Biotechnology in Denmark and Sweden

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CHAPTER 10. BIOTECHNOLOGY IN DENMARK AND SWEDEN[1]

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INTRODUCTION

Being a 'basic technology' or 'general purpose technology' biotechnology (like ICT) introduces fundamentally new technical principles that over time are expected to influence a broad range of other technologies. As these basic technologies develop, mature and integrate with other technologies it subsequently becomes more and more difficult to classify firms and activities according to their primary technology input and output. Reflecting this trend recent analyses often use the term 'life science' as a wider industrial classification for biotechnology related products and processes. Following Gestrelius, Sandström and Dolk (2008) 'life science industry' in this chapter refers to biotech companies within the three sectors: biotechnology, pharmaceuticals and medical technology. Applying this broad definition, life science holds strong positions in Denmark and Sweden. If we take traditional performance measures as patents, publications, new products, pipeline development, and new companies, Danish and Swedish life science industry in most categories belongs to the top five in Europe – if measured by capita.

There are several interrelated factors explaining this. Some relates to the overall general characteristics of the Danish and Swedish National Innovation Systems linked to the welfare state, some are specific for the life science sector, and some are even specific for particular technology areas and sub-sectors within life science. Specific framework conditions for the life science include for instance particular research funds for life science, European and national policies aiming at stimulating life science implementation. Technology specific framework conditions include for instance regulations for testing drugs, or specific tax reductions for bio-fuels. As in most OECD countries, life science is a prioritized policy area in both Sweden and Denmark.

Looking across the various specificities between the two countries, and the different life science technologies especially, the following factors have played a key role as drivers for the industrial success of Danish and Swedish life science sectors:

- *Home market and path dependency in the knowledge base.* The origin of the Danish and Swedish Life science industry has two main tracks back in time. One track relates to the Danish and Swedish welfare systems, especially within health care and environment. Both countries have a long history of research and industrial development within

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pharmaceuticals. The other track relates to the national production structures - in Denmark especially a long tradition of agriculture and food production and in Sweden raw materials (wood, pulp and paper industries).

- *Education, research and access to qualified employees.* The high research intensity of life sciences makes companies in this field very dependent on access to university research and graduates. This is clearly reflected in the fact that most companies locate their activities in close connection to the dominating universities and research institutes within the field. This is especially visible in the Danish case, where more than 80% of the companies and 90% of the employment in life sciences are located in the bi-national cluster, Medicon Valley, covering the Copenhagen area and the Skåne region of Southern Sweden. The rest of the Danish life science sector is located in close connection to the university cities Århus, Odense and Aalborg. In Sweden we see similar clustering of the life science industry around Stockholm/Uppsala, Gothenburg, Malmö/Lund and Umeå – with Stockholm/Uppsala hosting more than half of the Swedish employment in life science.
- *Network and triple helix collaboration.* A central feature of both the Danish and the Swedish national innovation systems is a relatively elaborated tradition for collaboration and networking between key actors, supported by public targeted funding for stimulating collaboration between universities, semi-public research institutions and industry.
- *Access to financial resources* is a key factor for any research-intensive industry and it has also been high on the policy agenda in both countries. In Denmark several of the larger life science companies (Novo Nordisk, Novozymes, Leo Pharma, Lundbeck, Carlsberg, Oticon) are controlled by specific foundations with access to research funds high on the agenda.
- *Attractive environment for clinical trials.* Especially within life science the possibilities to use systematic population and health data registers, allowing for patients to be tracked over time, provides an important research base and attractive environment for clinical trials. Both Denmark and Sweden provide such opportunities.

It is important to underline that it is not one single factor but the interdependency and co-evolvement of these various factors that have shaped the development of the Danish and Swedish Life science sector. Within the broader context delineated above and with reference to the background information on biotechnology industry characteristics and policy environment in Demark and Sweden as presented in Chapter 9, we take a closer look at two key aspects. First, the role of universities as one of the key actors, and second the role of public policies. Despite many similarities between the two Scandinavian neighbor countries, there are – as the following reveals – also interesting differences that are relevant seen from a policy learning perspective.

BIOTECHNOLOGY IN DENMARK AND SWEDEN AT A GLANCE

SWEDEN

Sweden historically has a record of strong medical research, forming a foundation for current activities and strengths in the biotech field. Two large international corporations have – part of

– their roots in Sweden. Both have merged with international partners in recent years, and currently only one of them, AstraZeneca, remains relatively intact. With approximately 28% of the total employment in Swedish life science AstraZeneca is still dominating the life science industry. The other, Pharmacia, has recently gone through a process of mergers and divisions, resulting, it has been argued, in a loss of competence that is problematic not least for the general development of Swedish pharma and biotech.

In their study from 2007, Sandström, Bergqvist and Dolk identified approximately 617 companies with 34,400 employees in the life science industry in Sweden involved in manufacturing, consultancy, product development and/or research and development (R&D).

Table 10.1: Number of companies and employment in Swedish Life Science industry 2006.

	Companies	*Employment*
Pharmaceuticals	229	19.474
Biotechnology	251	8.931
Medical technology	326	12.284
Total[1)]	617	34.468

[1)] 'Total' add up less than sum of the three sectors due to overlap between the sectors
Source: Sandström, Berqvist and Dolk (2007)

Pharmaceuticals
Within pharmaceuticals AstraZeneca accounts for nearly half of the 19.500 employees in the sub-sector. Pfizer and Bivitrum are two additional important players. Within pharmaceuticals drug discovery and drug development is by far the largest business segment (ibid.).

Biotechnology
The majority of the 251 companies in the biotechnology sector are active either in biotech tools and supplies, bioproduction or drug discovery. AstraZeneca is not active in this sub-sector, but a few other large companies, like the Pfizer bioproduction and GE healthcare Biosciences, are included (ibid.).

Medical technology
The medical technology sector employs 12,280 people in 326 companies. 60% of the total employees in the sector work within the three dominating business segments: electromedical equipment, active and non-active implantable devices, and medical disposables (ibid.).

The real growth in life science companies has occurred since the end of the 1990s. Among companies in existence in 2004 90% were formed after 1990, and 63% after 1999. Seen over the last decade (1997 until the present) there has been a modest positive trend in terms of relative results, but with a weakening towards the end. During the same period there has been increase both in terms of biotech companies and employees in that sector. It is particularly in the pharmaceutical and in the equipment/instrument industries that we find biotech making contributions to R&D and production. In both industries we find combinations of small innovative companies, linking academic research and corporate R&D to more well-established corporations (Norgren et al, 2007; Bergqvist, 2008).

