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Copenhagen Business School
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Executive Summary

- This report studies employment effects associated with the adoption of modern biotechnology in Danish industry. In this context we also examine industry structure, patterns of job creation, key outputs such as patents and the pipeline of projects in clinical trials. To see the development of Danish biotech firms in a relevant context we compare a Danish segment of biotech firms with a matching Swedish segment.
- From an overall assessment modern biotechnology, despite the three decades elapsed since the first genetic manipulation, is still in a stage of experimentation, learning how to turn its new tools and approaches into an operational, reliable, cost-effective technology, sufficiently "pluggable" with other technologies. Therefore employment directly related to biotech is particularly visible and identifiable in firms focused on R&D. Outside this core of R&D activity other industries appear as early adopters of biotech, but only parts of their activities relate to modern biotechnology. From the outside it is difficult to isolate what share of their employment is attributable to their activities within biotechnology.

- In pursuit of clarity on the role of biotechnology this report studies a segment of Drug Discovery Firms (DDFs), which almost exclusively are based on capabilities in biotech research. This delimitation gives the advantage of studying a homogenous segment of firms. At the same time, this segment of biotech research firms is an informative indicator of the ability of the Danish economy to perform in the transition towards knowledge and science-based competitiveness. That is so because DDFs to an unusual extent depend on the ability of their framework to perform as an *innovation system*, by which we refer to advantages growing out of interactions and complementarities between e.g. universities, firms and venture capital. That makes DDFs a sensitive "seismograph" for the ability of the Danish innovation system to foster new science-based technologies.

Structure

- The Danish DDF segment in 2004 consisted of 49 firms with 1012 employees. Most of these firms came into existence in the four-year period 1999-2002.

- In 1997 the Danish segment was only half the size of the Swedish counterpart, but by 2004 slightly outnumbered the Swedish segment regarding number of firms. The entire Danish segment, in other words, is comparatively younger than its Swedish counter part. Danish employment throughout the period remained below the Swedish level.

- Comparing the size structure of the Danish and Swedish segments reveals quite similar profiles for the number of micro firms (≤ 9 employees) and their employment. The key difference lies in the strong concentration of about half of all employment in the Swedish segment in one large firm, whereas Denmark has almost all its employment equally divided between firms in the two size categories of 10-49 and 50-199 employees.

Investment

- For almost all years included in this study (1997-2004) investments are higher in Denmark than in Sweden. Until 2001 invested DKK per Danish employee was about two times higher. Following the drastic decline in investment levels from 2001 onwards the two countries temporarily converge, until Denmark in 2004 again invests at intensity two times above the Swedish level.

- Both increase and subsequent decline in employment associated with the investment bubble in 2000-2001 are heavily concentrated in firms with more than 50 employees. These firms constitute about 10% of each DDF segment in Denmark and Sweden.

- The upswing of the bubble involved notably larger job creation in Sweden, but due to one firm only. Job creation in the upswing was remarkably similar in the two countries if we disregard this single firm.

- The overall decline in employment caused by the reduction in investments after 2001 is surprisingly modest. For the two countries combined the total 2002-2003 reduction of 411 jobs represents 15% of the employment recorded for 2002. This reduction breaks down into merely a 7% reduction for Denmark, whereas Swedish DDFs take a three times larger cut of 21%. One of the likely causes for this difference is the generally higher level of previous investments per employee in Danish firms, which gives Danish DDFs added financial robustness against a turbulent investment climate.

- The overall effects of the steep decrease in investments represent what could be termed a "soft shakeout" whereby firms rarely are brought to close down altogether. Instead they are being maintained in existence, but subjected to a cut-back in resources forcing them into prioritisation and selection of activities and objectives.

Patents

- Denmark and Sweden exhibit strikingly similar patenting per invested DKK. However, patenting per employee shows a different picture. In the 1997-2004 period Danish DDFs on average produced 0.08 patents per employee per year, 1.4 times higher than the corresponding average Swedish level of 0.056. The higher Danish patenting per employee plausibly may be explained by the higher capital-intensity in Danish DDFs.

