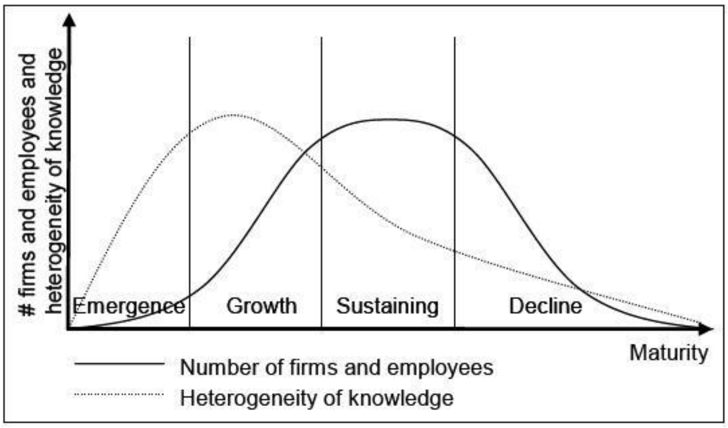
2.3 Cluster life cycle

Portraying a cluster as a phenomenon that once emerged, started to grow and eventually started to decline, it makes sense to think of a cluster as having its own life cycle. For analyzing clusters and their life cycles, the works of Aziz and Norhashim (2008)[xxxii], Menzel and Fornahl (2009)[xxxiii] and Sonderegger and Täube (2010)[xxxiv] form valuable resources. For the purpose of this research, however, the analysis on a cluster's life cycle is confined to the works of Enright, Ketels, and Menzel and Fornahl (2007). These works display the essential elements of the theory, complemented by one distinguishing factor (the non-fixed trajectory, see below).

With regard to cluster development, Enright made a distinction between four types of clusters; working clusters, latent clusters, potential clusters and so-called wishful thinking clusters. The degree of development of a cluster hereby refers not to the age of a cluster but to 'whether the cluster is benefiting from the co-location of firms, is self-aware, and is self-reinforcing.[xxxv] An overview of these clusters, categorized in terms of state of development is shown in table 6 (Appendix 3). In this regard, the cluster dimensions distinguished above can be used to further elaborate on the stage of development of a cluster. In addition to Enright, Ketels (2003) also distinguishes different types of clusters. According to Ketels, clusters can be classified along three dimensions. One of these dimensions entails that a cluster can be characterized by the stage of development it has reached. Whereas Enright measures cluster development in terms of degree of benefiting from co-location, being self-aware and self-reinforcing, Ketels classifies development relying on two more general dimensions: externally on the quality of the environment in which the cluster operates, and internally on the degree of organization among the cluster companies.[xxxvi] According to Ketels, most literature points towards the notion that clusters are 'a factor at every stage of economic development but that in weaker environments clusters will tend to be weaker and more narrow as well'. Seen from an internal perspective, development depends on 'the progress the cluster has made in mobilizing the potential of its business environment through active cooperation and other internal activities'. In this regard, most literature points out towards the notion that cluster dynamics can be strengthen, and in general, depend on deliberate and focused action.[xxxvii]

Menzel and Fornahl (2007) distinguish between a quantitative and a qualitative dimension of clusters.[xxxviii] The quantitative dimension describes the development of clusters by the number of firms, employees or turnover. The qualitative dimension describes cluster development in terms of diversity of knowledge and competencies.[xxxix] It describes the, 'heterogeneity of the firm's competencies available in the different stages'.[xl] One of the reasons for describing a cluster in terms of development rather than age is the possibility of the cluster to 'shift into new industries'.[xli] Menzel and Fornahl divide the development of a cluster into four stages: the emergence stage where only a few firms exist, the growth stage in which the number of firms and employees are growing, the sustaining stage where the cluster remains at a high level of economic performance, and a declining stage in which the number of firms and employees are decreasing.[xlii] The figure below presents these stages.

Figure 2. *Quantitative and qualitative elements of the cluster life cycle (Menzel and Fornahl, 2007).*



From the figure it can be seen that the qualitative aspect, the heterogeneity of the competencies within the cluster, is essential to the cluster's development. The cluster enters the declining stage when its heterogeneity cannot be kept at a stable level. Menzel and Fornahl argue that the development of a cluster is not a fixed trajectory from the left to the right, but rather a movement between these two in which the cluster can, in case of a renewed increase in heterogeneity, move back in the cycle to enter a new growth stage.[xliii] In this regard, Menzel and Fornahl assume that 'the movement of the most successful and established clusters takes place within the sustaining stage, in which they incrementally but steadily achieve to sustain their heterogeneity again and again'.[xliv] The identification of a cluster's life cycle as a non-fixed trajectory is a feature distinguishing the work of Menzel and Fornahl from the ones mentioned above. Its clear definition of the stages and indicators form a second argument in favour of applying this concept to the Massachusetts' cluster. For the purpose of this report the growing and sustaining stages of cluster development deserve a closer look. Indicators of both stages are listed in the table below.

Table 7. *Indicators of the growth and sustaining stage of cluster development* (based on: Menzel and Fornahl 2007).[xlv]

Stage	Indicators
Growth	- Increasing employment due to growth of incumbent firms - High number of new business formations - New firms concentrate on growth centres of the cluster which narrows the cluster's boundaries and makes the cluster more focused - Innovation networks and customer-supplier relations possibilities due to growing density of firms and institutions - Avoidance of isolation of single networks due to arising of new potential network partners
Sustaining	- Steady number of firms and employees (no large growth or decrease) - Cyclical fluctuations instead of structural - Exploitation of the various firm competences by dense and established networks - Inflow of new knowledge and networks that remain open due to connections of cluster firms to outside firms and institutions - Incremental move of thematic cluster boundaries due to integration of new technologies - Shaping the regional environment

The non-fixed trajectory aspect is evidenced by the method in which the sustaining stage ends. Two possibilities exist. The cluster's development can move into the declining stage, following the cluster's life cycle.[xlvi] Triggers are decreased diversity and a too narrowly focussed cluster in combination with an exhausted cluster path.[xlvii] The development can also go against the life cycle by going one step back and entering a new growth phase. Entering new markets and the accompanied generation of new diversity can hereby act as a trigger.[xlviii]

The cluster characteristics of the different development stages can be further classified according to the quantitative or qualitative nature, and according to the nature of impact. Each development stage brings about direct features. The 'interplay' between cluster firms and other institutions, however, affects the entire cluster, leading to so-called 'systemic' effects.[xlix]

Table 8. *Cluster characteristics at the growing and sustaining stage (based on Menzel and Fornahl 2006 and Menzel and Fornahl 2007).*

Growing cluster	Quantitative	Qualitative
Direct	Growing number of firms and employment	Growth of absolute diversity, decrease of heterogeneity (Focussing)

Systemic	Growing perception, possibilities for collective action, institution building	Open and flexible networks contribute to exploit diversity of competencies
Sustaining cluster		
Direct	Stagnating number of firms and employment on a high level	Homogeneous or focussed competencies, strong regional bias of the regional economy towards the cluster
Systemic	Cluster shapes the region	Open networks contribute to utilise existing synergies and external knowledge

2.4 Clusters and economic performance

Clusters are said to provide certain advantages which are not available to firms located outside a cluster. Various authors have examined these assumed benefits. Recently, Delgado (2010) investigated the role of regional clusters in regional economic performance. One of the conclusions drawn from the extensive dataset was that clusters have a positive impact on several dimensions of economic performance. [l] In this research, which was primarily focused on employment, a positive impact of clustering was found on employment growth, the growth rate of average wages, and the growth rate of patenting, which is a measure of innovation. A positive impact of clustering was furthermore found on 'entrepreneurship' (described below by Porter as: new business formation)[li]. Morosini (2004) divides the factors that determine the scope of competition of industrial clusters into three categories.[lii] A distinction is made between: External factors, which shape the outside characteristics of firms, internal factors, shaping the inner characteristics of firms, and social factors, which influence the human interaction and relations among firms, see Table 9 for an overview (Appendix 4). [liii]

Ketels also elaborated on the relation between cluster presence and company performance. In absence of any cluster effects, theory would suggest that 'different activities within a cluster or industry would be located at different locations to take advantage of factor price differences'. On the other hand, Ketels argues that if there is co-location to capture cluster effects, it should somehow be measurable in terms of company performances within clusters. Ketels mentions that a relationship exists between 'location-specific' factors connected to clusters (see Porter below) and financial and innovation company performance. Lastly, according to Ketels some researchers defend the notion that 'a high concentration of companies from a specific field in one location is not enough to generate full cluster effects'.[liv] These researchers claim that cluster benefits arise from the behaviour of cluster participants. Innovative performance can, for example, depend on the level of innovation of co-located firms.[lv] Accordingly, cluster externalities seem to be present but they are not guaranteed; 'if other companies in your regional cluster do not compete on innovation, your company is less likely to do so, too'.[lvi] In this way, Ketels argues that there are mutually reinforcing factors influencing economic performance.

The works of Ketels, Morosini and Delgado form valuable sources which are partially based on, or at least influenced by the works of Porter. In order to determine whether a cluster fulfils certain economic advantages subscribed to the workings of clusters, the theory of Porter can be seen as most comprehensive. Therefore, Porter's theory on clusters and economic advantages will be followed in the remainder.

Porter

Porter's theory is said to describe the main goal of implementing cluster theory in practice; to achieve synergy and economic advantage from shared access to information and knowledge networks, resources and other support services.[lvii] The performance of a cluster in total, or the companies of which it is composed, is dependent on the business environment in which it operates.[lviii] In his 1990 publication, Porter analyzed national competitive advantage by looking at the national environment.[lix] Within the environment Porter identified four elements that influenced firms in their ability to establish and sustain a competitive advantage (see figure 3 in Appendix 5). The four variables distinguished in Porter's 'diamond model' are factor conditions (the cost and quality of inputs), demand conditions (the sophistication of local customers), the context for firm strategy, structure and rivalry (the nature and intensity of local competition), and the presence of related and supportive industries (the local extent and sophistication of suppliers and related industries).[lx] Porter argues that a cluster is 'the manifestation of the diamond at work' in which 'proximity – the co-location of companies, customers and suppliers – amplifies all of the pressures to innovate and upgrade'.[lxi] This research will not analyze the Massachusetts cluster according to Porter's diamond model. In 2003, Porter did so himself, resulting in a valuable data set on the Massachusetts cluster. Chapter 4.4.1. presents a short overview of these findings. For now, it is focused on Porter's findings with regard to clusters and the competitive advantages they bring about.

Based on earlier research, Porter (1998) elaborates on the role clusters play in a competitive environment.[lxii] According to Porter, clusters affect competition – and thereby provide benefits – in three broad ways: firstly, by increasing the productivity of companies based in the area. Secondly, by driving the direction and pace of innovation, which underpins future productivity growth, and thirdly, by stimulating the formation of new businesses, which expands and strengthens the cluster itself. The advantages are summarized in table 10, which is followed by a more detailed description of the advantages.

Table 10. *Competitive advantages derived from clustering (Based on: Porter, M. (1998). Clusters and the new economics of competition).*

Competitive advantages
Increased company productivity
1. Better access to employees and suppliers
2. Local outsourcing instead of distant outsourcing
3. Access to specialized information
4. The benefit of complementarities
5. Access to institutions and public goods
6. Better motivation and measurement
7. Easier measurable and comparable performances
Driving the direction and pace of innovation
8. Clusters provide the capacity and the flexibility to act rapidly
9. Cluster companies can experiment at lower cost and can delay large commitments until they are more assured that a given innovation will work for them
10. Cluster companies have a better window on the market than isolated competitors
11. Forms of pressure contribute to innovation
Stimulation of new business formation
12. Individuals working within a cluster can more easily perceive gaps in products or services around which they can build businesses.
13. Barriers to entry are lower than elsewhere. Needed assets, skills, inputs, and staff are often available at the cluster location.
14. Local financial institutions and investors, already familiar with the cluster, may require a lower risk premium on capital.
15. The cluster often presents a significant local market, and an entrepreneur may benefit from established relationships.

i) Increasing company productivity

The first productivity-related advantage of being located in a cluster refers to employment. It is mentioned that a firm within a cluster has the possibility to search for employees within an existing group of specialized and qualified employees, which is said to lower recruiting costs. As another important advantage, it is mentioned that because of a cluster's reputation of offering 'opportunities' and because of the reduced risk for employees to relocate, it can easier attract people from other, more distant locations. A second advantage is said to be achieved by outsourcing locally instead of distantly. It is said to minimize the need for inventory and to remove importing costs and delays. In addition, it lowers the risk that a supplier will overprice or break his word on commitments since the supplier needs a good reputation in order to stay in business. A third advantage derives from the conditions that make information more transferable. The accumulation of market, technical, and competitive information within a cluster facilitates access to specialized information, whereas personal relationships and network ties are said to foster trust and facilitate the flow of information. As a fourth advantage, being located in a cluster offers a firm so-called complementarities. This can occur, in the simplest form, when products complement one another, but also when companies coordinate activities to optimize their joint productivity. In terms of marketing, a cluster enhances the reputation of a location in a specific field, wherefore buyers are said to more likely purchase from there. In addition, firms within a cluster can often benefit from the overall marketing efforts of the cluster, for example being represented at trade fairs, advertised in magazines, and so on. As a fifth advantage, access to institutions and public goods are mentioned. A firm's productivity is said to possibly be enhanced by investments made by government or other public institutions, like public spending for specialized infrastructure or educational programs. In this regard, Morosini (2004) distinguishes four roles (initiator, promoter, coordinator and manager role) that local, national and regional governments can fulfil.[lxiii] The cluster's information and technology pools and its reputation can also contribute to a firm's productivity in providing easy access to important information. In addition, since the potential for collective benefit is often recognized by cluster participants, collective investments made by companies in, for example, training programs, infrastructure and testing centers contribute to increase productivity. Local rivalry as a source of motivation is mentioned as a sixth advantage. It is argued that being located among competing-, indirectly competing- or even noncompeting companies increases peer pressure and therefore competitive pressure. Porter mentions that ‘pride and the desire to look good in the local community spur executives to attempt to outdo one another’.[lxiv] As a seventh productivity-related advantage, Porter mentions that within a cluster, performances are easier measurable and comparable. All companies operate under similar circumstances, like labor costs and local market access. Firms within a cluster are likely to have better knowledge of each others costs. This is facilitated by the possibility for financial institutions to monitor the cluster’s performance and publish reports on it.

ii) Driving the direction and pace of innovation

According to Porter, some of the factors that enhance current productivity have an even greater effect on innovation and productivity growth. Porter subsequently identified four main innovation-related advantages. As a first advantage, clusters are said to provide the capacity and the flexibility to act rapidly. Cooperation with local suppliers and partners can facilitate the innovation process, wherefore customers’ requirements can be better matched. Porter also mentions that a firm within a cluster ‘often can source what it needs to implement innovations more quickly’. The second advantage mentioned is that firms ‘within a cluster can experiment at lower cost’. Innovation related commitments can be delayed until more information about the likelihood of success is available. Relying thereby on local suppliers delivers the advantage of being better able to coordinate activities with other organizations. This advantage clearly relates to the local outsourcing advantage mentioned above. As a third advantage, Porter mentions that firms within clusters ‘usually have a better window on the market than isolated competitors do (…)’. The presence of sophisticated buyers in a cluster is mentioned to explain this advantage. In addition, the relationships with other firms and organizations within the cluster helps firms to stay informed on upcoming technology, ‘component and machinery availability’, and ‘service and marketing concepts’. Site visits and face-to-face contact are said to facilitate the process. An increasing level of cooperation between members of a cluster hereby positively impacts company performance.[lxv] The fourth advantage mentioned relates to the productivity related advantage of local rivalry. Local rivalry – competitive pressure, peer pressure and the constant comparison of performances among cluster entities – is said to ‘reinforce other advantages for innovation’. Therefore, clusters are said to ‘remain centers of innovation for decades’.

iii) Stimulation of new business formation

Porter starts by mentioning two reasons for the claim that it is no coincidence that many new companies grow up within a cluster instead of at isolated locations. The existing and concentrated customer base lowers risks for new supplying firms. Within a cluster, market opportunities are also easier recognized by starters. Suppliers are also said to enjoy ‘expanded opportunities’ since developed clusters are composed of related industries, relying on common or similar inputs. Porter then continues by mentioning that clusters are conducive to new business formation for several reasons, of which four are then mentioned. All four factors are said to ‘reduce the perceived risk of entry- and of exit (…)’. Firstly, it is mentioned that individuals already working within a cluster can build new businesses around perceived shortcomings in products or services. Secondly, entry barriers are lower than elsewhere. Porter states: ‘Needed assets, skills, inputs, and staff are often readily available at the cluster location, waiting to be assembled into a new enterprise.’ Thirdly, since local financial institutions and investors are already familiar with the cluster, they may require a lower risk premium on capital. Finally, the cluster itself often forms a considerable local market, and an entrepreneur may benefit from existing relationships. Porter concludes by mentioning that ‘the formation of new businesses within a cluster is part of a positive feedback loop’. When the cluster itself grows, the overall competitive resources within the cluster do so as well. The net result, according to Porter, is that firms in the cluster gain a competitive advantage over rivals at other locations. Table 10 above summarizes the factors that influence company productivity, innovation and new business formation within a cluster.