For an extended period in the 20th century and up until now, a rather limited set of large companies have been vital components of the Swedish economy. The dominance of MNCs in the Swedish economy applies also in the life sciences, where companies such as AstraZeneca and Pharmacia – as mentioned above – have merged into international conglomerates. As R&D and production are dominated by these actors and the priorities of the MNCs differ from the previously 'national' corporations, the sector as a whole has increasingly come to be appreciated as vulnerable, and in dire need of renewal. Still, however, the importance of AstraZeneca cannot be underestimated, and accumulated output within the sector to a considerable degree depends on the performance of that very corporation.

DENMARK

In Denmark industrial development of pharmaceuticals and biotech goes back to the early industrialization and has its historical roots in food production. As Table 10.2 shows, also medical technology as audiology, hearing aids and other medical devices builds on a long industrial history (Gestrelius 2008).

Table 10.2: Selected Danish large and old companies within life science

Company	**Established**	**Employees (FTE), Denmark 2006**
Pharmaceuticals		
LEO Pharma	1908	1.200
Lundbeck	1915	2.000
Novo Nordisk A/S excl. NNIT &NNE Pharmaplan (1989)	1920's	10.000
Nycomed (as DAK)	1922	700
Ferring Pharmaceuticals	1956/1999	400
ALK-Abelló	1923/1992	500
Biotech		
Carlsberg Research Centre	1875	175
Danisco (incorporated in Genencor in 2005)	1872	1450 (excl. sugar division)
Novozymes (split from Novo Nordisk in 2000)	1939	2200
Chr. Hansen	1874	850
Hearing aids and audiology measurements		
Oticon (W Demant)	1904	1.300
GN Resound (GN Syore Nord)	1943	400
GN Otometrics (GN Store Nord)	1960	200
Widex	1956	700
Interacoustics (W Demant)	1967	150
Sonion	1974	250
Medical devices and analysis instruments (excl. audiology)		
Radiometer	1936	950
Ambu	1937	350
Coloplast	1957	2400
Unomedical (first Pharma Plast, later Maersk medical)	1964	750
William Cook Europe	1969	600

Source: Gestrelius 2008.

The current turnover of the life science industry accounts for around 5% of the Danish GDP, making it a relative important industrial player for the Danish economy (Gestrelius 2008). Around 280 Danish life science companies have been identified, employing nearly 40.000 persons. According to the study made by Gestrelius, Sandström and Dolk (2008), 90% of the companies are research-intensive companies and manufacturing companies. A few large companies (over 500 employees) dominate the industry. This is especially the case within the business segment 'drug discovery and development' where Novo Nordisk alone employs around 10.000 persons, corresponding to 25% of the total employment of the Danish life science industry or half the employment within pharmaceuticals.

Table 10.3: Number of companies and employment in Danish Life Science industry 2006.

	Companies	*Employment*
Pharmaceuticals	129	21.363
Biotechnology	142	22.308
Medical technology	89	11.797
Total[1)]	280	39.375

[1)] 'Total' add up less than sum of the three sectors due to overlap between the sectors
Source: Gestrelius, Sandström and Dolk (2008)

Pharmaceuticals
As indicated above, especially one company, Novo Nordisk, dominates the Danish pharmaceutical sector. Furthermore, a few other companies like Leo Pharmaceuticals, H. Lundbeck and Nycomed have more than 1000 employees each (Gestrelius, Sandström and Dolk, 2008). These companies also belong to the drug discovery and development segment.

Biotechnology
In the Danish context there is a large overlap between the pharmaceutical and the biotechnology sector due to the fact that companies like Novo Nordisk, SSI, Ferring and around 50 young companies to a large extent base their products on biotech (Gestrelius, Sandström and Dolk, 2008). Novozymes, part of the Novo A/S and owned by the Novo Nordisk Foundation, with its 5000 employees is the largest company within the segment of industrial biotechnology. Novozymes, Chr. Hansen and Danisco specialise within enzymes, probiotics and cultures for food, health and industrial biotech. Furthermore, these large biotech companies are also active within energy and environmental biotechnology (for instance bioethanol) (ibid.).

Medical technology
The medical technology sector is dominated by three main business segments: medical disposables, electromedical & imaging equipment and audiological devices (ibid.). Within each of these three areas a few large international companies exist, for instance Coloplast, Unomedical and Dansac (medical disposables); Oticon, Widex and GN Resound (audiology/hearing aids) and Radiometer Medical (Electromedical & imaging equipment).

CLUSTERS AND TRIPLE HELIX RELATIONS

As life science represents an increasingly complex and widely distributed knowledge base, companies have become more and more dependent on collaboration with other companies, research institutes, hospitals and other actors (Cooke 2005, Moodysson et al. 2008). This is reflected in the very clear tendency for the life science industry to cluster and localize around a few larger universities in order to have access to a broad palette of relevant collaboration partners. At the same time it is an industry with a high degree of international research collaboration and multinational companies, where global network are crucial for innovation activities. Moodysson et al. (2008) seeks to explain this dichotomy around 'local node – global network' geography of innovation, or 'proximate' and 'distant' learning processes, by applying a distinction between 'analytical' and 'synthetic' modes of knowledge creation (Asheim & Gertler, 2005). In short, analytical knowledge creation mainly focuses on understanding and explaining based on discovery and application of science, while synthetic knowledge creation is mainly about engineering and concrete, technical problem solving. Both types of knowledge are present in most industries but to various degrees, and dependent on the concrete innovation activity in focus. Based on detailed case studies of different innovation projects in the Swedish-Danish cross-border Medicon Valley cluster they found that "analytical knowledge creation tends to be less sensitive to proximity effects between actors involved, thus favoring local collaboration. Synthetic knowledge creation, on the other hand, has a tendency to be relatively more sensitive to proximity effects between the actors involved, thus favoring local collaboration" (Moodysson et. al. 2008, p. 1052). Bringing in such more differentiated knowledge taxonomies may help explaining the clustering of the life science industry, and it might also be useful to include such considerations in (regional) policy making aiming at attracting and maintaining various types of knowledge intensive industries.