Projects

- Projects in clinical trials are key outputs from DDF activities, and could be seen as the meeting point where preceding efforts in pre-clinical inventiveness (as reflected in patents) are brought to bear on the actual commercial potential of the DDF.
- In 2004 firms on average had 2.2 projects in their pipeline; however, the Swedish average of 1.8 being notably lower that the Danish level of 2.6. This Danish lead is focused in the medium range of the size structure. Danish firms with 10-49 employees have 3.7 projects while those with 50-199 have 10.2 projects per firm, in both cases more than 2 times above their Swedish counterparts.
- The higher Danish project-productivity most likely grows out of the same investment-advantage, also argued to be behind the higher Danish *patent*-productivity. A stronger capital basis allows firms not only to deliver more patented inventions but also to push those

inventions further into a larger portfolio of projects in clinical trials. This Danish investment advantage appears to be particularly focused in the middle of the size structure, i.e. in firms with 10-200 employees, precisely where the Danish DDB segment has a notably higher concentration of firms compared to the Swedish counterpart.

General conclusion

- The Danish DDF segment has been notably better funded by venture capital than has its Swedish counterpart. Findings reported in this study suggest that Danish DDFs have translated their better financing into stronger inventiveness, as measured by patents per employee. More important for commercial performance, it also seems to have brought about a stronger ability on part of Danish DDFs to transform patented innovations into a higher number of projects in clinical trials, again measured per employee.

- An important question raised by this coherent theme in our findings concerns the role of *innovation systems*. If Danish firms are more productive it is because they are better funded. But they could be so for different reasons. One explanation for their better funding could be that the Danish institutional framework provides stronger links between venture capital firms and DDF, i.e. seeing the advantage as residing in the innovation system. A rivalling explanation could argue that Danish DDFs, regardless of their institutional setting, simply are better at attracting venture capital, e.g. because they pursue less uncertain discovery strategies in their research, or because they apply different business models, or differ by other attributes which are essentially firm-*internal* . It is a worthwhile agenda for further research to examine if better funding of Danish DDFs grows out of strategies at the firm level, or out of qualities in the Danish innovation system.

1 Introduction

1.1 What this study is about

Biotechnology plays an important role in Denmark's effort to perform in high technologies (Erhvervsfremmestyrelsen, 2001). Biotech has been the target of some of the most concentrated efforts in Danish science and technology policy, as exemplified by the BIOTEK and FØTEK programmes through the 1990s and by today's national strategic research programmes, where biotech still is a top priority.

This report studies *employment effects associated with adoption of modern biotechnology* in Danish industry, focusing on the following issues:

- How is the Danish biotechnology structured in terms of firm-size? E.g. to what extent is employment concentrated in a few firms vs. being distributed across a multitude of small firms?
- What has the pattern of job creation been since the biotech sector emerged in the mid-1990s? Has employment grown primarily by continual entry of new small firms or by growth in existing firms?
- What types of firms were more robust in terms of retaining employment when biotechnology in 2001 was affected by a major decline in investments?
- Are there pronounced differences between small and large biotech firms in output per employee in terms of patents and projects in clinical trials?

To see the development of Danish biotech firms in a relevant context we compare, throughout the study, a carefully delimited segment of Danish biotech firms with a matching Swedish segment.

1.2 Understanding employment trends in emergent technologies

Biotechnology[1] belongs to a category of "basic technologies" (Stankiewicz, 1990), also referred to as "general purpose technologies" (Helpman and Trajtenberg, 1998). Like semiconductors, lasers and other technologies in this category, biotechnology introduces fundamentally new technical principles, embodied in a novel technology, which subsequently becomes part of a broad range of other technologies. Rather than offering user-value by itself, a basic technology becomes a significant driver of economic growth by becoming part of other technologies, radically improving the performance/cost ratios by which the latter provide user-value.
This process takes an emerging basic technology through a sequence of three fairly distinct stages (Grupp, 1992; Schmoch and Frietsch 2006; Valentin and Jensen, 2002):

I) A stage of initial introduction of novel principles and potentials, attracting immediate awareness in the global science and technology community.

II) A prolonged stage - in some cases lasting several decades - of experimentation and learning how to turn the new basic principles into an operational, reliable, cost-effective technology, sufficiently "pluggable" with the other technologies. While this second, prolonged stage involves sizable efforts in R&D, job creation remains limited and occurs mostly within R&D.

III) A take-off stage when the new basic technology is mature enough to offer opportunities for innovation and product improvements across a broad range of industrial sectors, in many cases

[1] We follow OECD in defining biotechnology as "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services" (OECD, 2005).

given rise to significant increases in employment (Soete and Freeman, 1987; Freeman and Soete, 1997; Helpman and Trajtenberg, 1998).