The identified risks of clustering seem real and to a certain extend places Porter's findings in perspective. Yet, Porter's theory, as described above, remains attributing many advantages to businesses located within a cluster. The cluster concept hereby seems uncomplicated and straightforward of character. Some authors have criticized this concept. Their main arguments revolve around the accurateness and the scientific meaning of Porter's concept. For a discussion, see chapter 6.

Chapter III Methodology

3.1 Type of research

The report is descriptive of nature. The qualitative research was conducted by means of a literature study. The unit of analysis is the Massachusetts life sciences cluster. Cluster firms, cluster organizations, educational and research institutions and cluster experts function as the unit of observation.

3.2 Method of measuring cluster development

For the purpose of this report, several success factors are used to measure the development of the cluster. The success factors identified by Mone (2000) and Clar (2008) are very similar to the factors as outlined by the DTI report. The latter report seems, however, to present a more complete and detailed overview. For this reason, the success factors as outlined by the DTI report are used in the remainder of this research. In order to be able to use these factors they need to be put in measurable terms. This can be done by searching for indicators that determine the factors. Table 11 presents an overview of these indicators.

Table 11. *Cluster development indicators (based on: DTI 2004).*[lxvi]

Driver	Indicators
Network and partnerships	*Number of partnering arrangements*
	Number of co-operation agreements
	Number of networking events
	Number of joint research activities
	Extent of social capital
Innovation and R&D	*R&D employment*
	R&D expenditure
	Number of business spin-outs
	Number of patents applied for
	Number of innovation awards
	Number of new products/processes adopted
Human resources	*Number of vacancies*
	Educational attainment rates
	Number of defined qualifications
	Extend of measured skills gaps

In order to add significance to the numbers presented, the Massachusetts data is, where possible, compared to data of other life sciences focused states, predominantly California (including the San Francisco and San Diego areas) and to a lesser extend New Jersey. Both states have leading US life sciences sectors which make a comparison useful. Data on California and New Jersey was obtained from the online 2008 Biotechnology Industry Organization report (see bibliography).

3.3 Sources of information

Desktop research

Research on the Massachusetts life sciences cluster was conducted primarily by the use of secondary data. This reanalyzing of data that have already been collected for different purposes[lxvii], covers most inquiries made in this research. Examples of types of documents used are industry reports, originating from firms specialized in consultancy and from supportive institutions, and academic articles. The information collected on the success factors are derived from 7 sources, see table 13. The largest part of the documents used, originates from 2007 or later, making a comparison with the earlier (2003 and 2006) identified success factors possible.

Table 12. *Sources for success factors analysis.*

Source s
Massachusetts Biotechnology Council (2010)
Biotechnology Industry Organization (2008)
University of Massachusetts Donahue Institute (2007 & 2008)
PricewaterhouseCoopers Industry reports (2007 & 2008)
Massachusetts Infrastructure Investment Coalition (2005 & 2006)
Owen-Smith & Powell (2004)
Lazonick (2007)

Interviews

Next to this type of information a series of conversations with experts from within the field were used as a source of information. Table 13 presents an overview of the conversations that were held. In order to collect meaningful data, the unstructured conversations were systematically prepared. As a first step, the represented organization was scanned. It varied from businesses (Octoplus and Wyeth) to local and state governmental organizations and a foreign government agency (the NFIA). Different organizations are likely to attribute dissimilar levels of importance to the various aspects of the Massachusetts' cluster (the two businesses for example stressed the importance of having a strong business climate, whereas the government stressed the need to invest in early education). As a second step, the function of the expert was examined. The knowledge so obtained enabled a smooth conversation of which the findings could be placed into perspective.

Table 13. *Conversations with life sciences cluster experts.*

June 24, 2008	**Company / Organization**	**City**
Marco Smit	*The Netherlands Foreign Investment Agency*	Boston
Michiel Lodder	*Octoplus*	Cambridge
Mary Beth Totten	*Massachusetts Office of International Trade and Investment*	Boston
Melissa Walsh	*Massachusetts Life Science Center*	Boston
Jon Mahoney	*Massachusetts State Life Science Director*	Boston
Daniel O'Connell	*State Secretary for Economic Development and Housing*	Boston
June 25, 2008		
Wim Scheele	*Wyeth*	Cambridge

Michael Graney	*Western Massachusetts Economic Development Council*	Springfield
David W. Miller	*Business Development, Pioneer Valley Life Sciences Institute*	Springfield
Paul Friedman	*Pioneer Valley Life Sciences Institute, Dean's Professor in Biomedical Innovation, Isenberg School of Management, UMass Amherst*	Springfield

3.4 Data-analysis

The research findings on the cluster's Critical Success Factors (CSF's) will be combined with the findings by Porter (2003) and MTC (2006) in order to determine the cluster's life cycle stage and in determining the level of fulfillment of cluster advantages. In the conclusion, the various strengths and weaknesses will be compared and confronted. From there on the importance of the findings will be discussed.

3.5 Feasibility

The research did not intend to describe the cluster extensively. Most recent data was used where possible. It was not the main goal of the research to describe the cluster on its most up-to-date data. Furthermore, the theory presented in chapter 2 mostly reflects the main points of the topic under discussion. In order to keep the research within boundaries, articles were used that bring together views of different authors, wherefore an extensive overview on the contributions of different authors was left aside.

3.6 Research outline

Firstly, by using the DTI report, it is tried to identify the strength of the cluster on certain factors contributing to the cluster's development. Literature suggests that the factors used by the DTI report are crucial to the development of a cluster. Secondly, information obtained from the conversations is used to further elaborate on these success factors. Having reached this stage, a conclusion can be drawn on sub-questions 1 and 2. Based on the findings on CSF's 1-7 and the research by Porter and MTC, it is then tried to classify the cluster's present state into a specific cluster life cycle stage as identified in literature. Subsequently, it is tried to formulate an answer to sub-question 3. In the following chapter it is tried to assess whether, based on the information collected for this research, the cluster advantages advocated by Porter are realized in the Massachusetts cluster. Chapter 5 presents the conclusion in which the findings will be assessed and compared. The research is finalized by a discussion chapter in which the research restrictions are mentioned and the critique on cluster theory is addressed.

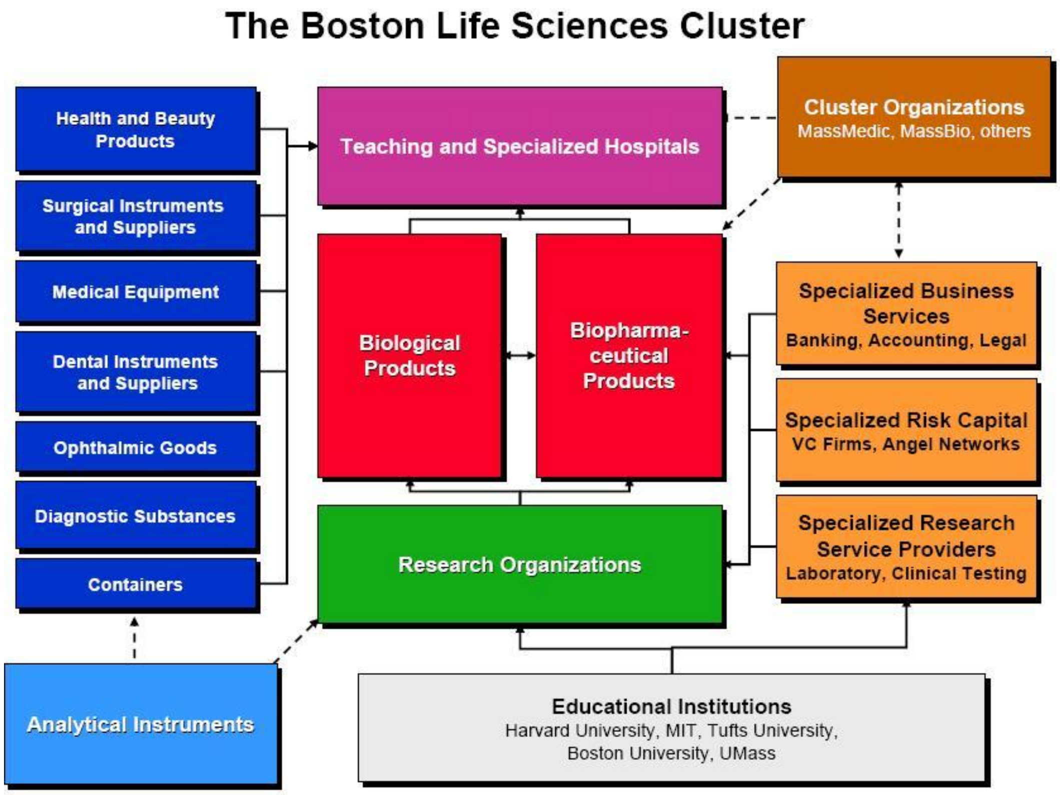
Chapter IV Findings

4.1 *The cluster's dimensions*

The Massachusetts cluster

The Massachusetts Life Sciences sector includes activities from many actors; from universities, hospitals, and research institutions to specialized companies, trade councils and venture capital firms.[lxviii] Porter presented these actors in a useful overview, shown below.

Figure 4. *The Boston Life sciences cluster (Porter 2008 report).*



This overview can be seen as the practical realization of two out of Porter's four cluster elements (the presence of companies together with other institutions, and the connectivity in line with the cooperative competition). Harvard University (1640) and the Massachusetts Institute for Technology (1865) in this regard provided an early research foundation. The remaining two cluster elements are 'geographical concentration' and 'specialization'. The physical closeness of the cluster actors follows from the concentration around the Boston-Cambridge area. The Boston area's network of organizations outperforms similar areas in terms of geographic density, scientific quality, and financial resources. Actors cooperate in generating new biotechnology knowledge. The Massachusetts cluster contains many biotechnology and venture capital firms (see success factors 3 and 7), and public research and educational institutions (Harvard, MIT, University of Massachusetts, Harvard Medical School, and the BU School of Medicine).[lxix] In addition, various hospitals and medical centres are part of the cluster (Massachusetts General Hospital, Beth Israel Deaconess Medical Center, Tufts-New England Medical Center, and the Dana-Farber Cancer Institute). The geographical concentration, as a necessary requirement to the cluster concept, follows from the cluster actors' physical closeness around the Boston-Cambridge area, which can be seen as the cluster's central point. Kendall Square in Cambridge and Longwood Medical Area in Boston are seen as the two key centres of the cluster. Kendall Square thereby focuses on research; laboratories and biotechnology and pharmaceutical research, whereas Longwood Medical Area represents 'the cutting edge of medicine'.[lxx] MIT, the Whitehead Institute for Biomedical Research as well as Genzyme and Biogen's global headquarters are located within one mile from the Massachusetts General Hospital.[lxxi] Over the years the cluster started to grow towards other areas in Massachusetts, expanding its geographical scope. The cluster nowadays spreads in three directions: Twenty miles to the south (Serono Laboratories), thirty-miles to the north (Wyeth's major biotech manufacturing plant), and thirty-five miles to the west along the Massachusetts Turnpike (University of Massachusetts Medical Center).[lxxii] The presence of these actors together makes Boston 'the most organizationally diverse regional cluster in the U.S. biotechnology industry', facilitating the establishment of a 'local organizational field or knowledge community' in which information 'could diffuse widely'.[lxxiii]

Activities of the abovementioned cluster actors ultimately determine the cluster's performance. They will therefore function as input for the following chapter, in which the cluster's performance is investigated by the use of several success factors. Where possible, a comparison is made to the performance of other states in order to place the findings in perspective.

4.2 *Success factors & the Massachusetts cluster*

Critical Success Factor 1
Network and partnerships

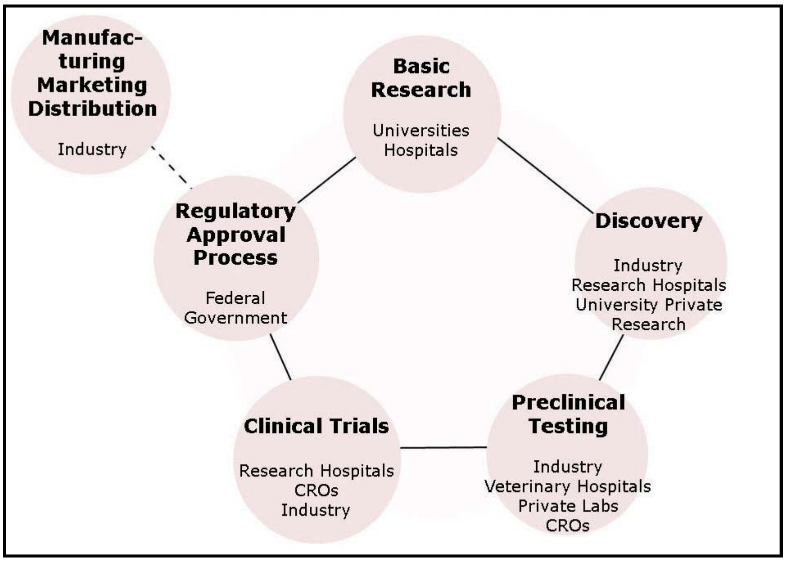
Forming alliances
The high cost and complexity of R&D and the general risk involved in the development of a bio-pharmaceutical product cause a funding gap. In order to overcome this gap, biotechnology and pharmaceutical firms have set up relationships.[lxxiv] The Umass Donahue Institute investigated investment records and announcements from 13 major pharmaceutical and biotechnology firms in Massachusetts in order to document the forming of alliances (ranging from licensing agreements, equity investments and full collaborations to co-develop drug discoveries and therapies) for the Massachusetts cluster. The report counted 357 alliances, worth a total of $13.4 billion, supporting 'drug discovery and product development at key stages of the product development life cycle'[lxxv]. For the year 2006, calculated from January – October, the 13 firms entered into fourteen alliances with a combined worth of $5.2 billion, see table 14.

Table 14. *'Thirteen Company Survey, Summary of Alliances and Values, 2000-2006' (Nakajima &Loveland (2007)).*

Year	Number of unknown value (N/A) alliances	Number of known-value alliances	Upfront dollar value of known-value alliances	Potential additional dollar value over life of alliance
2000	51	12	359,500,000	2,249,000,000
2001	57	8	783,750,000	529,000,000
2002	39	7	251,400,000	410,000,000
2003	38	18	4,685,900,000	956,000,000
2004	41	9	291,500,000	2,192,000,000
2005	21	16	1,824,083,000	1,367,500,000
2006	26	14	5,214,800,000	6,971,500,000
Total	**273**	**84**	**13,410,933,000**	**14,675,000,000**

In this regard, smaller firms and independent research groups provide resources and services to larger firms who tend to outsource early-stage R&D. University-based research institutes and forprofit clinical research organizations also become more important alliance partners[lxxvi]. Smaller firms and research hospitals benefited from alliances with large firms in providing resources to develop drugs and in providing specific business expertise like regulatory knowledge.[lxxvii] Figure 5 displays alliances during different stages of drug development.

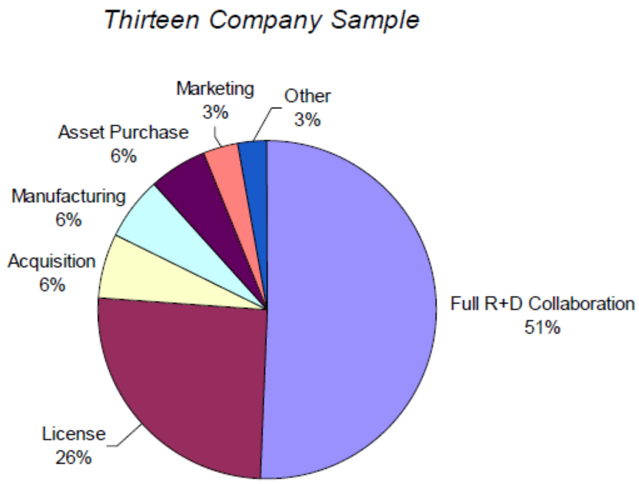
Figure 5. *'Bio-pharma Development Lifecycle: Phases and Institutional Players' (Nakajima & Loveland (2007)).*



Scope of alliance

Alliances can take many forms. In most collaboration, a license for a product or technology is combined with more far ranging activities. The report mentions that within the cluster, the greatest number of alliances could be categorized as 'full collaborations', meaning: 'Extensive partnerships between two firms involving research, development and commercialization phases.'[lxxviii] Figure 6 displays the Massachusetts alliances by type.