Figure 1 in Appendix provides an overview of life science clusters in 31 regions (NUTS II level) of the Baltic Sea region. The region includes more than 102.000 employees in life science (2004). Out of these Copenhagen (DK) accounts for around 22.200 employees, Stockholm/Uppsala (S) 16.900 employees, Malmö (S) 5.900 employees and Gothenburg (S) 5.400 employees. In other words, half of the employees are concentrated in these four clusters. The rest – except Kiel (GE) with 14.700 employees and Helsinki (FI) with 7.000 employees – are rather small clusters (Graversen & Rosted, 2010).

Swedish biotech research, both academic and corporate, is located mainly in four regions: Uppsala/Stockholm, Gothenburg, Malmö/Lund, and Umeå.

Uppsala/Stockholm is the strongest cluster in Sweden, in which we find a focus on pharmaceuticals, bioproduction, biotech tools and functional food. The quality of research and institutions is high by international standards. Academic actors include Karolinska Institute, Stockholm and Uppsala universities, Swedish University of Agricultural Sciences, and university hospitals in both cities. Companies in the region include AstraZeneca, GE Healthcare, Biovitrum, Biacore and Pfizer. As a measure of the strength of a key actor in the biomed field, Karolinska Institutet in Stockholm is ranked below Harvard, Cambridge and Oxford, but ahead of Stanford, Imperial College and Johns Hopkins.

In *Gothenburg* the cluster strengths are found in biomaterials, stem cell research, medical technology, diagnostics and analytical tools, cardiovascular and metabolic diseases, drug discovery. The regional academic infrastructure in the field is Gothenburg University, Chalmers University of Technology, and Sahlgrenska University Hospital. Among important corporations are found AstraZeneca, Nobel Biocare, NeuroSearch, and Cellartis.

In *Umeå* a focus on biomedicine, microbiology, protein chemistry, molecular genetics and plant biotechnology is found. The central academic actor is Umeå University, and we also find here the Swedish University of Agricultural Sciences (as in Uppsala), along with a range of research centers linked to the university.

In the *Malmö/Lund* region the main focus is on pharmaceuticals, agrobiotechnology, and environmental biotechnology. Lund and Malmö universities, the Ideon and Medeon Science Parks, and the university hospitals in the respective cities provide an infrastructure. Important companies include AstraZeneca, Active Biotech, Gambro, Bioinvent and Acadia. Of special interest in this study is the Malmö/Lund region, as it also forms part of the cross-national Øresund Region, together with Copenhagen/Zealand in Denmark, see below.

There are indications that the concentration to these regions has become even more pronounced in recent years (Sandström & Norgren, 2003; McKelvey et al, 2003; Ministry of Industry, Employment and Communications, 2005; Biotech Sweden, 2009).

Medicon Valley

Under the ’Medicon Valley’ initiative or ’brand’, officially in place since 1997, the cross-national Øresund Region has positioned itself as one of the leading biotech regions in the world, alongside Cambridge, Boston and San Francisco. Obviously it builds on a longer history than that, going back even to the 19th century. It is one of the major life science clusters in Europe; the Swedish part of it constitutes 20% of the national sector as a whole (Biotech Sweden, 2009). As mentioned in the introduction, in Denmark it accounts for nearly 80% of the Danish biotech companies and for 90% of the Danish employment in the sector.

The strength of the Øresund Region can be said to rest upon three pillars. The primary strength, according to a study by The Boston Consulting Group (BCG) (2002), is the presence of large and mature pharmaceutical companies (especially Novo Nordisk, AstraZeneca, H. Lundbeck, and LEO Pharma), an almost unique concentration; the only comparable concentration is found in Boston. These corporations provide a kind of basic structure for the region, for other actors, both academic and commercial, to build upon. The relative maturity of the corporations of the region may outweigh some of the generally problematic ’youthfulness of the Europe biotechnology sector’ (Critical I, 2006), but this can be considered mere speculation. In addition to the mature companies is found a range of up-starts, prominent among which are: Acadia, Active Biotech, Alligator, BioInvent, Gambro, Biogaia, Probi, and Camurus.

Add to this the broad range of academic research available in the region (primarily Copenhagen and Lund universities, and their associated university hospitals), and, finally, well established interaction of commercial actors and academic research around clinical research and trials. The actors in the region together contribute what is considered the three crucial elements in the success of biomedical R&D: basic academic research, corporate R&D, and

clinical R&D. Relevant both to current conditions and to future development is the breadth of activities in the region. In BCG's evaluation Medicon Valley comes out as one among four top biotech regions in the world; the others being Boston, San Francisco Bay Area, and Cambridge (U.K.). According to the Medicon Valley homepage, the cluster includes 477 companies, 10 universities, and 33 hospitals (www.mediconvalley.com), see Appendix Figure 2.

Unlike some other rather specialized biotech regions in Europe the operations of corporations as well as the academic research performed in the Øresund region cover many areas, foremost among them diabetes, inflammatory diseases, neuroscience, and cancer. Due to the presence and high profile of all relevant categories of actors, the commercial and appropriation potential within these areas are considered the highest. According to the study, in the Øresund region other research areas with a high reputation are also found but with a lower commercial potential; those are hematology, infectious diseases, receptor studies, molecular biology, stem cell research and cardiology (The Boston Consulting Group, 2002).

As much of the evolving 'ecology' among mature Big Pharma corporations and smaller more flexible biotech companies concerns opportunities for interaction, the possibilities of the latter supplying the former with new drug candidates, it is crucial that conditions for such interaction do indeed emerge. The Ideon Science Park, in the immediate vicinity of Lund University can be appreciated as a facilitator to such ends. It was the first of its kind in Scandinavia, and has so far provided opportunities for such interaction. A broad range of new companies, as well as spin-outs from the former Pharmacia operation can be found in the science park.

However, it should be emphasized that the true and hoped for synergies of R&D activities in 'Medicon Valley' as a whole, across national boundaries, remain to materialize. The quality of academic output in some studies is found to be high, but innovations in Denmark and Sweden are not on corresponding levels. Among weaknesses found is that the number of scientific discoveries leading to patents is high, but the commercial use of those patents is low. Patents can be appreciated either as actual innovation or as innovation potential. It seems that quite some effort is spent on securing patents, but not so much, in comparison, on developing research results into long term business cases. Additionally, the relative low-staffed Technology and Transfer Offices (TTOs) have limited industry or commercial experience. These analyses point in the direction of focusing efforts on improving the innovation systems as the primary area of action, overcoming the often observed fragmentation of the regional innovation system (Medicon Valley Academy, 2004).