Figure 6. '*Massachusetts Bio-pharma Alliances by Type, 2000-2006' (Nakajima & Loveland (2007)).*



It can be seen that 51% of the alliances take on full R&D collaboration; representing 178 alliances with a value of over $1.2 billion. Table 15 mentions the number and value of the different types of alliances.

Table 15. *'Alliances by alliance category' (Nakajima & Loveland (2007)).*

Alliance Category	# of Alliances	Value	Potential Value
Full Collaboration	178	1,220,583,000	8,401,000,000
License	88	41,500,000	119,000,000
Acquisition	22	2,248,000,000	1,671,000,000
Manufacturing	21	608,000,000	50,000,000
Asset Purchase	20	5,366,600,000	4,426,000,000
Marketing	12	203,750,000	0
Other	10	3,552,000,000	8,000,000
Merger	1	3,500,000,000	0
Settlement	7	52,000,000	8,000,000
Equity	2	0	0
Total	**351**	**13,240,433,000**	**14,675,000,000**

Included in the sample of 13 firms were 5 Massachusetts-headquartered firms which engaged in alliances throughout the U.S. but also in 15 different countries. With regard to national alliance partners, California was the most likely location for establishing partnerships; 40% of U.S. alliances were made with a California based firm, representing a value of $1.6 billion over the six year period. Alliances within the cluster were less frequent but accounted for the highest value; $3.5 billion. The report further mentions that, apart from California and Massachusetts, no other state showed a significant amount of alliance activity, which emphasizes the leading roles of both states.[lxxix]

The importance of the Massachusetts cluster has been recognized by the state government. Different kinds of governmental supporting bodies have been set up (for example, the Massachusetts Life Sciences Center and the Massachusetts Office of International Trade and Investment). There also exist a separate life sciences department within the Massachusetts Department of Business Development, which can direct newcomers to the cluster. Next to these governmental institutions, there also exist a biotechnology trade organization; the Massachusetts Biotechnology Council (MBC). The MBC's membership consists of over 600 firms which can function as a platform for networking activities.

Critical Success Factor 2

Innovation and R&D

R&D expenditures

U.S. academic bioscience R&D expenditures continued to grow since the year 2004. Total U.S. expenditure amounted to almost $32 billion in the year 2008, representing more than 60% of all U.S. academic R&D. Figure 7 (2006) and figure 8 (2008) present bioscience R&D expenditures per state. For 2006, Massachusetts ranks 8th, with California as leading state. On a per capita basis, Massachusetts takes on 3rd place overall. For 2008, these rankings remained the same. Total Massachusetts R&D expenditure increased by $95,115,000 over the two year period 2006-2008.

Figure 7. *Leading States—Academic Bioscience R&D Expenditures 2006 (Battelle BIO 2008).*

Academic Bioscience R&D			
Leading States	Total in $ Thousands	Leading States	Per Capita
California	$4,008,809	District of Columbia	$306.82
New York	$2,528,232	Maryland	$234.50
Texas	$2,217,069	Massachusetts	$174.02
Pennsylvania	$1,478,008	Vermont	$172.59
Maryland	$1,313,685	Connecticut	$161.29
North Carolina	$1,310,490	North Carolina	$147.75
Illinois	$1,127,038	Nebraska	$141.46
Massachusetts	$1,119,740	New York	$131.12
Ohio	$1,048,200	Iowa	$130.43
Florida	$560,576	Missouri	$127.08

Source: Battelle calculations—based on NSF data and U.S. Census Bureau population estimate.

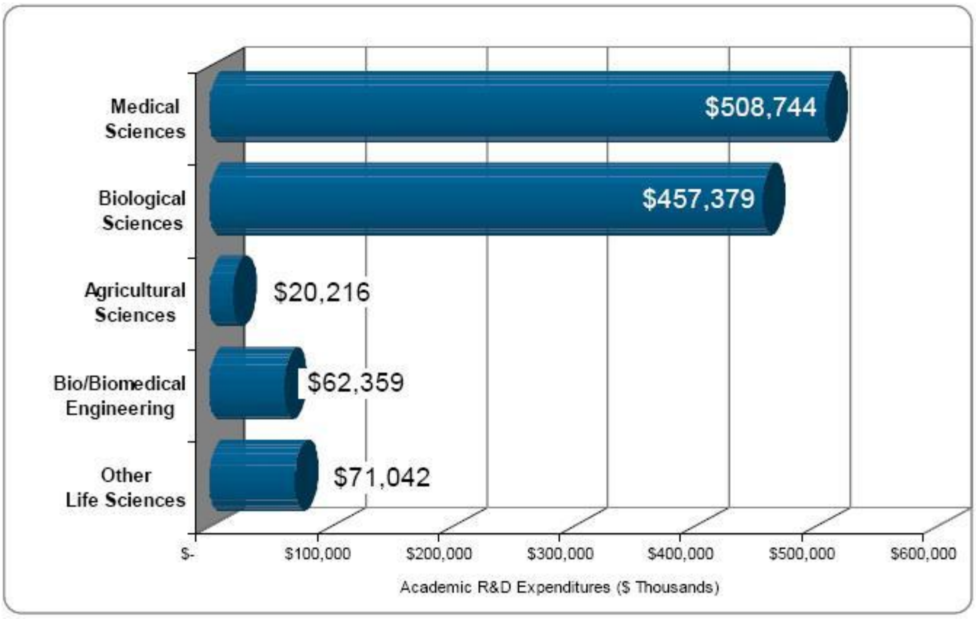
Figure 8. *Leading States—Academic Bioscience R&D Expenditures 2008 (Battelle BIO 2010).*

Academic Bioscience R&D Expenditures			
Leading States	Total in $ Thousands	Leading States	$ Per Capita
California	$4,395,602	District of Columbia	$354.73
New York	$2,677,763	Maryland	$240.23
Texas	$2,449,890	Massachusetts	$178.14
Pennsylvania	$1,614,981	Connecticut	$169.72
North Carolina	$1,517,418	North Carolina	$164.10
Maryland	$1,359,357	Vermont	$156.38
Illinois	$1,283,347	Nebraska	$141.09
Massachusetts	$1,165,655	New York	$137.55
Ohio	$1,162,471	Wisconsin	$135.02
Michigan	$950,939	Missouri	$132.99

Source: Battelle calculations based on National Science Foundation (NSF) data and U.S. Census Bureau population estimate.

As figure 9 shows, 2006 Massachusetts medical and biological sciences were on top of total R&D expenditures. Compared to New Jersey (176 and 206 million) and California (2,733 and 967 million) Massachusetts only fell behind to California in Medical R&D expenditures when measured in absolute terms. As for the rest, Massachusetts 2006 R&D expenditures were higher than that in the other states.[lxxx]

Figure 9. *'Bioscience Academic R&D Expenditures in Massachusetts, FY 2006'* (*Battelle BIO 2008*).



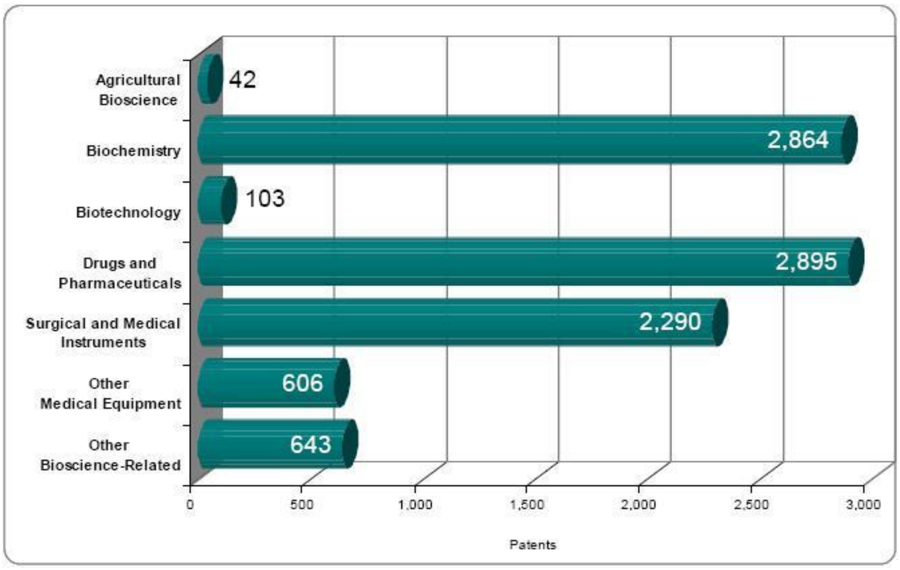
R&D Employment

Boston's 2001 leading role in R&D alliances is also reflected in R&D employment numbers. According to Cortright and Mayer (2002), the Boston area led the San Francisco area in 1997 in the number of people employed in life sciences R&D by 11,249 to 9,674. An 2002 update by Lazonick (Lazonick, 2007) shows that Boston led San Francisco by 15,863 to 14,756, while San Diego improved from 7,487 (1997) to 14,754 people employed in life sciences R&D in 2002.[lxxxi]

Number of patents

The number of patents issued is an indicator of the cluster's performance on innovation and R&D. The graphic below portrays the number of patents granted in Massachusetts for a six year period.

Figure 10. *Bioscience-related patents by classification group in Massachusetts, 2002-2007 (Battelle BIO 2008).*



For Massachusetts and California there are three groups that count for most of the patents; drugs and pharmaceuticals (hereafter: D&F), biochemistry and surgical and medical instruments. For New Jersey it is the D&F group that leads the number of patents. Other groups are falling behind compared to Massachusetts. When focussing on the D&F, Massachusetts (2,895 in total) had a yearly number of 483 patents, New Jersey (2,810) had 468 patents and California (5,206) counted for 868 patents a year. Taking the demographic factors into consideration, Massachusetts is outstanding in terms of patents when compared to the other states.[lxxxii] According to research by Lazonick (2007), the known value of R&D alliances in the nine leading biotechnology centres in the US amounted to $9.8 billion in the period 1996-2001. Over this period, the Boston area was the leading region. Ten years earlier, the Boston area was also leading. In the first half of the 1990s, the San Francisco area surpassed Boston and the San Diego area became important too, see table 16 in Appendix 6.[lxxxiii]

The number of clinical trials conducted can also function as a measure of innovation and R&D development. The BIO-report (2010) collected data on over 5000 clinical trials conducted in the U.S. in 2009.[lxxxiv] Figure 11 shows that Massachusetts ranks 10th, indicating the possibilities for improvement with regard to the clinical trial-activities in the state.

Figure 11. *2009 number of clinical trials for leading states (Battelle BIO 2010).*

Clinical Trials			
Leading States	Total Clinical Trials	Leading States	Clinical Trials Per 1 M Population
California	1,353	District of Columbia	307
Texas	1,213	Rhode Island	138
New York	1,008	Nebraska	136
Florida	895	Maryland	126
Pennsylvania	843	Vermont	122
Ohio	735	North Dakota	117
North Carolina	732	Montana	101
Maryland	717	Massachusetts	99
Illinois	661	Utah	97
Massachusetts	650	Kansas	96

Critical Success Factor 3

Human Resources

Biotechnology and pharmaceutical (Bio-pharma) employment facts

In the year 2009, 46,553 people were employed in the Massachusetts biotechnology sector. Between 2000 and 2009, industry employment grew by 60%, see figure 12.[lxxxv]

Figure 12. *Employment growth 2000-2009 (MBC 2010).*

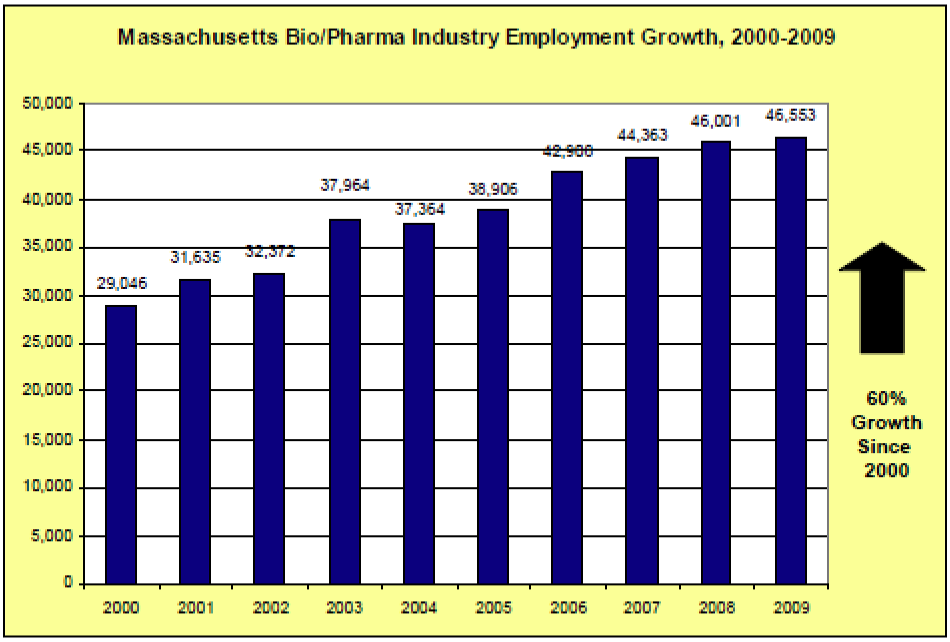
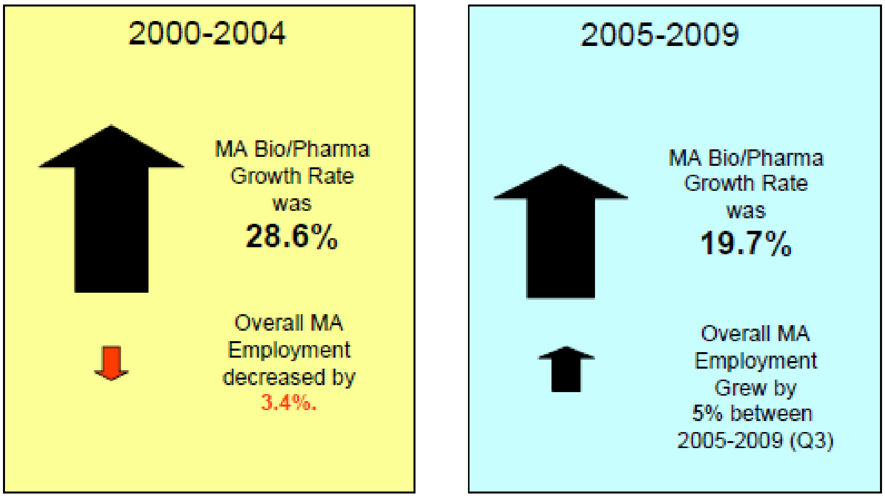


Figure 13 shows that total employment grew significantly over the last decade. Growth slowed down, however, for the second half of the decade.