The various actors (academic research, corporations, and hospitals for clinical trials) still operate under the general conditions of the national systems (Denmark and Sweden, respectively). Differences apply e.g. for funding and for the handling of intellectual property rights, and it is unlikely that they will be harmonized in the near future. The Medicon Valley Alliance points to obstacles that impede integration and cooperation in the region, for instance how national boundaries in some cases prohibits cross-border investments. While earlier studies have underlined that though the general picture of the presence of relevant categories of actors applies, the actual interaction was limited (The Boston Consulting Group, 2002; Medicon Valley Alliance, 2004), a recent study (Graversen & Rosted, 2010) finds that cluster concentration actually matters for economic performance. For instance, 41% of firms report a

high level of collaboration on research. Graversen & Rosted (2010) conclude that "cluster policies seems to matter for innovation and collaboration and through those channels leading to higher productivity" (p. 122).

THE ROLE OF UNIVERSITIES IN BIOTECH RESEARCH

Research in Life sciences accounts for 40% of research performed at Swedish universities. This share is comparable to that found in other countries.[2] In the most recent years (2005-2008) the funding has increased by approximately 20%. In comparisons such as these it should, however, be noted that many countries of comparison are currently in a phase with even larger relative increases in funding (Norgren et al, 2007).

Access to qualified graduates and PhDs is especially important for a research-intensive industry as life science, and one of the main explanations why life science industries cluster around the universities. Sweden and Denmark both have a relatively high share of graduates and PhDs within life science, and the 'production' of candidates is increasing. In Denmark around one third of the co-funded Industrial PhDs is found within life science (period 2002-2006).

Life science is a highly dynamic sector with relatively many new small start ups, and university spin-offs is an important part of the industrial dynamics. In Denmark, more than half of the start-ups have their roots in local Public Research Institutions and universities.

Both Sweden and Denmark belong to a group of countries (along with e.g. Switzerland, USA and Finland) that display a range of strengths and few weaknesses across R&D and commercialization. Measured in terms of patenting, Denmark performs exceptionally well in comparison with other EU countries, a position that it conquered already in the mid-1990s. However, both Sweden and Denmark suffer from some weaknesses when it comes to publicly funded R&D, and Sweden, additionally, when it comes to general funding available for biotech research (Reiss et al, 2004; Patel et al, 2008).

From the perspective of companies, collaboration with academia is important for several reasons. This is especially pronounced for small and medium sized companies. It is difficult, however, to obtain information on the exact volume of such collaboration. Seen across the entire population of companies (all industries), active in relevant fields, R&D collaborations primarily take place with national universities, but there are significant differences between different categories of companies. Collaboration comes in various forms: with R&D work together with research groups at universities, co-authoring of articles, and recruitment – not least in certain geographical locations. However, within biotech the overall collaboration for both Swedish and Danish firms is oriented towards international linkages, especially with U.S. partners. Such cooperation is more important than local or European. Co-location in firm to firm-collaboration is not found to be an important factor. In the Swedish case McKelvey et al. (2003) found that those intra-Swedish deals that do occur are mostly between the largest firms

[2] Danish universities account for 40% of the public R&D spending within health. 32% of universities' R&D spending is within health.

and SMEs, supporting the observation that the larger firms are indeed international in orientation, with relatively little connection to the national development. The increasing importance of tapping into strategic international collaboration is clearly reflected in The Life Science Ambassador Program launched by the Medicon Valley Alliance in 2008, see box.

The Life Science Ambassador Programme

The Life Science Ambassador Programme is a global network of innovative life science clusters around the world. The Programme provides companies and research institutions within the life sciences industry, a unique opportunity to find partners, collaborators, investors, and sponsors around the world.

The Life Science Ambassadors operate as full time interlockers, identifying potential opportunities with strategic partners and facilitating communication between decision-makers so as to foster the development of global collaborations and partnerships. The Life Science Ambassadors are uniquely proficient in providing such connections because they are all multi-lingual and have extensive experience, knowledge, and established networks in the life sciences industry from the cluster they represent.

The Life Science Ambassador Programme promotes innovation and increases the competitiveness of the participating clusters through the building of strategic partnerships and international alliances. Companies and academic institutions will have access to leading life science innovation environments and talents to further research and development, which may lead to commercial opportunities.

Currently, five regions are participating in the exchange of Life Science Ambassadors: Medicon Valley, Denmark and Sweden, Kobe-Kansai, Japan, British Columbia, Canada, Seoul, South Korea and Boston, USA.

http://www.ambassadorprogramme.com/ (September 2010)

When it comes to collaboration between universities and firms, the picture is slightly different. Here we find, regardless of the main trend, examples of local and national initiatives. For the main regions mentioned above it is possible to identify rather well established and long-term forms for cooperation, involving firms and academic research. In Uppsala and Lund, for example, we find such built upon spin-offs from the former Pharmacia operation. Differentiating between three types of collaboration – firm-to-firm, firm-to-academia, and academia-to firm, it is in the last category that we find most examples. McKelvey et al. (2003) found that Swedish biotech SMEs are more likely to engage in collaborations with universities, in forms that to some degree depend upon geographical proximity. In consequence, the biotech specializations at various universities have implications for what substance there might be in these collaborations.

BIOTECHNOLOGY POLICY ENVIRONMENT

The debate on the future of life sciences and biotech in Sweden and Denmark takes place under conceptions similar to those found in the rest Europe for the last couple of years. A recurrent theme is the development in Europe compared to the U.S. In these analyses Europe mostly comes out unfavorably, in the sense that it does not get enough productivity out of its R&D investments.

Since the late 1990s the notion of a 'Swedish paradox' has been put forward, claiming that the high input of R&D investments is not reflected in expected corresponding output in form of innovation and growth (Bitard et al., 2008). The debate can be said to relate back to similar ideas in the 1980s on the prevalence of 'eurosclerosis', i.e. rigidities in markets resulting in the European nations lagging behind its main competitors globally. Both concepts have been criticized from theoretical as well as empirical points of departure (Granberg & Jacobsson, 2006; Ejermo & Kander, 2008), but they still frame much of the analyses of the current orientation of academic research.

A general funding issue, often brought up especially by actors directly involved in innovation activities, is that Sweden is one among only a few countries within the OECD not to have tax incentives for R&D, resulting, so the argument goes, in competitive disadvantages. According to the critics this disadvantage is both real and symbolic, in the latter case as it may send a signal to actors and observers that Sweden does not promote innovation (Royal Swedish Academy of Engineering Sciences, 2008).

In Denmark, the discussion has focused more on the actual lack of public and private R&D investments (relative to especially Sweden and Finland) and the likelihood not to be able to fulfill the Bologna targets. However, especially in relation to biotech or life sciences, the access to funding has been relatively favourable. In Denmark specific foundations control several of the larger companies. This goes for instance for Novo Nordisk, H. Lundbeck and Leo Pharma. The same goes for some of the medical technology firms, for examples the Oticon and Danfoss foundations. In addition, biotech has been a priority area for the Danish State investment fund ('Vaekstfonden') that provides a broad spectrum of finance solutions for SMEs.

As in many other settings there has in both countries been an increased focus on how to make academic research more responsive to the needs of the private sector. In Denmark this discussion has been linked to a policy with a strong focus on commercialization of university research. Due to certain idiosyncrasies of the Swedish research system the question of 'industry relevance' has some special features that concern the division of labor between various categories of research-performing actors. Over the second half of the 20th century universities in Sweden came to take on the role that in comparable countries is performed by research institutes. In Sweden the industrial research institutes sector is small, and there are no institutes specialized in biotech (Sandström & Norgren, 2003). In a formulation widely in circulation the universities should be 'the research institutes of society'. This, in turn, has meant that the transformational pressure on universities, to link and to some degree adopt academic research to the demands of industry, arguably, has been higher in Sweden. Obviously this is an issue of considerable importance to actors inside and outside academia, as it concerns fundamental ideas and ideals regarding the ethos and justification of universities.

Another recurrent theme in the Swedish debate is the dominance of a few major corporations in the national economy. Swedish industry in general is heavily export oriented, and top-heavy in the sense that across sectors a few large corporations have come to dominate, being responsible for roughly 70% of business R&D (Reiss et al, 2008). In terms of volume the most important sectors are non-electrical machinery, motor vehicles, pulp and paper, telecommunications and iron and steel (Marklund et al, 2004). Many of the companies in those sectors trace their roots back to the 19th or early 20th century, and over the years the country as well as certain regions have come to depend considerably on the strength of those companies on the global market. In recent decades many of them have been absorbed into international MNC groups, thus losing their previous national focus. This, it has often been observed, makes Sweden vulnerable to the vagaries and priorities of these MNCs. Thus, renewal from below has emerged as a concern, as there seems to be a lack of expanding SMEs that can fill any void emerging when the MNCs change their focus.

In contradistinction to Sweden, the Danish 'mode of innovation' has historically been dominated by SMEs continuously making incremental innovations based on learning by doing, learning by using and learning by interacting, especially with customers and suppliers (Christensen et al., 2008). However, when it comes to private R&D expenditure, the distribution is much skewed. In 2001 2% of all firms conducted nearly 40% of the total private R&D. In particular the two major companies, Novo Nordisk and Sauer Danfoss, dominate the research scene. Although the main part of private R&D expenditure is in-house, there is an increasing tendency to establish laboratories outside Denmark. This also goes for Novo Nordisk. Around 5200 people work in research out of Novo Nordisk's 29.000 employees. 55% of the employees are located outside Denmark (www.novonordisk.com (September 2010)). Although this trend is prevalent in most countries hosting large research-intensive international companies, it may be a cause of concern especially for a country with only a relatively few R&D-intensive firms.

POLICIES AND AGENDA SETTING ON NATIONAL LEVEL

Handling the boundaries for what to consider relevant to the development of 'biotech' proper is difficult, as much development of the field – both general and more narrow – is presumed to occur on the very boundaries between various disciplines, not only the life sciences but also e.g. information technologies (cf. Lacasa et al, 2004). In a sense, biotech can be appreciated as paradigmatically 'modern', as it is not so much a traditional 'discipline'; rather, it can be understood as a set of interrelated techniques and instruments, drawing on various bodies of knowledge. Such observations make it necessary also to consider the balance between vertical (sector specific) policy instruments and horizontal (generic). In addition to this the application fields corresponding to the dynamics of different industrial sectors should be taken into account. The outcome of considerations such as the above has implications for the choice among policy measures; how much and what type of intervention, or absence of it, is adequate. Over time one may notice in Sweden and in Denmark shift towards more of horizontal/generic funding instruments. (cf. Reiss et al, 2004; Lacasa et al, 2004).

The national policy on biotech is thus obviously linked to the more general research and industry policies. The 'toolbox' is similar, grounded in a rather common understanding of how companies, universities and research institutes may interact for production and welfare gains.

Table 10.4: Typology of biotechnology policies for Denmark and Sweden (2004)

Sub-areas of the Biotechnology Innovation System	Policy goals	Policy Area: Education	Research	Exploitation	Industrial development	Regulation	Fiscal measures	Demand
Development of the knowledge base and human resources	1. To promote high level of bio-technology basic research		5 5 4 3			5 5		
	2. To promote high level of industry-oriented (and applied) research		5 5 4 3					
	3. To support knowledge flow between scientific disciplines		4 4 3 3					
	4. To assure availability of human resources	3 4						
Knowledge transmission and application	5. To facilitate transmission of knowledge from academia to the industry and its application for industrial purposes			4 4 2 1		4 5		
	6. The adoption of biotechnology for new industrial applications						3 0	1 nd
	7. To assist firm creation	0 0			3 2 3 1	4 5	2 0	
Market	8. To monitor and improve the social acceptance of biotechnology							5 4
	9. To facilitate the introduction of new products					3 5		
	10. To strengthen the economic sectors exploiting biotechnology						3 0	
	11. To keep/attract large firms (important market, important for firm development: tacit knowledge etc.)						3 0	
Industry	12. To encourage business investment in R&D				3 3		4 0	
	13. To improve firm's competitiveness	0 0				4 5	4 0	
	14. To exploit regional potentials				1 1			

Source: Reiss et al. 2005.

Note: Light gray: generic policies; dark gray: biotechnology-specific policies

0: no policy in place; 1-5 scale for policy activity, where 5 is the highest level.