Figure 13. *Ten years of industry employment growth (MBC 2010).*



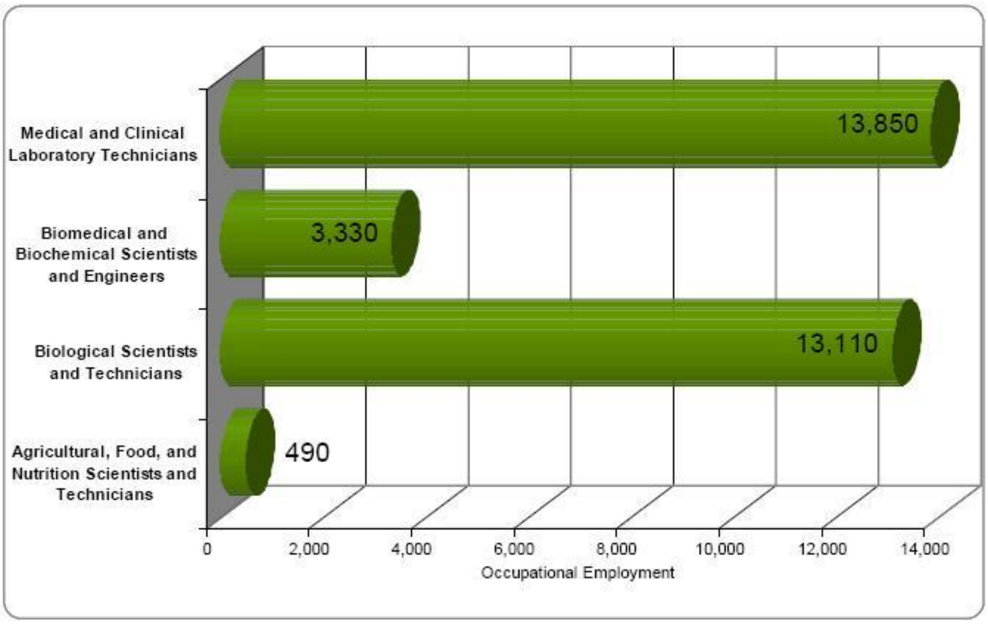
Bioscience degrees

The amount of bioscience related degrees granted can indicate the presence of a source of future bioscience workforce. Measured in absolute terms, Massachusetts ranks 9th in 2006 as well as in 2008. In total, 4,321 and 4,916 higher degrees related to bioscience were granted. Taking the demographic aspects into account, Massachusetts outperforms the rest of U.S. states (see figures 14 and 15. Appendix 7-8).

Comparative employment facts

In Massachusetts nearly 14,000 people are employed as medical and clinical laboratory technicians and well over 13,000 are employed as biological scientists and technicians. In New Jersey, these figures are respectively 7,900 and 8,200. California with 22,300 laboratory technicians and 34,500 biological scientists and technicians of course leads the comparison in absolute terms. Stated as a fraction of total state population, however, Massachusetts out counts California (California's population is 5.67 times as high as Massachusetts's population whereas the employment differences are not).[lxxxvi]

Figure 16. *Bioscience-related Occupational Employment in Massachusetts, 2006 (Battelle BIO 2008).*



A skilled and mobile work force is one of the most important factors to the Massachusetts Life Sciences sector. As indicated by Susan R. Windham-Bannister, President and CEO of the Massachusetts Life Sciences Center, the "*Massachusetts' world-class workforce is the number one reason that life sciences companies and research institutions grow or locate in the state.*"[lxxxvii] The 2006 MTC report concluded that the depth of the Commonwealth's educational resources from K-12 through higher education provides Life Sciences companies and institutions a stream of skilled workers. Furthermore, Massachusetts workers in Life Sciences have a significantly higher level of educational attainment than U.S. workers in the same industries. Specifically, 38.4% of Massachusetts medical equipment workers have a bachelor's degree or higher, versus 28.2% of U.S. medical equipment workers. In 1999 Boston had the second-largest number of PhDs granted and the second-largest number of life scientists in the workforce after the New York/New Jersey region. Also, average wages in the cluster are among the highest in the country and continue to grow. For example, the average wage for the Healthcare Technology cluster was $70,467 in 2004, up from $68,565 in 2001 (measured in 2004 dollars).[lxxxviii]

The 2007 Massachusetts Life Sciences report by PwC concluded that although Massachusetts has a leading position in Life Sciences, the investments in the sector are falling behind, which is likely to influence the possibility to attract qualified employees.[lxxxix] The cluster is doing well but is has to pay attention in order to remain attractive. The same PwC report concludes that the cluster has an 'innovative and entrepreneurial' workforce. This is confirmed by the fact that the entire Life Sciences workforce, representing 77,247 employees, grew 8 percent between 2001 and 2006, see table 17. In comparison, the entire Massachusetts workforce shrunk by 2.5 percent during the same period. On the other hand, as national and global competition increases, one of Massachusetts biggest challenges constitutes the creation of 'the next generation of scientists, researchers, entrepreneurs and leaders'. The report mentions that industry leaders say Massachusetts must create more workers by inspiring local children to pursue careers in life sciences. Business, education and government officials must expose students to the world of work in the life sciences by expanding internship and cooperative education programs.[xc]

Table 17. *2001-2006 Massachusetts life sciences industry employment by sector (BIO 2008).*

Sector	2001	2002	2003	2004	2005	2006	Change 2001 to 2006
Pharmaceuticals	7,169	7,673	8,149	6,208	6,922	6,976	– 3%
Biotechnology	16,346	17,288	17,070	18,794	19,708	20,909	28%
Medical Device and Equipment	25,455	25,353	23,409	22,532	22,159	23,467	– 8%
Wholesale Trade	10,059	10,274	11,506	11,364	11,010	11,257	12%
Medical and Testing Laboratories	4,264	4,539	4,820	4,863	4,971	5,068	19%
Teaching Hospitals	8,229	8,686	8,966	9,116	9,308	9,570	16%
Total	71,522	73,813	73,921	72,877	74,078	77,247	8%

The presence of a strong work force in the life sciences cluster is also evidenced by the top 20 employers in the city of Cambridge. Among the top 20 employers are 6 biopharmaceutical drug companies (Biogen Idec, Millennium Pharmaceuticals, Genzyme, Novartis, Wyeth and Vertex), 3 universities (Harvard, MIT and Lesley) and 3 levels of government (local, state and federal). In relation to the entire Cambridge population of 101,000, the number of employees working in life sciences and R&D related functions is high.[xci] For an overview see table 18, Appendix 9.

(Contributing) Success Factor 4

A sufficient physical infrastructure

Massachusetts counts over 35,000 miles of physical infrastructure in terms of 'roadway', of which 8% are owned and maintained by the Massachusetts state and of which 89% is owned and maintained by local cities and towns. The condition of Massachusetts roadways in general can be classified as poor. Interstate highways and a number of arterial roadways are in good condition, but several other arterial, collector and local roadways are in 'serious need of rehabilitation', see figure 17 (appendix 10).[xcii] In addition, many Massachusetts' based bridges will become in need of repair and rehabilitation very soon. This is evidenced by taking into account a bridge's life cycle, combined with the fact that over 40% of the bridges were constructed between 1950 and 1970, see figure 18 (appendix 11).[xciii] The relatively poor condition of Massachusetts-based roads and bridges can be related to the shortage in available funding. There are plans for improving the infrastructure deficiency. As various sources report, the U.S. government in September 2010 announced a 50 billion investment in infrastructure.

(Contributing) Success Factor 5

The presence of large firms

Over 480 biotechnology firms are located in Massachusetts.[xciv] Four of the largest biotechnology firms located within the cluster are Biogen Idec (1,767 employees), Genzyme (1,231 employees), Millennium Pharmaceuticals (1,339 employees), and Wyeth (780 employees). But also Vertex Pharmaceuticals, Alkermes, ImmunoGen and Transkaryotic Therapies, together with the East Coast research labs of Amgen and the World research headquarters of the Swiss pharmaceutical company Novartis, are located within the cluster.[xcv] Relatively seen, and in relation to the importance of the Massachusetts cluster in general, the number of life sciences related headquarters in the cluster is low.

(Contributing) Success Factor 6

A strong entrepreneurial culture

The online startup archive of Mass High Tech (MHT), a Massachusetts-based organization which keeps track of the regions technology incubation, lists over 500 firms that were started between 2006 and 2010. The existence of an entrepreneurial culture in the Massachusetts life sciences cluster is further evidenced by the ability to attract financial resources (see success factor 7) and by investment rates in R&D (see success factor 2). More information on entrepreneurial culture was obtained by the conversations held for this research (see chapter 4.3).

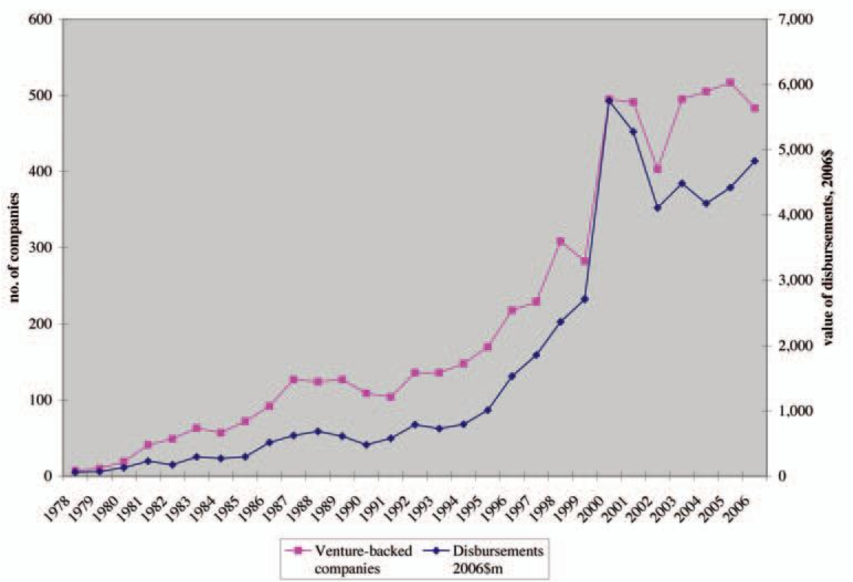
(Contributing) Success Factor 7

Access to sources of finance

Venture capital

Figure 19 shows that since 2000, venture capital (VC) investment in the entire US biotechnology industry is at a high level. Prior to the 2000 rise, investments grew steadily since 1978. ‘Comparing 2000-2006 with 1993-1999, the average annual number of venture-backed companies more than doubled from 213 to 484, while the average annual amount of disbursements in 2006 tripled from $1,572 million to $4,720 million.’[xcvi]

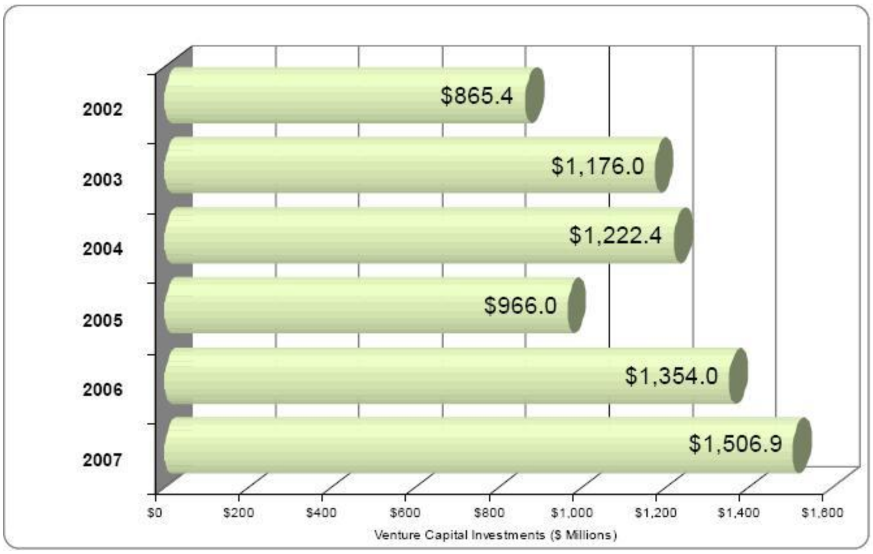
Figure 19. *‘Venture-backed companies and venture-capital disbursements in US biotechnology, 1978-2006’ (Lazonick 2007).*



Massachusetts

VC investments for Massachusetts have been increasing since the year 2002, with one exception in 2005 where the amount drastically decreased (see Figure 20). Without taking this one year decline in consideration, the VC investments annually increased by an average of 160.5 million dollar[xcvii]. In comparison, New Jersey had its peak in 2003 when it attracted 646 million dollar of VC investments. Since that year, the amount decreased to about 430 million a year and has stayed at this level ever since. California, leading in absolute terms, attracted 2,573 million dollar on VC investment in 2002. The amount reached in 2007 was 5,134 million dollar which leads to an average annual growth of 512 million dollar[xcviii]. From an annual growth, VC investment point of view California would, according to these statistics, be the leading state in this comparison. Important factor hereby would be the 2005 decline in investments for Massachusetts (this year included, the average annual growth would surely be much lower). This 2005 decline is remarkable actually, since Massachusetts and New Jersey both had a significant decline in that year.

Figure 20. *Bioscience-related venture capital investments in Massachusetts, 2002–2007 (Battelle BIO 2008).*



According to the June 2008 PwC Massachusetts Life Sciences report, venture capital firms invested money in Massachusetts biotechnology companies at all stages of development, from tiny start-ups to expanding enterprises, as shown in Table 19. Over the years 2006-2007, 17 biotechnology start-up companies were funded by 24 venture firms. For the same period 87 venture firms funded 47 biotechnology companies that were in the so called expansion stage. Most of the venture capital firms funded a single company. Exceptions to this were Atlas Venture, Polaris Venture Partners and Flagship Ventures funding ten, nine, and eight investments, respectively. HealthCare Ventures LLC and Polaris Venture Partners were most active in start-up biotechnology in Massachusetts, funding six and three start-ups respectively. At the early-stage level, 41 companies received funding from 56 venture capital firms over the two-year period. In the later-stage arena, 28 biotechnology companies at this level received funding from 85 venture firms. Again, the vast majority of venture capital firms invested in one private equity deal. Exceptions to this were MPM Capital and Polaris Venture Partners, each funding six projects. Also, Oxford Bioscience Partners and Venrock Associates both participated in five funding deals during the two-year period.[xcix]

Table 19: Analysis of venture capital funding for biotechnology companies at different stages of development, 2006-2007 (BIO 2008).

Industry	Startups	Early stage companies	Expansion stage companies	Later stage companies
Number of participating financing firms*	24	56	87	85
Companies funded	17	41	47	28
Number of firms funding one company	15	35	61	60
Number of firms funding two companies	7	9	14	14
Number of firms funding three or more companies	2	12	12	11
Most active venture capital firms at this level	Healthcare Venture, Polaris Venture Partners	Atlas Venture, Polaris Venture Partners, Flagship Ventures	Flagship Ventures, Oxford Bioscience Partners, HealthCare Ventures, Polaris Venture Partners	MPM Capital, Polaris Capital Partners, Oxford Bioscience Partners, Venrock Associates

Compared to the biotechnology area of San Francisco, the Massachusetts cluster is lagging behind in terms of venture capital. Private investment is significantly higher in the former, while the San Diego area is coming closer. With regard to the number and value of biotech deals over two six-year periods (1995-2000 and 2001-2006), the Boston area ranked second to the San Francisco area, but well ahead of every other metropolitan area. In 2001-2006, the number of deals in the Boston area was 78 percent of that in the San Francisco area, and the value of investments reached 71 percent', see table 20 (Appendix 12).[c]

The trend described above is confirmed by looking at venture capital investments. Over the period 1998 – 2005, California is leading while Massachusetts holds on to second place with more than twice as much venture capital investments received than the next best state, New Jersey.[ci]

Table 21. '*Top ten competitor states in biotechnology venture capital, 1998 & 2005'* *(Nakajima, E., Loveland, R. (2007).*

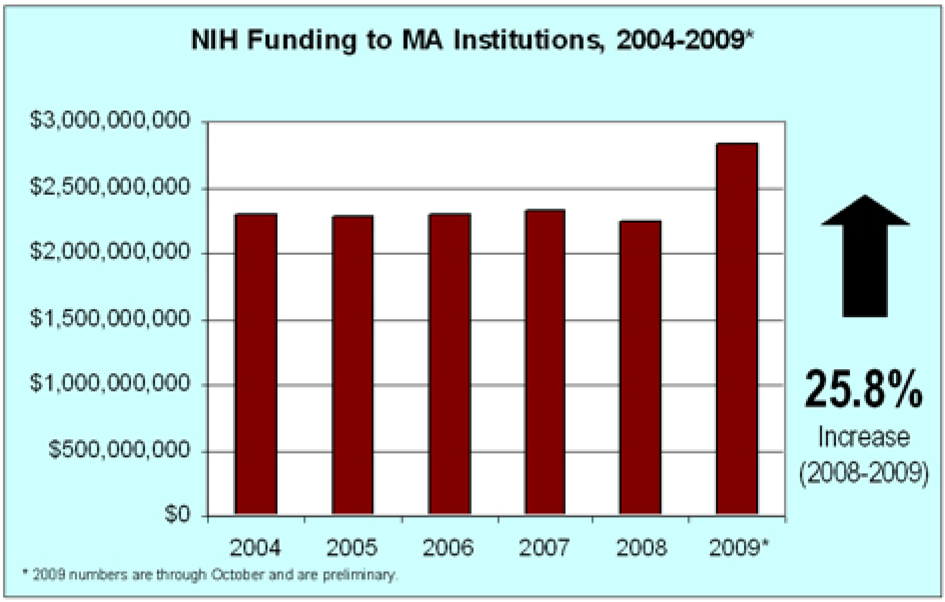
1998			2005			1998-2005
Rank	State	Venture Capital	Rank	State	Venture Capital	Venture Capital % Change
1	California	$608,002,200	1	California	$1,819,071,900	199%
2	**Massachusetts**	**$279,367,500**	**2**	**Massachusetts**	**$561,724,900**	101%
3	New Jersey	$105,132,600	3	New Jersey	$191,642,600	82%
4	Pennsylvania	$77,045,100	4	North Carolina	$190,907,700	304%
5	Texas	$68,073,400	5	Maryland	$147,560,200	808%
6	Washington	$54,067,500	6	Pennsylvania	$133,025,200	73%
7	North Carolina	$47,236,100	7	Washington	$131,444,900	143%
8	New York	$41,750,000	8	Connecticut	$56,555,000	195%
9	Michigan	$34,500,000	9	Texas	$53,368,000	-22%
10	Connecticut	$19,159,000	10	Michigan	$30,599,700	-11%
	USA	$1,560,396,300		USA	$3,907,359,500	150%