With pattern: DK; without Sweden

Table 10.4 uses a typology developed by Reiss et al. (2005) and Dominguez-Lacasa (2007), see similar typology in this volume Chapter 12 on Germany. The four sub-areas (Development of the knowledge base and human resources, knowledge transmission and application, market, and industrial development) provide a framework for the seven listed policy measures.

From an overall view the two countries look rather similar when it comes to policy implementation, although some differences exist, if we take a closer look, at some of the issues.

Development of the knowledge base and human resources

VINNOVA. In Sweden a major overhaul of the research funding system was implemented in 2001, including, among other things, the establishment of The Swedish Governmental Agency for Innovation Systems (VINNOVA), with a strong mandate to influence the interaction among academic and commercial actors. Other agencies reorganized or were established at same time, and the explicit purpose of the 2001 reform was threefold:

- to focus national efforts on a set of scientific areas appreciated to be of special importance
- to promote collaboration between actors involved in fundamental research and those actors more oriented towards development activities, and finally
- to facilitate the so called 'third task', i.e. society-wide information on and dissemination of research and results

The reform, and especially the establishment of VINNOVA, has been appreciated as a move to initiate a national, comprehensive policy on innovation, involving also a higher degree of coordination among funding agencies (D'Este & Costa 2007).

The reform, not least establishing an agency that in name and in deeds embodies the innovation system approach, can be understood as an instrument well anchored in a Swedish policy tradition of interventions compensating for market failures. Among the concrete initiatives taken we find several such instruments, such as linking actors to each other and thus creating or strengthening networks, also opening up cooperation across technological and scientific fields (cf. Lacasa et al, 2004).

The Swedish Foundation for Strategic Research. Another important actor in financing biotech research has been The Swedish Foundation for Strategic Research (SSF), a semi-public body established in the mid 1990s. The mission of the foundation is to support "both pure basic research and applied research, as well as research that bridges the gap between these extremes", a statement that might be understood as a tentative definition of 'strategic research', one that bears resemblance to VINNOVA's bridging role.

As Figure 3 in the Appendix shows the Danish funding system for research and innovation consists of several bodies from which life science and biotech can apply for funding (in competition with other research areas): *The Danish Council for Independent Research* funds specific research activities within all scientific areas divided into five main areas of which medical sciences is one. Another important body is *The Council for Strategic Research* with the ambitious mission to ensure Denmark's position as a global frontrunner regarding welfare, wealth and science in the short and long term. Furthermore, The Danish Council for Strategic Research seeks to promote international cooperation in research, including cooperation with the new high-growth countries. *The Danish National Advanced Technology Foundation* is an

independent body that offers grants in the form of co-funding for high-technology research and innovation initiatives and projects. The Danish National Research Foundation has the objective to promote and stimulate basic research at the frontiers of all scientific fields. The main funding mechanism is Center of Excellence (CoE). *The Danish Council for Technology and Innovation* administers a number of initiatives to promote innovation and dissemination of knowledge between knowledge institutions and enterprises:

- Cooperation and interaction (Innovation Consortia, Approved Technological Service, Industrial PhD, Knowledge Pilot, Networks of High Technology)
- Entrepreneurship and commercialization (Technology Transfer, Business Incubators)
- Initiatives at a regional level (Innovation environments, Regional growth environments, Regional ICT initiative)
- International innovation (Pre-projects to the European Commision's 7th Framework Programme)

In short, the development of the Danish research funding system has followed the same development path as most European research funding system in the sense that an increasing share of the funds are allocated to selected high-tech areas (biotech, nanotech, ICT, life science, renewable energy) at the same time as demands for consortia and excellence are put forward as.

Linkage to international research, and to international actors. In research as in the national economy in general, small economies are obviously highly dependent on international contacts. Furthering contacts with the internationally leading research environments poses special challenges for small countries. Thus, an important policy component has been to facilitate mobility for international researchers to Sweden and Denmark. Apart from the obvious issues related to research as such, reforming tax regulations for specialists in various fields, not only science, are also among the specifics discussed. Internationalization and international contacts are important in another dimension as well: new companies now finding themselves, ideally, in a growth phase, searching for partners and markets abroad are pressed to mobilize the resources necessary to link up to international actors. Supporting new companies, with limited resources, in establishing such contacts is an important general policy field. The instruments are organizations like for instance Invest in Sweden Agency, and its sister organization Invest in Denmark Agency. There are also regional initiatives for the same purposes, and Medicon Valley Alliance can be found among these.

Knowledge transmission and application

In both Sweden and Denmark various policy measures exist to stimulate collaboration between universities and firms. One example is the Danish 'Center Contracts', providing funding for research projects that include partners from universities, private companies and approved technological service institutes – GTS (Advanced Technology Group). The systemic view on innovation processes that informs much of the Swedish and Danish policy landscape, more or less prescribes an increased focus on network formation – academy, industry and public bodies on all levels. 'The triple helix' has entered as the general, rather uncontroversial heuristic within which policies are formulated and implemented. Much focus in the debate in many countries has so far been on strengthening the science base, appreciated as a prerequisite for the general

system performance, and this is in line with much of the development in countries of comparison (Lacasa et al, 2004). This goes for Sweden and Denmark as well, but the orientation of funding agencies, with an explicit agenda of furthering interaction among academia and industry, may very well be seen as a development in step with more generally observed trends, more application oriented initiatives increasing in relative weight. This is a shift that has brought considerable debate and occasional resistance, however strong the drift in line with the policy.

Among initiatives taken to further actual interaction between universities and companies we find the formation of a large number of ”competence centers” and networks. The guiding idea for these is to promote problem-oriented research, and still with high scientific quality. Related to this, the ambition to promote and vitalize the – so far – rather insignificant research institute sector is raised. This is considered to be especially important for SMEs as they, normally, do not in-house have enough research capacity. The institutes may serve both as R&D performing actors in themselves, and as bridges between academia and companies (VINNOVA, 2002).

Entrepreneurship and university-industry linkages. As a response to and confirmation of policy trends throughout industrialized economies in general there has in both Sweden and Denmark been an increased emphasis on academic entrepreneurship, and linking industry and universities. Several new companies stem from university research, and it is an obvious policy to discover and promote such opportunities. Academics often do not consider themselves entrepreneurs in a strictly commercial sense, and thus it becomes all the more important to implement support structures that allows a certain division of labor between different actors, such as the academics, TTOs at the universities, and companies in different phases of development. As the latest (among many) initiative to stimulate entrepreneurship activities the Danish government has set up a Foundation for Entrepreneurship in order to create a coherent national commitment to education and training in entrepreneurship.

Among the measures taken in Sweden to further interaction and mobility of competencies between academia and industry we find e.g. adjunct professors, usually persons with a predominantly industrial experience having 20% of their position at a university, and the remainder in another – private or public – organization, and industry-based doctoral students. Both forms of interaction have increased in recent years. A measure that has been suggested is to systematically encourage senior university researchers to take temporary positions in industry.

Industry

Venture capital and financing R&D. In their benchmarking study, Ernst & Young (2008) ranked Denmark among the European “Top 5” in 2007 when it comes to the ability to raise venture capital. Ten Danish specialized biotech Venture Capital firms invested in 2006 9 billion DDK (1,2 billion €) in life science; of these around 1.5 billion DKK (200 mill. €) in new start-ups (Vaekstfonden, 2007). Although nearly half of the total Danish VC investments is in life science (2006), it may still be too small taken into account that in average it requires around 400 million DDK for each start up.

Though there has been considerable concern regarding the availability of venture capital, the statistics are mixed. In a recent OECD report, Sweden ranks number one in 2007 both if measured as life science venture capital investment as a percentage of GDP or as share of all national venture capital investments (OECD, 2009). Denmark rank second and tenth respectively. Despite these rankings, an important field of interest is the financing of early stage commercialization. Seed investments is one priority, tax incentives for young innovative companies another. The Swedish Fund for Industrial Development (Industrifonden) is the most important public, policy directed actor, often aligning itself with private investors in providing funds for seed investment. VINNOVA has launched a ”Concept testing program” aimed at small biotech companies, through which they can get one year of proof of concept tests. In the last decade about 20 new biotech companies have started each year in Sweden. Most of those are spin-offs from university research, often located in proximity to universities. Supporting such processes, providing adequate economic and infrastructure conditions for starting new companies, in general, has evolved into a central concern for policy makers and actors at all levels. Among instruments used we find e.g. seed financing, incubators, science parks and university spin-off organizations. The motives for public intervention is often considered to be, on the one hand, the market failure associated with the high risks involved, and, on the other, the potential public and societal benefits associated with the value added by new knowledge-intensive products and firms. In biotech these considerations are especially pertinent, as the period from discovery to – possible – application can be quite extended, involving high risk and high costs. The Swedish government has made some efforts to intervene and to amend this situation. In the case of biotech specifically, a handful of government agencies have been instrumental for early stage financing, establishing public venture funds, notably NUTEK (The Swedish Business Development Agency), and SIC (The Innovation Centre Foundation). Regionally the Foundations for Technology Transfer have contributed, as well as holding companies linked to the universities. Within the regional initiatives the ambition has been to enroll a range of actors, trying to further the coordination that has often been missing. One crucial aspect has proved to be the commercial viability of biotech projects, and the concern to ensure that the public funds have enough commercial competencies to make proper evaluations of such (Sandström & Norgren, 2003; SwedenBio, 2005).

Strengthening of regional cooperation. Strong research environments are, by nature and by necessity, geographically situated. Thus, strengthening the interaction in the regional settings, near the major universities, has become an important objective in both countries. The fragmentation among actors in these settings has also evolved into an issue to solve, the ambition being to coordinate research, industry activities and funding. The universities have increasingly taken on the role as regional facilitators of cooperation, providing organization and infrastructure. Judging from the current state of affairs there is still a lot to be done in this field, and it hardly comes as any surprise that regional actors, both inside and outside academia, look to the universities to take the lead, to provide local or regional platforms for cooperation.

The really strong links of cooperation are, expectedly, found among science and technology intensive spin-off companies, located near the universities. Unfortunately they have not been growing strongly, and in some sense they do not compensate for the cuts resulting from structural reforms in the big, established life science companies. Here is found an absence of a

certain type of actor, a middle level, something that is central to understand recent policies. However, changing this situation is a very long-term effort, stretching over decades, and the scope for policies actually amending the situation is difficult to evaluate.

SUMMARY AND CONCLUSIONS

Sweden and Denmark show very high performance within life science. They build on a strong knowledge base, knowledge transfer and application in combination with various private and public funding schemes in both countries, and they both have long experience in designing and implementing programmes to promote biotechnology. Despite many similarities there are also significant differences between the innovation systems of the two small Nordic welfare states.

Sweden has the highest R&D expenditures as a percentage of GDP in Europe (over 4 per cent) and the highest business expenditures on R&D in the OECD, which serves to highlight the importance of the corporations in the research portfolio. However, the relative role and weight of corporate R&D efforts is decreasing as a proportion of GDP, a serious issue in any country. Public investments in R&D are also decreasing, measured as a proportion of GDP. Public investments in the corporate sector is decreasing, mostly due to cuts in defense spending, historically in Sweden an important area for public investments, as an instrument for industry as well as R&D policies. In contradistinction to Sweden, R&D expenditure as percentage of GDP has increased in Denmark – although at a slow speed. In 2008 Denmark spend 2,88 percent of GDP on R&D, of which the private sector spend 2,01 percent (Danish Agency for Science, Technology and Innovation, 2010).

According to the Biotechnology Innovation Scoreboard 2002 (European Commission, 2003) Denmark and Sweden came out as two of the leading countries for nine out of 12 indicators. Sweden had more biotechnology publications and dedicated biotech companies, while Denmark score high in terms of drug approvals and US patents. Looking at newer data, the two countries still perform well. Using the number of product candidates in the various phases of the pipeline in 2009, Denmark ranks third after UK and Germany. Sweden comes out as number six after France (4) and Switzerland (5) (Ernst & Young, 2010).

Differences exist in the institutional framework for university IPR. In Sweden the individual professors enjoy full ownership to IP based on public research activities while Denmark adopted a variation of the American Baye-Dole Act model in 2000 with the purpose to generate future revenues from patents taken out by universities and increase the commercialization of public research. It is an important question if and how the changed IPR regime in public research affects collaboration with external partners in the short and the long run. One effect might be that companies actually become less motivated in collaboration with universities if they have to share patent rights.