Public Financing

NIH funding

The National Institute for Health (NIH) is a federal agency that aims at improving the health of the nation as a whole. It funds health and biotechnology related research wherefore it is an important actor to life sciences research in Massachusetts.[cii] Figure 21 shows that between the years 2004 – 2008, NIH funding did not increase. The level of funding in 2006 was at the same level of 2003: $2.2 billion. With rising inflation and increased research costs this could lead to stagnation in the development of new drugs and applications and in general to the development of the whole cluster. In 2007, NIH funding increased again, which was followed by a decrease in 2008. In 2009, NIH funding increased significantly. Nationally speaking Massachusetts remains one of the leading NIH grantee states; measured in absolute terms, Massachusetts ranked second only to California in receiving funds, see figure 22 (Appendix 13). Measured on a per capita basis, Massachusetts ranked number one.[ciii]

Figure 21. *NIH funding 2004-2009 (MBC 2010).*



According to 2009 statistics, 5 out of the top 8 NIH funded hospitals are located in Massachusetts.[civ] The type of organizations that received NIH funding emphasizes Boston's competitive advantage in biotechnology. The 2006 top five recipients of largest NIH funds included two hospitals and three universities. For an overview of the complete top 15 recipients, see figure 23 (Appendix 14).[cv]

Small business administration funding; SBIR and STTR programs

The Small Business Administration (SBA) programs are established to help small companies compete more effectively and to bring new technologies to market. Although these grants form just a small part of total NIH funding, they are important because they often play a critical role in moving research from the laboratory to the commercial world.[cvi] Two types are important; the Small Business Innovation Research (SBIR) program and the Small Business Technology Transfer (STTR) program. The former is established to help high technology companies develop their research into commercial products and services, while the latter is established to help companies and organizations to bring their innovations to market. Two basic requirements for attracting such programs are that a firm must be based in the United States and that it must have 500 or fewer employees.[cvii] Massachusetts received a total of $82.7 million dollar in SBIR and STTR grants in 2006, with SBIR grants taking into account the largest part, which is $76.5 million dollar. Both programs include two phases in which separate grants are awarded. The figure of total grants received puts Massachusetts in second place nationally when measured in absolute terms, and ahead of every other state when measured on a per capita basis: Massachusetts received $82.7 million or $12,84 per capita compared to $118.3 million or $3.26 per capita in California and $28.5 million or $1.48 per capita in New York.[cviii]

Life Sciences Act 2008

In June 2008, Massachusetts government passed a 1 billion dollar Life Sciences investment bill (Life Sciences Act). The Act's allocations and creations are listed in table 22.

Table 22. *Allocation by the Life Sciences Act 2008.*

Life Sciences Act 2008: Allocation
• $500 million in Capital Funding to be spent over a 10 year period; $299.5 million for targeted infrastructure projects and the balance - $200 million in unrestricted funds for investment in public infrastructure projects, [which lies] at the discretion of the Massachusetts Life Sciences Center (MLSC)
• $25 million each year for 10 years for the Massachusetts Life Sciences Investment Fund, held at the MLSC, for loans, grants, fellowships, and investments to stimulate increased research and development in the life sciences sector
• $25m each year for 10 years in tax incentives to be awarded to certified life sciences projects
• Creates the MLSC Life Sciences Investment Program to expand employment in the life sciences sector in Massachusetts and to promote health-related innovations by supporting research and development, manufacturing and commercialization in life sciences
• Creates 5 Regional Technology and Innovation Centers to be identified from among existing life science regional centers
• Adds an 18 member advisory board to be appointed by the Governor, and creates four additional funds to be administered by the MLSC

The tax incentives mentioned under the third point are awarded through the so called Life Sciences Tax Incentive Program. The above mentioned Life Sciences Act gives the MLSC the authorization to offer (a combination of) nine different tax incentives to certified life sciences companies. According to the MLSC the various incentives are intended to support companies at all stages of development. As an example, the MLSC mentions that some of the incentives (the Life Sciences Investment Tax Credit, the FDA User Free Credit and the $38M Research Credit in particular) are refundable, meaning that also companies without taxable income may be able to qualify for cash payments through these incentives.[cix] All nine credits apply for taxable years beginning on or after January 1, 2009 and are available to certified life sciences companies or persons only to the extent authorized pursuant to the Life Sciences Tax Incentive Program.[cx] Seven of the nine tax incentives are listed in table 23.[cxi]

Table 23. Seven *(out of nine) tax incentives created by the Life Sciences Act*[cxii]

Life Sciences Act tax incentives
• Elimination of the Massachusetts throwback provision
• Creation of a 100% refundable FDA User Fee Credit
• Creation of a sales tax pass through for bricks and mortar purchases
• Allowance of a project to take the current Research and Development Tax Credit as a refundable credit
• Elimination of the mathematical test so that true R&D companies can take sales and use tax exemption on appropriate purchases with certainty, as manufacturers do
• Creation of a redeemable 10% ten year carry forward Life Sciences Investment Tax Credit, allowing projects to receive an additional 2% credit if they locate in an Economic Opportunity Area
• Extension of the Net Operating Loss Credit to 15 years

4.3 Conversation findings on CSF's

Employment

A recent study by the Massachusetts Life Sciences Center elaborates on current and prospective trends, existing programs and recommended strategies for future employee growth.[cxiii] One of the findings of the study is that there is a need of improving preparation and motivation of K-12 students in order to secure future employment. Government officials are aware of this need; in a conversation with Massachusetts' government, the importance of the issue in regard to the 1 billion dollar Life Sciences investment bill was emphasized. First point of attention with regard to this bill was the research on qualified people. The needs and supplies for over 5, 10 and 15 years were investigated. As an outcome it was found that one has to go back all the way to elementary school, 6th grade approximately. At this point decisions about future studies are already made. Once a person has chosen not to enter the technical, scientific studies at that moment, it is likely it will never do so in the future. It was recognized that, in order to foster growth of the sector, it is important to allocate resources to this early stage decision-making.

Business climate

From the conversation with Wyeth Clinical Research director, Mr. Scheele, it was found that the basis for a new life sciences company often comes from a person having a good idea about some technology application. The person(s) involved almost always had the opportunity to do basic research, for example at a university. In 'doing' something with this idea, two possible, main strategies can be followed. Mr. Scheele:

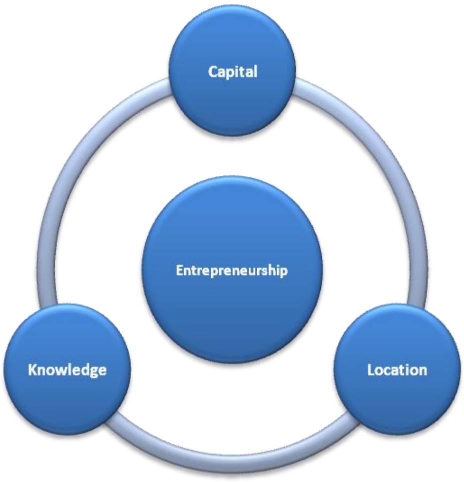
> *The entrepreneur has the choice to join an existing company (incorporation by a large company, the 'big pharma' concept) or to start searching for financing, most of the time in the form of venture capital, to start a new company. The Boston area hereby contains many venture capital firms specialized in life sciences that can be of help.*

In this regard, the Massachusetts life sciences cluster offers several important features to support newcomers to the cluster. As we have seen, the ability of firms within the cluster to attract venture capital is very good. The many venture capital firms understand the sector's business model in which most firms have an early exit-strategy, by which a business concept or technology is sold after a few years. Within the cluster, several organizations exist that can be of help to newcomers. Support can concern, for example, permit information or an introduction to people within the right network. Whether it is entrepreneurs starting new businesses, or existing businesses trying to set up business development centres, they could both benefit from the knowledge of these organizations. From the conversation with Octoplus' Mr. Lodder it was found, for example, that the MBC was of help in order to obtain information used for deciding in which area to locate a business development office.

The exit-strategy often used by small firms was further clarified in the conversation with experts from Western Massachusetts. For small firms it is difficult to compete with large companies. It was indicated that an average phase 3 trial costs between $50 and $100 million and, to even reach this point, a great amount of money already needs to be spend. The risk of not getting anywhere remains highly present. Big pharma's buy small firms and this is indeed what most companies are looking for (a clearly defined exit strategy). Big pharma's buy these firms to use the research done so far and to market the product. Protectionist reasons can also play an important role in buying these smaller firms.

From the conversation with NFIA director Mr. Smit, it was found that the Massachusetts cluster can, indeed, be a place where new businesses can be founded easier than at some other random place. It was argued that there are three essential ingredients for sustainable growth of the cluster; ‘knowledge’, ‘environment’ and ‘capital’.

Figure 24. *Cluster development factors knowledge, location, and capital brought together by the fundamental factor entrepreneurship*.



These three elements are covered in the Massachusetts cluster. Knowledge: the presence of Harvard University, MIT, Tufts University, Boston University and the University of Massachusetts. Environment: the cluster with all its different companies, research institutes and supportive and sector organizations. Capital: specialized venture capital in the form of VC’s and angel investors that are highly present in the cluster. These three elements are held together by the factor ‘entrepreneurship’, which, according to Mr. Smit, goes hand in hand with the US as a whole:

> *Relatively seen there are many entrepreneurs and there is an open attitude towards entrepreneurship in the U.S. Firm bankruptcy is relatively accepted as a normal business feature. The general business climate reflects this and even further promotes the establishment of new businesses. This entrepreneurial climate is perhaps even more present within clusters where actors are specialized and collaborate more often*

In this sense, the knowledge obtained by people active in the cluster and the opportunities identified in response can encourage new business formation. The high number of startups and small firms in the cluster can possibly function as indicator of a supportive business climate.

From the conversation with experts from Western Massachusetts it was found that two sectors exist in which the Massachusetts State is willing to stretch out during negotiations; life sciences and renewable energy. Depending on the scope of a business proposal (for example, starting a new company attracting 5 employees or 200 employees) an entrepreneurs negotiation position is stronger or weaker. From the conversation with Mr. Lodder (Octoplus, director of Business Development) it was found that existing companies, intending to set up business activities within the cluster, would compare the ‘Massachusetts offer’ with possibilities in other states. This information could then be used in the negotiation process as well.

Conclusion

Cluster dimensions

From the findings presented above the following can be concluded with regard to the cluster's dimensions. The cluster can be characterized as localized, with the Boston area functioning as cluster centre. The large amount of firms makes the cluster dense while the existence of interconnected industries (for example biotechnology, pharmaceuticals, medical devices and medical & testing laboratories) characterizes the cluster as broad. Despite the cluster's declining manufacturing rates, the cluster's general input-independence on firms outside the cluster labels the cluster as 'deep'. In terms of activity-base, the cluster can be seen as a rich cluster since fundamental value adding activities (for example: R&D) are carried out within the cluster. With regard to growth potential, the cluster most likely falls in the category 'noonday-competitive', since the cluster seems well able to attract the resources necessary for growth (capital, knowledge and alliances). The cluster's innovative capacity is high, evidenced by high rates of R&D and emerging firms.

Sub question 1: **What constitutes the Massachusetts life sciences cluster?**
Answer: *The Massachusetts life sciences cluster can be characterized as a localized, dense, broad, deep, activity-rich, noonday-competitive and highly innovative geographical concentration of specialized firms and institutions.*

Success factors

The following can be concluded with regard to the cluster's success factors.

Networks and partnerships: Knowledge driven partnerships are frequent within the cluster. Over 50% of the partnerships constitute so-called full R&D collaboration (research, development and commercialization) and more than 25% of all alliances are focused on licensing. Large firms hereby tend to outsource early-stage R&D, leading to partnerships with smaller firms and research institutions. Networking is facilitated by the Massachusetts Biotechnology Council, which functions as a member-driven platform with over 600 members, ranging from small and large firms to research institutions and supportive organizations.

Innovation and R&D: In terms of R&D expenditure the Massachusetts cluster is performing very well. Measured in absolute terms, the cluster ranks second in the US behind the California region. Measured, however, in relative terms, the cluster outperforms all other states in the U.S. Over the period 2002 – 2007, Massachusetts generated 2,895 drugs- and pharmaceutical-related patents. In comparison to New Jersey and California, Massachusetts generated the second highest number measured in absolute terms. Again, when considering demographic factors, Massachusetts' yearly average of 483 patents outperforms that of other states. The number of clinical trials constitutes a cluster specific indicator on the level of innovation and R&D. In 2009, 650 clinical trials were conducted in Massachusetts, ranking the cluster's performance at tenth place. California, Texas, and New York all conducted over 1000 clinical trials. Compared to other states the cluster's performance on clinical trials is falling behind.

Human resources: Between 2000 and 2009, bio-pharmaceutical employment grew by 60%, reaching 46,553 employees in 2009. The first half of these years showed a 28% growth, while in the second half growth declined, reaching 19%. The cluster's workforce can be described as 'innovative and entrepreneurial', which is confirmed by the fact that the entire Life Sciences workforce, representing 77,247 employees in 2006, grew 8 percent between 2001 and 2006. Employment in wholesale trade (12%), medical and testing laboratories (19%), and teaching hospitals (16%) grew between 2001 and 2006. For 2006, among the top 20 Massachusetts-based employers, 12 actors were involved in the life sciences sector in one or more ways, including 6 biopharmaceutical firms and three universities. The need to improve preparation and motivation of K-12 students in order to fulfill future employment needs is recognized by the state government. Research has shown that decisions about future studies are already made at 6th grade elementary school. A choice made at that moment most likely determines future employment in terms of sector. The government acknowledged this and stressed the importance of allocating resources to inform and interest young people.

Access to sources of finance

i) Venture capital: The cluster's ability to attract financial means is very well developed. Biotechnology-related venture capital investments in Massachusetts heavily increased during the 2002 – 2007 period, reaching $5,134 million by 2007. For 2006 – 2007, relatively more startups and early-stage firms (compared to expansion- and later-stage firms) received venture capital investment. In absolute terms of venture capital invested, California is leading, followed by Massachusetts. The third state, New Jersey, follows at distance with less than half the value of Massachusetts-based investments.

ii) NIH funding: The cluster's performance on receiving NIH funding is developed equally well. Massachusetts is one of the top NIH funding recipients. NIH funding over the years 2003 – 2008 did not significantly increase, ranging around $2.2 billion. In 2009, NIH funding to Massachusetts increased to $2.8 billion, ranking the state in second place behind California ($3.8 billion). Out of the top 8 NIH-funded hospitals in the U.S., 5 are located in Massachusetts. From these NIH funds, Massachusetts received a total of $82.7 million in SBIR ($76.5 million) and STTR grants in 2006. California, again leading in absolute terms, received $118.3 million.

iii) Life Sciences Act 2008: Massachusetts government passed a $1 billion act in 2008, aimed to further strengthening the life sciences cluster. Half of the amount is allocated to capital funding, of which $300 million is appointed to targeted infrastructure projects. A vast amount is allocated to public infrastructure projects, loans, grants, fellowships and tax incentives.