Foreign-owned firms have, due to a number of mergers in recent years, come to play a crucial role. The dependence on a few large firms, increasingly foreign-owned, exacerbates the vulnerability of the Swedish innovation system to decisions outside the purview of national actors (for further details see Reiss (this volume); D'Este & Costa, 2007). Mergers and acquisitions are also present in the Danish life science industry, but the specific ownership

structure based on foundations has preserved several of the old large Danish life science companies.

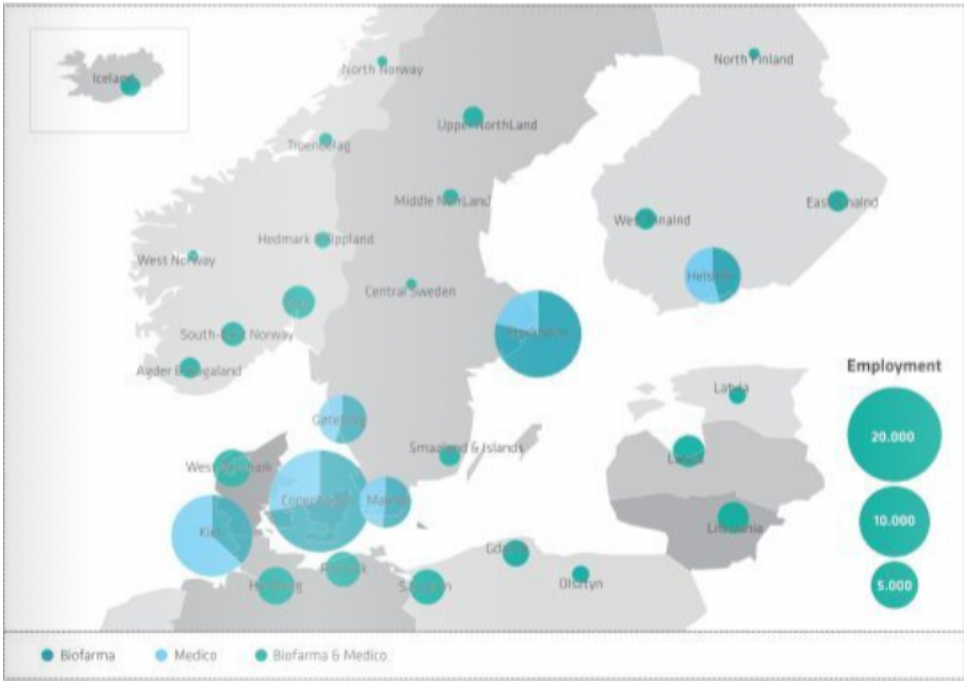
Both countries have a long tradition for implementing various policies to promote biotechnology, e.g. specific research programs, venture capital, public-private partnerships, and industrial PhDs. However, the establishment of VINNOVA reflects a more systemic and long-term perspective on the Swedish policy approach than what currently characterizes the Danish innovation policy. Following Swedish government directives a comprehensive national strategy for biotech was introduced in 2005, covering the field in the narrow sense, as well as how they connect to application areas, and the potential renewal in a range of industry sectors. A number of primarily structural goals over the period 2005-2015 are delineated in this strategy, e.g:

- A 50 percent increase in the number of employees in the life sciences sector
- A doubling of Swedish net export from the biotech sector
- A more diversified industry structure, with more SMEs
- A broadened research base

However, the current economic crisis has also hit the biotech industry. First of all, more difficult access to capital – which is a key for any research-intensive industry – has slowed down investments in new innovation activities. Lay off of workers has followed mergers and acquisitions, and many VCs have given priority to existing portfolios (IRIS Group 2009; Ernst & Young, 2010). This situation makes public policies that maintain and further stimulate investments in high-risk R&D important.

Appendix

Figure 1: Employment in Life science in the Baltic Sea region.

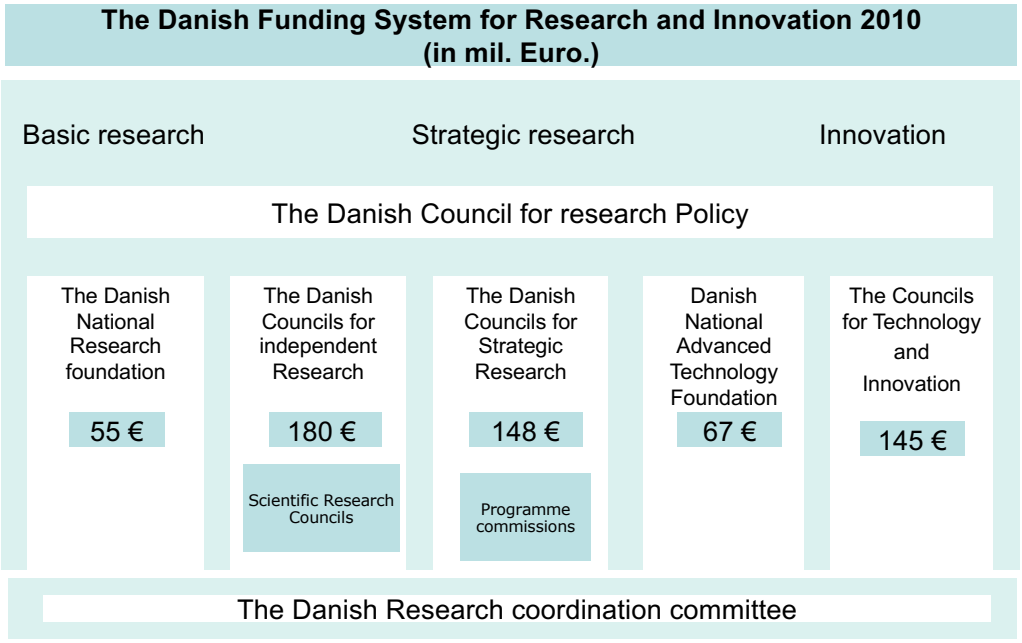


Source: Graversen & Rosted, 2010, p. 23.

Figure 2: Medicon Valley cluster map

Source: www.mediconvalley.com (2010)

Figure 3: The Danish Funding System for Research and Innovation 2010



Source: Danish Agency for Science, Technology and Innovation, (http://en.fi.dk/councils-commissions/the-advisory-and-funding-system-for-research-and-innovation) (2011)

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