Physical infrastructure, presence of large firms & entrepreneurial culture: Massachusetts' physical infrastructure could be improved, maintenance and rehabilitation are necessary in several areas. Large firms are present in the cluster but relative to other states, the cluster consists of smaller firms. The cluster's strong entrepreneurial culture follows from the cluster's performance on other success factors. The presence of knowledge creating organizations (for example Harvard University, University of Massachusetts, MIT), the presence of numerous firms (over 480, including Biogen Idec, Genzyme and Wyeth) and supportive institution (Boston Biomedical Research Institute, Dana Farber Cancer Institutes, Forsyth Institute, for example), and the availability of capital (facilitated by venture capital firms like Atlas Venture, Polaris Venture Partners and Flagship Ventures) are fundamental aspects strengthening the cluster's entrepreneurial culture. The open-minded attitude towards business creation and failure, as found in the U.S., supports new business development in general.

Sub question 2: **What cluster success factors are fulfilled by the Massachusetts cluster?**

Answer: *The cluster takes on a leading role with regard to success factors 2, 3 and 7. The cluster's high R&D expenditure and number of patents, the availability of high-quality human resources and the cluster's ability to attract financial resources stand out from the rest. In addition, the cluster upholds a strong business culture based on the knowledge, location and capital requirements. Two success factors were found to be 'less fulfilled'; the physical infrastructure and the presence of large firms.*

4.4 *Earlier findings: Porter (2003) and MTC (2006)*

The Massachusetts life sciences cluster has been subject to research on its performance before. The findings of two reports are outlined below. Together with the findings presented above, these findings will be used in determining the cluster's life cycle stage (4.4), and in determining the level of fulfilment of cluster competitive advantages.

4.4.1. Porter (2003)

For his 2003 life sciences cluster competitiveness research, Porter extracted data from several sources. Among them where recent studies of the cluster, a survey of 250 Massachusetts companies (50+ from the Life Sciences), 125+ in-depth interviews with cluster leaders and an analysis of regional and cluster data from the Institute for Strategy and Competitiveness at Harvard. Porters' findings are presented below.[cxiv]

With regard to competition and collaboration, Porter found that a strong base of local companies exist that compete on innovation using the newest scientific findings. Local companies were found to compete and cooperate intensively. Competition hereby mostly regarded skilled labor. On the contrary, it was seen that the pharmaceutical manufacturing in the state is limited and that only few headquarters of big international companies are located within the cluster. With regard to the costs and quality of the cluster's own resources, the cluster was found to have a strong educational system with an equally strong science base. Leading researchers and academic research centers were found to be located within the cluster. The transfer of technology from research to industry scored high as well as the availability of risk capital and federal research funding. Porter also located input factors that could be improved. The research showed that within the cluster the cost of doing business is relatively high, which was also found for the cost of living. In addition, the physical infrastructure, especially Logan Airport as well as the upcoming shortage of mid-level professionals raised concerns. Another factor of importance addressed was the conduct of clinical trials. The Massachusetts' cluster scores low compared to other states. A lack of responsiveness and mechanisms to facilitate the process were found as underlying reasons. Rising recruitment costs and a decrease in efficiency with regard to the execution of trials (caused by a high drop-out rate) also contribute to this. Increasing the numbers of clinical trials would lead to an important competitive advantage as the trials form an important source of revenue for hospitals, improve the quality of healthcare delivery, and facilitate innovation throughout the cluster. The Massachusetts' cluster scores well on the number and quality of related and supporting industries. The cluster contains many service providing firms (law firms and consultants for example) as well as instrument companies and other suppliers. Porter also examined the role of the government and the existence of institutions for collaboration. The government was found to have increased its recognition of the potential of life sciences for the state. On the contrary, three aspects were discovered that need improvement. A lack in a consistent and predictable process for site regulation, a lack by the state government of overall responsiveness and a coordinated approach in order to support the cluster, and the unstructured R&D tax credits intended to benefit support companies. With regard to facilitating collaboration, a strong array of industry councils, technology transfer offices, enterprise networks and other institutions for collaborating were found to be present in the cluster. A major deficiency was also detected: the facilitation of networking across segments. According to Porter, an overarching strategy is needed to facilitate and coordinate processes between cluster actors in order to improve the competitiveness of the entire cluster. Based on these findings, Porter in 2003 identified the following points that need improvement, see the table below.

Table 24: *Massachusetts cluster aspects in need of improvement (based on Porter 2003).*

Massachusetts cluster aspects in need of improvement
- **Address weaknesses in the physical infrastructure, especially in transportation**
- **Increase the supply of housing to lower the cost of living in the State**
- **Work with local governments to identify, develop, and permit promising sites for life sciences companies (e.g., single site locator)**
- **Improve the structure of R&D incentives for life sciences companies**
- **Create a clear point of contact for existing companies in the Life Sciences cluster as well as potential out-of-state investors**
- **Participate actively in the Life Sciences cluster development process**
- **Increase the overall responsiveness of state government to business needs**
- **Improve technology transfer**
- **Make Massachusetts' health care delivery the most advanced and innovative in the nation**
- **Secure the State's medium skilled workforce position**
- **Expand clinical trials in the State**
- **Capture more downstream manufacturing**

4.4.2. MTC 2006

The Massachusetts Technology Collaborative (MTC) is an economic development agency set up by the Massachusetts state government. Task of the MTC is to enhance the state's economic competitiveness, including the life sciences cluster. The MTC report[cxv] starts by elaborating on the identified competitive advantages and disadvantages of the life sciences cluster. It then continues by listing 7 potential cluster priority areas and by a description on how to cope with these issues. Compared to Porter's 2003 report, the character of the report can be classified as more general. Sources for the report were economic literature and different studies relating to Life Sciences in Massachusetts as well as to specific issues identified as priorities at the 2003 Life Sciences Summit. For some aspects Porters' 2003 report is used as a reference.[cxvi] This last referral would lead one to think that the result of this report might be similar to those from the report discussed above. The tables below summarize the report's findings on the cluster's competitive performance.

Table 25. *Identified competitive strengths of the Massachusetts cluster (based on MTC 2006).*

Massachusetts cluster strengths
The Life Sciences concentration and the Massachusetts Economy
- Size, diversity and quality
- Significantly greater concentration of life sciences than in the U.S. as a whole
- Strong multiplier effect of life sciences industry

Leadership in innovation - Close relationships between research institutions and industry facilitate technology transfer opportunities - Largest national amount of investments in R&D in healthcare technology ($3.4 billion in 2004) - Second highest number of new approval for biotechnology drugs
Employment resources - Strong educational resources from K-12 through higher education - High general level of education (Specifically, 38.4% of Massachusetts medical equipment workers have a bachelor's degree or higher, versus 28.2% of U.S. medical equipment workers)

Table 26. *Points of attention for the Massachusetts cluster (based on: MTC 2006).*

Massachusetts cluster weaknesses
Employment - **The cluster's total manufacturing employment declined 7.7% from 2000 to 2004** - **Employment in medical equipment and supplies manufacturing (51% of the cluster's total employment in 2004) declined 11.3% over the same time period** - **Medical and diagnostic laboratories (16% of total) rose 15.7%** - **Pharmaceutical manufacturing, 27% of total cluster employment, declined 9.5% from 2000 to 2004** - **Difficulties in housing for employees due to high cost of housing**
Impediments to business retention and growth - **Difficulties in attracting new companies due to high cost of doing business in Massachusetts, specifically the costs of labor and real estate** - **Transportation and communications infrastructure** - **Complexity of doing business as a limiting factor (permitting process and the regulatory environment)** - **Fewer downstream production and commercialization activities (more early stage activities in the cluster)**
The competitive environment - **Aggressive competition from other states as a threat towards Massachusetts' leading role; life sciences initiatives and strategies by other states are increasing** - **Relocations and outsourcing manufacturing operations and employment due to high manufacturing costs**
Industry specific issues - **Increased competitiveness in technology transfer of other states** - **Low number of clinical trials**

The report is concluded by presenting priority areas for future initiatives which are aimed at enhancing the clusters growth and competitiveness, see table 27 below.

Table 27. *Cluster priority areas (MTC 2006, p. 8 For ongoing initiatives, see pp. 8-15).*

Priority areas
- **Improving technology transfer**
- **Improving quality and efficiency by adapting Massachusetts-based technology to health care delivery systems**
- **Workforce recruitment, development and retention**
- **Expansion of clinical trials in the state**
- **Capturing more downstream manufacturing**
- **Attracting new life science companies and improving the permitting process**
- **Life Sciences and regional economic development**

4.5 *F*indings combined

Comparison: earlier research – success factor research

Both earlier reports identified strengths that can be summarized by the high rate or availability of competitiveness of the cluster, the collaboration among cluster actors, human resources and finance. The research on success factors in chapter 4.2 showed a similar outcome. As concluded earlier, the cluster takes on a leading role with regard to factors 2, 3, and 7 (strong innovation and skills base, and ability to attract finance). In addition, both reports identified specific weaknesses: A low level of manufacturing, clinical trials, and large firms, rising cost of living, high complexity of doing business (in terms of permits and regulations), a physical infrastructure in need of improvement, and a coordinated support shortage. The research on success factors (chapter 4.1) partially identified the same points in need of improvement; the number of clinical trials, the physical infrastructure and the number of large firms located within the cluster. Resulting from combining these data sets, is what can be summarized as follows: The cluster scores well on research and innovation capacity, the ability to attract finance (especially NIH funding), the presence of collaboration facilitating institutions, the sophisticated educational system, and on the ability to attract skilled work force. The cluster performs less well with regard to the number of large firms, the processes of doing business (amount of permits), the number of clinical trials, the physical infrastructure, and the presence of coordinated cluster approach.

Weakness meets opportunity: A possible solution for a weakness identified by earlier research

Both earlier reports mention the lack of coordinated cluster support (on state level). The 2006 report is thereby concluded by presenting examples of ongoing initiatives on various subjects. It follows from the report that, on the one hand, a lot of initiatives have been undertaken independently by public and private institutions of higher education, industry and trade associations or non-governmental organizations. On the other hand, many other initiatives were realised because of collaboration between state government, private industry, healthcare and research institutions and trade associations. It is also mentioned that collaboration was present in attempts to 'capture downstream manufacturing, attracting new companies to the state, improving the permitting process and expanding regional economic development'.[cxvii] According to the report, however, an assessment of these initiatives and the competitive needs of the state indicated concerns:

> *In many instances, even in those where collaboration has been evident, there has not been a mechanism to extend that collaboration beyond the initial partners. Often the joint efforts have been serendipitous and few have been coordinated either in terms of information transfer or economies of scale.*[cxviii] *The ongoing initiatives are predominantly aimed at improving the operational effectiveness of various elements of the cluster. In many cases, they are similar to or are based on, models utilized by other states. There is a lack of strategic and unique activities that can truly move the Massachusetts Life Sciences industry to a new level of operation and provide cluster members with a lasting competitive advantage.*[cxix]

The 2008 Life Sciences Act, discussed on page 39, can be seen as a (partial) solution to this weakness. Next to providing tax incentives, the Act established a basis for a structured approach to cluster policy on state level by the enactment of the Massachusetts Life Sciences Center (MLSC). The MLSC's task is to invest in life sciences research and economic development, whereby it functions as hub between the private and public sector.

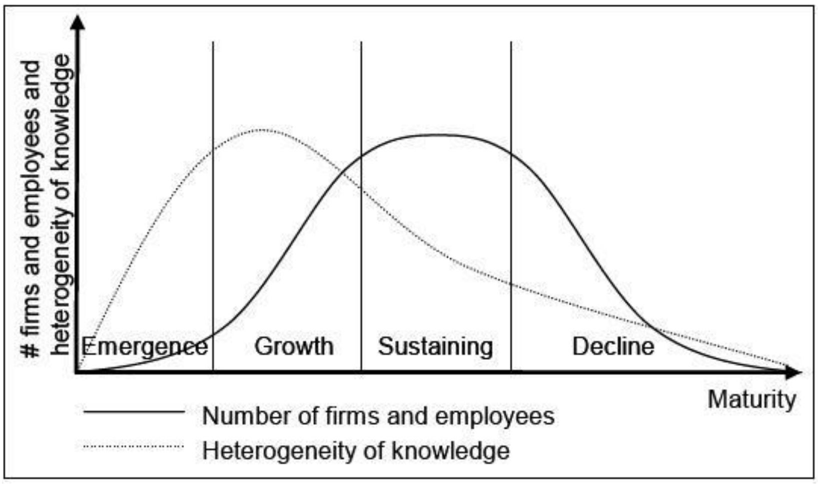
4.6 Cluster life cycle stage

Based on the findings of chapter 4.2 and the research by Porter and MTC, it is tried to classify the cluster's present state into a specific cluster life cycle stage. Chapter 2 elaborated on these stages. It was seen that the quantitative dimension described the development of clusters by the number of firms, employees or turnover. The qualitative dimension described cluster development in terms of diversity of knowledge and competencies. The table below shows the indicators of a cluster's 'growing' stage and their presence in the Massachusetts cluster. Table 28 again shows a cluster's life cycle according to Menzel & Fornahl (2007).

Table 28. Growing-stage indicators found in Massachusetts (based on Menzel and Fornahl 2007).

Growing cluster	Quantitative (X)		Qualitative (Y)	
Direct (1)	Growing number of firms and employment		Growth of absolute diversity, decrease of heterogeneity (Focussing)	
Systemic (2)	Growing perception, possibilities for collective action, institution building		Open and flexible networks contribute to exploit diversity of competencies	

Figure 2. *Quantitative and qualitative elements of the cluster life cycle (Menzel and Fornahl, 2007).*



The data as found points towards classifying the Massachusetts cluster in the life cycle stage of 'growth'. The findings on success factor 3 showed that Life sciences employment continues to increase, signifying the fulfilment of indicator X1 (and thereby rejecting a criterion from the sustaining stage). Data directly signifying the presence of indicators X2, Y1 and Y2 could not be abstracted from the findings. Although an existence of a growing number and value of investments and the high rate of patterns issued were found, no real evidence was found on a (high) number of new business formations. In addition, no data was found on the existence of new potential network partners. There are, however, findings that presume the fulfilment of these indicators. The findings on CSF 1 & 2, for example, evidenced that the Massachusetts cluster has a strong innovation and R&D position. Porter's findings confirm this by mentioning the presence of a strong science base and by the presence of firms competing on innovation with regard to the latest scientific developments. The limited manufacturing within the cluster, as found by Porter, can be a result of a focus on specific knowledge-driven activities. The 2008 Life Sciences Bill and the establishment of the MLSC could possibly be seen as an example of growing perception and possibilities for collective action. These findings point more towards the fulfilment of the remaining three indicators of the growth stage, rather than to those of other stages. A level of development somewhere between the growth and the sustaining stage is possible as well. Menzel and Fornahl (2007) argued that clusters can move rather freely between the growth and sustaining phase, responding for example to new sources of growth.

Conclusion

The most significant indicator of the cluster's presence in the growth-stage is employment growth, which is evidenced by the findings on success factor 3. Although the fulfilment of other indicators could not directly be evidenced from the findings, their presence can be presumed by referring to related characteristics of the Massachusetts cluster. Inferring the fulfilment of the remaining indicators from these more general findings is possible but places restrictions on the validity of the outcome.

Sub question 2: *At what cluster life cycle stage is the Massachusetts cluster operating?*

Answer: *The findings suggest the classification of the cluster at a 'growing' stage. It is here labelled as a suggestion since the direct evidence to support this thought is little: One out of the four indicators pointed in this direction, hereby excluding other stages.*

4.7 *Realization of Porter's cluster advantages?*

Porter advocated the following competitive advantages from being located in a cluster: *Increased company productivity, driving the direction and pace of innovation, and the stimulation of new business formation.* From the elaboration on the critical success factors above it can be seen that several indicators shown in table 35 are present in the Massachusetts cluster. Their existence in return point towards the presence in Massachusetts of three competitive advantages related to the existence of the cluster.

Table 35. *Presence of Porter's competitive advantages for the Massachusetts cluster (Based on: Porter 1998).*

Competitive advantages	**Presence**
Increased company productivity	
❖ Better access to employees and suppliers	Found
❖ Local outsourcing instead of distant outsourcing	Found
❖ Access to specialized information	Found
❖ The benefit of complementarities	Found
❖ Access to institutions and public goods	Found
❖ Better motivation and measurement	Not Found
❖ Easier measurable and comparable performances	Found
Driving the direction and pace of innovation	
❖ Clusters provide the capacity and the flexibility to act rapidly	Not Found
❖ Companies within a cluster can experiment at lower cost and can delay large commitments until they are more assured that a given innovation will work for them	Not Found
❖ Cluster companies have a better window on the market than isolated competitors	Found
❖ Forms of pressure contribute to innovation	Not Found
Stimulation of new business formation	
❖ Individuals working within a cluster can more easily perceive gaps in products or services around which they can build businesses.	Not Found
❖ Barriers to entry are lower than elsewhere. Needed assets, skills, inputs, and staff are often readily available at the cluster location.	Not Found
❖ Local financial institutions and investors, already familiar with the cluster, may require a lower risk premium on capital.	Not Found
❖ The cluster often presents a significant local market, and an entrepreneur may benefit from established relationships.	Not Found

The presence of all cluster-related advantages, as promoted by Porter, could not be evidenced by the findings from this research. A more dedicated, specific research towards exploring the presence of these advantages would be needed. The findings from this research point towards the presence of one of the three competitive advantages; 'increased company productivity'. The Massachusetts cluster characteristics, for example, enhance access to specialized knowledge and increases the possibility for collaboration. Existing networks and other collaboration possibilities facilitated by the various supportive organizations make this possible. The cluster's performance is measurable and comparable since it is being watched by financial institutions. A large amount of academic literature is also available. The societal benefit of the cluster is recognized by the state government which makes access to public goods more available. Important example here is the Life Sciences Act, which could form the solution to the scarcity of integration and coherency within the cluster and it potentially could be seen as a plan for an overarching strategy that the cluster is currently lacking. Innovation is fostered and supported within the cluster. Collaboration between companies and research institutions and also collaboration (and competitiveness) among companies contribute to the high level of innovation and they provide the capacity and the flexibility to act rapidly. The cluster's ability to attract financial resources in the form of venture capital and NIH funding is outstanding.

Conclusion

It this part, the earlier research by Porter and the MTC was presented. These sources of information, combined with the research on the cluster's success factors, were subsequently used to classify the Massachusetts cluster into a specific cluster life cycle stage. In addition, an attempt was made to assess whether the various advantages allegedly assigned to operating within clusters were actually realized in the Massachusetts cluster. The most interesting finding that derived from the comparative analysis of the works of Porter and MTC was the possible solution to the weakness ‘lack of coordinated cluster approach’. As a possible solution, the 1 billion dollar Life Sciences Act can not only provide the necessary financial impetus, it can potentially act as the cluster’s central point from whereon the cluster’s further development is organized. The little evidence that was found to classify the Massachusetts cluster into a specific life cycle stage resulted in the classification ‘growing cluster’. The enacted Life Sciences Act also plays a role; the financial and organizational boost is not likely to slow down the growing process, instead it will be more likely to facilitate it. The assessment on the realization of Porter’s cluster advantages in Massachusetts showed that the advantage of ‘increased company productivity’ can be regarded as fulfilled. ‘Driving the direction and pace of innovation’ and ‘the stimulation of new business formation’ could not be found as advantages provided by Massachusetts cluster.

Chapter V Conclusion

5.1 Conclusion

This research focused on the Massachusetts life sciences cluster. The aim of the research was to obtain knowledge on the cluster, and more specifically, on its level of development. In order to assess the cluster's level of development the research focused on identifying the cluster's characteristics, success factors, and life cycle stage. In addition, an attempt was made to assess whether being located within the Massachusetts cluster brings about competitive advantages as suggested by Porter.

Sub-question 1 provided a first look at the Massachusetts cluster. It was concluded that the cluster can be characterized as *localized* (with the Boston-area as main geographical basis), *dense* (the large amount of firms), *broad* (interconnected industries as biotechnology, pharmaceuticals, medical devices and medical & testing laboratories), *deep* (input-independence) and *activity-rich* (value adding activities are located within the cluster). In addition, it was found that the cluster's innovative capacity is high, evidenced by the high R&D-rates and the large number of small firms.

With regard to sub-question 2, the cluster was found to have a leading role on three out of the seven factors, including two critical success factors and one contributing success factor. High R&D-rates combined with a high number of patterns issued make that the Massachusetts cluster is performing among the best U.S. states in terms of innovation and R&D. It was also found that the cluster is performing well with regard to the factor 'human resources'. Bio-pharmaceutical employment grew significantly over the last ten years. The cluster seems able to attract a skilled workforce and the government is trying to locate more resources to promote the cluster among young people within the state, in this way trying to secure future employment demand. The third success factor on which the Massachusetts cluster was found to score well is the 'ability to attract finance'. Biotechnology-related venture capital investments heavily increased between 2002 and 2007. In terms of NIH-funding, the Massachusetts cluster ranks among the top recipients. The period 2002 – 2008 did not display a significant increase. For 2009, however, NIH-funding increased, ranking Massachusetts as the second largest NIH-receiver in the U.S. The cluster's score on the remaining success factors could not directly be evidenced from the findings. The presence of a strong entrepreneurial culture could arguably follow from the cluster's strong performance on other success factors. The number of R&D-related organizations, the large number of firms and supportive organizations as well as the cluster's ability to attract finance, indicate that the cluster's entrepreneurial culture is strong. Little evidence was found with regard to the factors 'networks and partnerships', 'physical infrastructure', and 'presence of large firms'.

By combining the research on success factors with earlier research it was tried to assess the cluster's strengths. Next to confirming the strengths on 'innovative capacity', 'human resources', and 'the ability to attract finance', the earlier research included related strengths like the presence of collaboration facilitating institutions and a sophisticated educational system. The earlier research identified as weaknesses among others the low number of large firms and the deterring condition of the physical infrastructure. The low number of clinical trials was found to be confirmed in both cases. The lack of a coordinated cluster approach, evidenced by Porter's findings, could possibly be neutralized by the relatively new Life Sciences Act (2008). This Act provides both financial and organizational means to structure and strengthen the cluster as a whole.

In terms of cluster life cycle stages, it can be concluded that the Massachusetts cluster is operating within the growth-stage. High employment growth hereby functions as the main indicator, placing restrictions on the meaning of the classification. The increased financial and organizational attention to the cluster (by means of the Life Sciences Act) could trigger the cluster's growth and provide an extra indication towards classifying the cluster's activity as being growth-stage related.

Advantages subscribed to being located within a cluster are a frequent subject of discussion. Porter, as probably the most widely known advocate of these advantages, listed them extensively. As overarching benefits, Porter distinguished three types of competitive advantage: Increased company productivity, driving the direction and pace of innovation, and the stimulation of new business formation. This research found evidence for the fulfillment of the first advantage, as 6 out of the 7 indicators could be regarded as confirmed by the findings. A statement that the cluster is to be regarded as emerging, or less developed, due to the inability to provide all benefits, seems unlikely to pass a validity-test.

At this stage it is possible to formulate an answer to the central research question:

> *How can the cluster's performance on success factors be described and what overall level of development is reached by the Massachusetts life sciences cluster?*

The cluster's performance on success factors showed that the cluster has a leading role with regard to innovation and R&D, human resources and the ability to attract finance. Only two success factors were identified that are in need of improvement: the physical infrastructure and the presence of a relatively low number of large firms. Overall, it can be concluded that the large amount of different cluster actors and the fulfillment of most of the success factors indicate a high level of development reached by the Massachusetts cluster. The cluster is hereby labeled as operating in its growth stage whereby one of the three major competitive advantages is realized. The latter hereby implicates that a well established and recognized cluster does not necessarily provide all cluster benefits as suggested by Porter.

Chapter VI Discussion & Recommendations

Research restrictions

The outcome of this research should be valued in the light of several restrictions. In the first place, the research did not attempt to be extensive. The wide range of cluster theory covered by the research brings about two implications; on the hand it enabled a broad view on the cluster and its development, whereas on the other hand the depth of the research is restrained. As a result, certain characteristics could not be attributed to the cluster (fulfilment of success factors and competitive advantages, for example). Further research could very well evidence the presence of these elements for the Massachusetts cluster. In addition, the research drafts no conclusions on the existence of a causal relationship between advantages and their presence in the Massachusetts cluster. The evidence found points towards an indication. Several factors and cluster advantages were difficult to measure wherefore specific information on these advantages for the Massachusetts cluster could not be obtained.

Cluster Theory Critique

Cluster theory has been criticized for many years. For this research, the works of Martin & Sunley (2003) and Perry (2005) are of particular importance. Besides criticizing general cluster theory, these authors also specifically criticize the work of Porter. Their views revolve around three arguments; not all firms benefit, the cluster term is used as a marketing tool and towards the notion that the cluster concept is too vague.

Not all firms benefit

By criticizing cluster theory in general, Perry argues that there exists no certain evidence that businesses within a cluster gain an advantage over businesses located elsewhere.[cxx] The cluster concept is broad of character, which leads to a high range of possible interpretations. Conclusions from single studies are therefore easy challengeable.[cxxi] According to Perry, the claim that businesses within a cluster gain a competitive advantage over businesses located elsewhere implies that all activity should be located in clusters.[cxxii] Not all firms, however, are able to benefit in a cluster setting. Cluster advocacy tends to presuppose that all firms, regardless of type and context, can benefit from concentration. In reality, research has shown that some activities tend to cluster more than others and that the background of locations and industries are important factors to the ultimate development of locations.[cxxiii] Firms in information-intensive, dynamic sectors thereby have a tendency to be relatively concentrated, especially during the first years of development.[cxxiv]

The cluster term used as marketing tool

Next to these specific elements of cluster theory, Perry argues that the cluster concept in general has been used as a marketing tool rather than a scientific, economic analysis tool.[cxxv] Perry states:

> *Just as commercial organizations use a brand image to seek to differentiate an otherwise 'ordinary' product, the cluster label has been attached to a set of ideas that essentially are little different to standard business-agglomeration theory and associated policy recommendations.*[cxxvi]

Cluster advantages cannot explain clustering

According to Perry, the presence of cluster advantages is wrongfully used as the explanation for clustering. This is why, according to Perry, most explanations of clustering start by mentioning the many advantages that firms can possibly enjoy from being located within a cluster. Such an approach is said to have three problems; firstly, it does not explain how the clustering accumulated to the extend that advantages emerged. Secondly, the advantages attributed to clusters are numerous and partly in competition with each other. Thirdly, it suggests that all activity should be located in clusters.[cxxvii] Perry argues that there is a 'need to get beyond surface impressions', in which he refers to the tendency to justify cluster promotion for any activity displaying growth and disproportionate presence in a particular location.[cxxviii]

Vagueness of the concept

Martin and Sunley (2003) elaborated on the question why Porter's contribution has proved so 'fashionable and influential', while at the same time the work of economic geographers has not. Three possible reasons were identified*:* i) Porter's use of the term 'competitiveness' as a term triggering politicians and policy-makers, ii) Porter's accessible method of communication (easy writing style, avoiding a more 'academic approach'), iii) The general character of the cluster concept, argued as being 'deliberately vague and sufficiently indeterminate'. It is suggested that the cluster concept, by keeping it as general as possible, can be applied to all forms of growth in a certain area, also to those that would normally (according to standard business-agglomeration theory) not deserve the classification as cluster. As a result, it is argued that the cluster concept loses significance. [cxxix] It is also argued that it leads to 'conceptual and empirical confusion'.[cxxx] To indicate the conceptual confusion, Martin and Sunley compiled an overview of ten different cluster concept definitions (see Table 29 in appendix 15).

Implications for this research

The critical assessments by Martin & Sunley (2003) and Perry (2005) on the one hand included general critique on contemporary cluster theory and on the other hand critique specifically directed towards cluster theory as promoted by Porter. The general critique pointed towards the thought that clustering itself does not bring about advantages in all cases and for all cluster participants. One of the reasons for the emphasis on this point stems from the notion that the cluster concept in recent years has been increasingly used as a 'marketing tool', rather than a scientific, analysis tool. Critique specifically directed towards Porter partially stems from this latter notion. As one of the reasons for the popularity of Porter's cluster theory, the 'deliberately vague and sufficiently indeterminate' character of the concept was mentioned. To newly developed areas with concentrated economic activity, these points of critique can be of value; it is not unlikely that implementing cluster policy in a non-cluster area could have a negative impact. Within the research at hand, however, they are less meaningful. The Massachusetts cluster already functions as a prime example of what constitutes a cluster. The educational and research foundations of the cluster were laid over a hundred years ago. In the mean time, many actors, ranging from government institutions to private financial institutions and firms, have recognized it as such.

A different point of critique focused on Porter's advocacy of cluster advantages and its wrongful use as the explanation for clustering. The literature by Porter that was used for this research does not, however, suggest that the advantages listed also explain the cluster's enactment. It is argued by Porter that being located within a cluster brings about certain competitive advantages. It is not argued, as mentioned, that these advantages explain why and how the cluster once started to become a cluster.

Therefore, the implications that might be connected to this point of critique do not apply to the research at hand.

Recommendations

Academic

The research suggests that a business cluster can be classified as highly developed without performing extraordinary well on all success factors which are normally attributed to those clusters. Governments trying to stimulate cluster growth or firms assessing business opportunities should therefore not overemphasize the fulfilment of success factors. Although relevant, implications drawn from cluster theory critique seem to have a small impact on established and recognized clusters. Government officials as well as businesses representatives should take these points into consideration without excessively emphasizing them.

Consulate General

The Massachusetts life sciences cluster was found to be a highly developed cluster, especially in terms of innovation and R&D, attracting and maintaining the right human resources and the ability to attract financial resources. For Dutch life sciences firms it could be interesting to see the Consulate preserve its existing ties with several cluster actors. The network so maintained could be shared with Dutch firms willing to locate business activities within the cluster. The relatively easy access to this source of information could provide starting firms with a benefit as they could analyze their business potential thoroughly before spending money on professional analysis or visiting the cluster. In addition, the Consulate could, for example, organize meetings between cluster actors and representatives from Dutch firms thinking about starting business activities in the cluster. An important task for the Consulate in this regard is to increase its visibility as a starting point for Dutch businesses wherefrom sector specific information can be obtained.

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- National Institutes of Health: www.nih.gov
- PricewaterhouseCoopers: www.pwc.com
- Biotechnology Industry Organization: www.bio.org
  In order to access information on different states, the online address (http://www.bio.org/local/battelle2008/MA_BIO_08.pdf) was used in which the state initials MA (Massachusetts) were subsequently changed to NJ (New Jersey) and CA (California).

Appendix 1

Table 3. *Critical success factors by Mone* (Mone 2000).

Critical Success factors
Availability of Venture Capital - *Quantify and analyze the amount of capital provided to businesses*
Research & Development Capabilities - *Quantify and analyze the amount of R&D funding provided in a given state or region per year*
Availability of Skilled Labor - *Quantify and analyze the number and quality of educated workers in a given state or region*
Training/Education Infrastructure - *Measures the state public and private institutions of higher learning*
Energy, Transportation, and Information Infrastructure - *Measure energy cost (electricity, gas), physical condition of the roads, availability of high speed telecommunication lines*
Presence of Market-Leading Companies - *Quantify the number of leading firms in a given state*
Entrepreneurial Climate - *Quantify and analyze the incentives offered to small-businesses and inventors and the actual entrepreneurial activity*
Quality of Life - *Measure factors like number of insured people, crime and poverty rates, recreational appeal, etc.*

Appendix 2

Table 5. *Cluster risks* (based on: Clar et al. 2008).

Risk	**Explanation**
Vulnerability	Due to its specialization, a cluster can be weakened by changing circumstances like technological discontinuities, a changing economy, trade patterns and customer needs
Lock-in effects	Highly relying on established practices by focusing too much on internal factors like local contacts and tacit knowledge, together with disregarding external factors and not looking ahead can lead to a locked-in effect
Creating rigidities	Dense cluster structures can be slow in adapting to changed circumstances; needed re-orientation or other structural adjustments can be postponed too long.
Decrease in competitive pressure	A high level of cooperation between firms can lead to reduced competitive pressure, which can negatively influence a firm's performance by decreasing

	productivity, or the innovation rate.
Self-sufficiency syndrome	A cluster relying too much on (the collective learning derived from) earlier successes faces the risk of failing to identify new developments.
Inherent decline	*As a successful cluster will generate higher factor costs, the neighbourhood may experience increased property prices and exclusion of outsiders* (Portes/Landolt, 1996).

Appendix 3

Table 6. *Types of clusters in terms of development* (based on Enright 1998).

Type	***Characteristics***
Working cluster	▪ Critical mass of local knowledge, expertise, personnel, and resources ▪ Creating agglomeration economies ▪ Used by firms in competing with firms outside the cluster ▪ Tendency to dense patterns of interactions among local firms ▪ Complex pattern of competition and cooperation ▪ Often able to attract mobile resources and key personnel from other locations
Latent cluster	▪ Critical mass of firms in related industries ▪ Sufficient to benefit from clustering, but: ▪ Less developed level of interaction ▪ Less developed level of information flows ▪ Wherefore not able to benefit entirely from co-location
Potential cluster	▪ Contain some elements necessary to become a successful cluster ▪ Gaps in inputs, services or information flows that support cluster development ▪ In order to benefit, these elements need to be deepened and broadened
Wishful thinking cluster	▪ Lack a critical mass of firms or favourable conditions for organic development ▪ Clustered firms are too broad ▪ Chosen by governments for support ▪ Rely on government, rather than market forces; 'policy driven clusters'

Appendix 4

Table 9. *Factors determining the scope of competition* (based on: Morosini 2004).

Scope of competition of industrial clusters

External factors

- Main customers
- Main product and services markets
- Key demographic trends
- Main legal and regulatory Frameworks

Internal factors

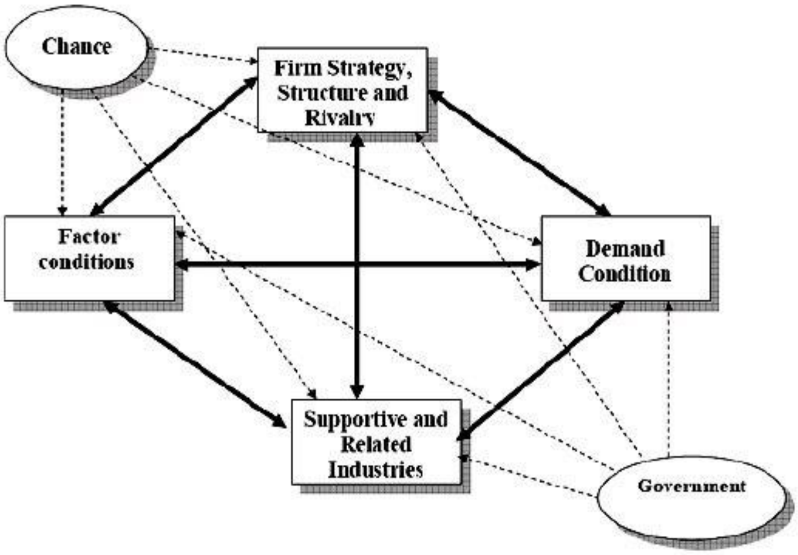
- Key resources (i.e. human capital, financial capital)
- Key processes (i.e. innovation, product development, supply chain management)
- Key competencies and capabilities
- Key competencies and capabilities (i.e. key technologies, speed of innovation)

Social factors

- Learning (i.e. about customers, products, technologies, managerial approaches)
- Knowledge creation
- Knowledge sharing
- Cultural behaviour and norms

Appendix 5

Figure 3: *Porter's Diamond* (Porter 1998a).



Appendix 6

Table 16. *Value of research and development alliances in pharmaceuticals/biotech by metropolitan area, prior to 1990, 1990-1995, 1996-2001* (Lazonick 2007).

Metropolitan Area	$ millions			percent of period total*		
	Pre-1990	1990-1995	1996-2001	Pre-1990	1990-1995	1996-2001
Boston—Worcester—Lawrence, MA—NH—ME—CT CMSA	254	882	3,924	30.6	17.5	38.3
San Francisco—Oakland—San Jose, CA CMSA	230	1,357	1,205	27.7	27.0	11.8
San Diego, CA MSA	46	1,022	1,615	5.5	20.3	15.7
Raleigh—Durham—Chapel Hill, NC MSA	0	33	192	0.0	0.7	1.9
Seattle—Tacoma—Bremerton, WA CMSA	68	45	579	8.2	0.9	5.6
New York—Northern New Jersey—Long Island NY—NJ—CT—PA CMSA	149	724	1,729	18.0	14.4	16.9
Philadelphia—Wilmington—Atlantic City PA—NJ—DE—MD CMSA	5	85	127	0.6	1.7	1.2
Los Angeles—Riverside—Orange County, CA CMSA	0	73	69	0.0	1.5	0.7
Washington—Baltimore, DC—MD—VA—WV CMSA	17	260	358	2.1	5.2	3.5
Total value of R&D alliances for nine leading metropolitan centers	769	4,481	9,798	92.7	89.2	95.6

Appendix 7

Figure 14. *Leading States—Bioscience Higher Education Degrees 2006* (Battelle BIO 2008).

Bioscience Higher Education Degrees			
Leading States	Total Degrees	Leading States	Per 1 M Population
California	17,051	Massachusetts	5,293
Illinois	9,622	District of Columbia	5,005
Texas	9,096	Maryland	3,159
New York	8,510	Rhode Island	3,142
Pennsylvania	7,506	Connecticut	3,057
Florida	5,717	Washington	3,040
Ohio	5,351	Pennsylvania	2,998
Michigan	4,721	Vermont	2,638
Massachusetts	4,321	North Carolina	2,635
North Carolina	4,174	New York	2,573

Source: Battelle calculations—based on NCES IPEDS data and U.S. Census Bureau population estimate.

Appendix 8

Figure 15. *Leading States—Bioscience Higher Education Degrees 2008* (Battelle BIO 2010).

Bioscience Higher Education Degrees			
Leading States	Total Degrees	Leading States	Per 1 M Population
California	19,999	District of Columbia	1,824
Texas	10,504	North Dakota	926
Illinois	10,355	Nebraska	813
New York	9,630	Illinois	806
Pennsylvania	8,390	Rhode Island	785
Florida	6,886	South Dakota	779
Ohio	6,206	Vermont	773
Michigan	5,548	Massachusetts	751
Massachusetts	4,916	Wisconsin	728
North Carolina	4,473	Utah	721

Source: Battelle calculations based on National Center for Education Statistics (NCES-) Integrated Postsecondary Education Data System (IPEDS) data and the U.S. Census Bureau population estimates.

Appendix 9

Table 18. *Top 20 employers in Cambridge, Massachusetts, 2006* (Lazonick 2007).

Name	Number of Employees	Organization Type
Harvard University	10,282	University
Massachusetts Institute of Technology	7,026	University
City of Cambridge	3,251	Government
Cambridge Health Alliance	1,775	Healthcare provider
Biogen Idec	1,767	Biopharmaceutical drugs
US Government	1,656	Government
Mount Auburn Hospital	1,379	Hospital
Millennium Pharmaceuticals	1,339	Biopharmaceutical drugs
Genzyme	1,231	Biopharmaceutical drugs
Draper Laboratory	1,052	R&D lab, including biomedical engineering
Novartis Institute for Biomedical Research	960	Biopharmaceutical drugs
Wyeth Research	780	Biopharmaceutical drugs
EF International	703	Language school
Commonwealth of Massachusetts	692	Government
Quest Diagnostics	649	Diagnostic testing, including biomedical
Camp, Dresser, and McKee	631	Engineering
Whole Foods	612	Supermarket
Lesley University	569	University
Vertex Pharmaceuticals	539	Biopharmaceutical drugs
Shaws Supermarkets/Star Market	510	Supermarket

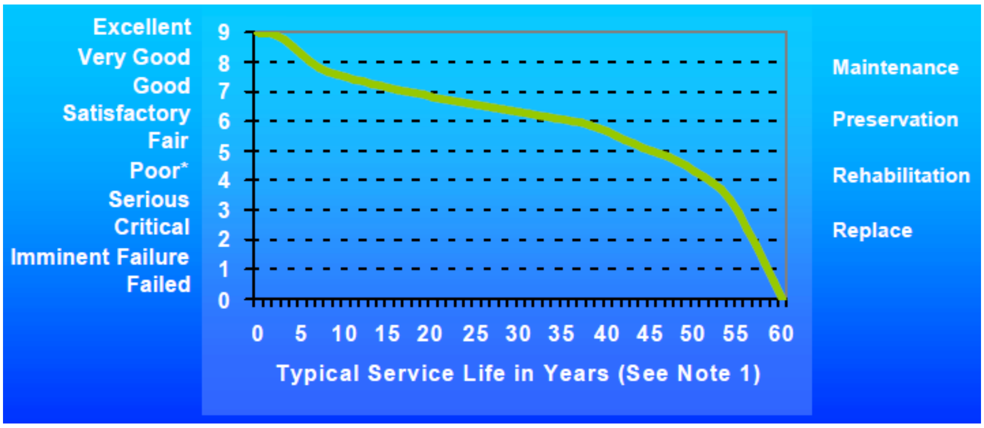
Appendix 10

Figure 17. *'Massachusetts road condition by functional classification'* (NI: Not inspected. States are not required to provide road condition data for local roads. Source: Massachusetts Infrastructure Investment Coalition 2006).

Classification	Very Good	Good	Fair	Mediocre	Poor	Total
Interstate	66.5%	5.1%	24.1%	4.0%	0.2%	100%
Arterials	0.8%	5.0%	50.4%	33.5%	10.3%	100%
Collector Roads	3.2%	10.4%	53.3%	24.4%	8.7%	100%
Local Roads	NI	NI	NI	NI	NI	NI
Total	5.2%	7.3%	50.3%	28.1%	9.1%	100%

Appendix 11

Figure 18. *'Bridge condition versus repair type'* ((Massachusetts Infrastructure Investment Coalition 2005).



Appendix 12

Table 20. *Biotech deals and investment comparison (based on Lazonick 2007).*

	San Francisco Area	Greater Boston Area	San Diego Area
1995 – 2000			
Biotech deals (numbers)	369	314	238
Biotech Investment ($m)	3,277	2,135	1,605
2001-2006			
Biotech deals (numbers)	522	409	312
Biotech Investment ($m)	6,855	4,855	3,534

Appendix 13

Figure 22. *2009 NIH funding by state* (Battelle BIO 2010).

NIH Funding			
Leading States	Total in $ Thousands	Leading States	$ Per Capita
California	$3,852,298	Massachusetts	$429.80
Massachusetts	$2,833,927	District of Columbia	$374.76
New York	$2,318,843	Maryland	$207.24
Pennsylvania	$1,658,949	Rhode Island	$167.52
Texas	$1,283,792	Connecticut	$155.22
Maryland	$1,181,164	Washington	$143.11
North Carolina	$1,141,200	Pennsylvania	$131.61
Washington	$953,722	North Carolina	$121.65
Illinois	$884,277	New York	$118.66
Ohio	$768,868	Vermont	$118.55

Appendix 14

Figure 23. *Top 15 recipients of largest NIH funds (BIO 2008).*

Rank	($ millions) Award
1. Massachusetts General Hospital	$301
2. Brigham and Women's Hospital	$241
3. Massachusetts Institute of Technology	$184
4. Harvard University (Medical School)	$166
5. Boston University Medical Campus	$129
6. Beth Israel Deaconess Medical Center	$129
7. Dana-Farber Cancer Institute	$128
8. Harvard University (School of Public Health)	$116
9. University of Massachusetts Medical school, Worcester	$109
10. Children's Hospital Boston	$92
11. Tufts University Boston	$66
12. Boston University	$50
13. New England Medical Center Hospitals	$47
14. Harvard University	$44
15. Boston Medical Center	$41

Appendix 15

Table 29: *'Clusters: the confusion of definition' (Martin & Sunley, 2003)*.

Porter (1998a, p. 199) 'A cluster is a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities.'

Crouch and Farrell (2001, p. 163) 'The more general concept of "cluster" suggests something looser: a tendency for firms in similar types of business to locate close together, though without having a particularly important presence in an area.'

Rosenfeld (1997, p. 4) 'A cluster is very simply used to represent concentrations of firms that are able to produce synergy because of their geographical proximity and interdependence, even though their scale of employment may not be pronounced or prominent.'

Feser (1998, p. 26) 'Economic clusters are not just related and supporting industries and institutions, but rather related and supporting institutions that are more competitive by virtue of their relationships.'

Swann and Prevezer (1996, p. 139) 'Clusters are here defined as groups of firms within one industry based in one geographical area.'

Swann and Prevezer (1998, p. 1) 'A cluster means a large group of firms in related industries at a particular location.'

Simmie and Sennett (1999a, p. 51) 'We define an innovative cluster as a large number of interconnected industrial and/or service companies having a high degree of collaboration, typically through a supply chain, and operating under the same market conditions.'

Roelandt and den Hertag (1999, p. 9) 'Clusters can be characterised as networks of producers of strongly interdependent firms (including specialised suppliers) linked each other in a value-adding production chain.'

Van den Berg et al. (2001, p. 187) 'The popular term cluster is most closely related to this local or regional dimension of networks... Most definitions share the notion of clusters as localised networks of specialised organisations, whose production processes are closely linked through the exchange of goods, services and/or knowledge.'

Enright (1996, p. 191) 'A regional cluster is an industrial cluster in which member firms are in close proximity to each other.'

[i] Enright, M.J. (1998). The globalization of competition and the localization of competitive advantage: Policies toward regional clustering. Paper presented at the Workshop on the globalization of multinational enterprise activity and economic development, May 1998, p. 3.

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[iv] DTI (2004), pp. 16-17.

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[vii] Enright (1998), p. 16.

[viii] Ibid., p. 16.

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[xii] Enright (1998), p. 16.

[xiii] Perry, M. (2005). Business Clusters. An international perspective. Abingdon: Routledge, p. 15.

[xiv] Ibid., p. 10.

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[xviii] Enright (1998), p. 17.

[xix] Ibid., p. 17.

[xx] Ibid.

[xxi] Ibid., p. 19.

[xxii] Enright (1998), p. 19.

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[xxiv] DTI (2004). A practical guide to cluster development. A Report to the Department of Trade and Industry and the English RDAs, Ecotec Research & Consulting. Available at: http://www.dti.gov.uk/files/file14008.pdf, (last visited: March 9th, 2011), p. 6.

[xxv] Clar (2008), pp. 22-23. *Clar et al.'s factor 'promotion of cluster development by an experienced facilitator or promoter' is categorized under critical success factor number 1, listed above. Not a single person but a government agency then takes on the role of promoting the cluster. In this way, many factors formulated differently share essentially the same meaning.*

[xxvi] DTI (2004), pp. 5-6.

[xxvii] Ibid., p. 6.

[xxviii] Ibid., p. 6.

[xxix] Clar (2008), p. 14.

[xxx] Ibid., p. 14, *referring to Harrison and Glasmeier (1997) in stating that industry cluster respond best to incremental changes in technology and market demand.*

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[xli] Ibid., p. 8.

[xlii] Ibid.

[xliii] Ibid., p. 9.

[xliv] Ibid.

[xlv] Ibid., pp. 19-20.

[xlvi] Ibid., p. 20.

[xlvii] Ibid.

[xlviii] Ibid., pp. 20-21.

[xlix] Ibid., p. 11.

[l] Delgado, M., Porter, M. Stern, S. (2008). Convergence, Clusters and Economic Performance. Available at: http://www.nber.org/~mdelgado/index_files/DPS_Cluster.pdf, (last visited: March 9th, 2011), p. 5. *The research was conducted using the a dataset from the US Cluster Mapping Project, including many attributes of cluster composition and economic performance between 1990 and 2005, covering 177 areas in the US.*

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[liii] Morosini (2004), p.313

[liv] Ketels (2003), pp. 13-14.

[lv] Ibid., p. 14.

[lvi] Ibid., p. 14.

[lvii] Ibid., pp. 313 and 325-326.

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[lxiii] Morosini (2004), p. 321.

[lxiv] Porter (1998), pp. 1-14.

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[lxxvi] Ibid., p. 16.

[lxxvii] Ibid.

[lxxviii] Ibid., p. 22.

[lxxix] Ibid., pp. 25-26.

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[lxxxi] Lazonick (2007), p. 19.

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[xciii] *Ibid.*

[xciv] MBC (2010).

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[xcvi] Ibid., p. 35.

[xcvii] The differences of $311m, $46m, $132m and $153m, make up for an average of $160.5m.

[xcviii] The differences of $81m, $105m, $834m, $440m and $1.1b make up for an average of $512m.

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[ci] Nakajima and Loveland (2007), p. 11.

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[civ] Battelle BIO 2008, p.15.

[cv] Lazonick (2007), p. 15, PWC (xxxx), p. 12.

[cvi] BIO (2008), p. 14.

[cvii] BIO (2008), pp. 14-15.

[cviii] BIO (2008), pp. 14-15.

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[cxix] Ibid.

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[cxxi] Ibid., p. 202 (as an example Perry refers to the variableness of the sub-concept of ‘business interdependence’).

[cxxii] Ibid., p. 207.

[cxxiii] Ibid.

[cxxiv] Ibid.

[cxxv] Ibid., p. 204.

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