Modern biotechnology, despite the three decades elapsed since the first genetic manipulation, is still from an overall assessment in Stage II. This is not to deny that its toolbox has developed significantly and that many applications have appeared, particularly in pharmaceuticals, agriculture and food processing. When biotechnology nevertheless is assessed as a Stage II technology it is primarily because of large remaining shortcomings in our understanding and control of living matter. These shortcomings translate into sizable uncertainties in the application of biotechnology to specific innovation problems. The areas in which biotechnology has produced results are few compared to the huge areas of potential applications which cannot be realized because of deficiencies in our understanding and control of the steps required to get there. In that sense biotechnology on the whole is far from offering reliable engineering (Drews, 2000; Pisano, 2006).

Recognizing current biotech as a Stage-II technology has direct implications for our understanding of its employment effects. Employment in activities *entirely focused on biotechnology* is quite small, and concentrated predominantly in R&D. Outside this core of R&D activity other industries appear as early adopters of biotech but only parts and aspects of their activities relate to modern biotechnology (Springham, 1999; Bud, 1993). From the outside it is difficult to isolate what share of their employment is specifically attributable to their activities within biotechnology.

1.3 Implications for delimitation of the biotech sector

In response to these large variations across industries in the role played by biotechnology, OECD has introduced a useful terminology, distinguishing firms based on whether they are active in biotechnology regarding merely a *minor* part of their activity [2], or regarding their *predominant* activity, the latter making them "dedicated biotechnology firms" (DBFs) [3].

Even the more restrictive OECD definition of DBFs leaves ambiguities concerning the critical relationship between biotech R&D and the predominant activity of the firm. I.e. although affecting a firm's predominant activity, biotechnology may constitute a modest element in its R&D. That could be the case if the firm applies biotech techniques which largely were acquired from other firms, say in the form of instrumentation or licenses. In this case, to what extent would the firm's competitiveness, and the employment derived from it, grow out of its biotech capabilities, as distinct from other potential sources of competitiveness, e.g. its abilities in customization or in marketing?

The present study resolves these issues of delimitation by focusing on a segment of firms, which compete based virtually *only* on their capabilities in biotechnological research. Such firm may do research in a variety fields (e.g. food- or environmental biotech). In reality, however, most biotech firms have their research focused on discovery and early development of pharmaceutical drugs. We refer to them as Drug Discovery Firms (DDFs), this way also denoting that by and large they confine their activities to the early stages of the drug discovery cycle. The high costs of taking drug candidates through clinical trials, manufacturing, and marketing are largely beyond their financial reach. In a few cases DDFs on their own move into clinical trials. But in most cases at this point

[2] *Biotechnology active firms*, as defined by OECD refers to all firms "engaged in key biotechnology activities such as the application of at least one biotechnology technique […] to produce goods or services and/or the performance of biotechnology R&D […]" (OECD, 2005).

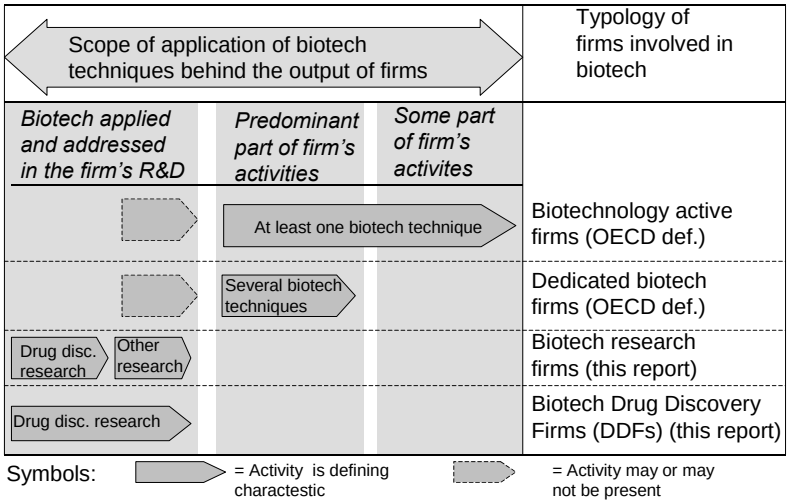
[3] *Dedicated biotechnology firms,* in the OECD definition, are "biotechnology active firm whose predominant activity involves the application of biotechnology techniques to produce goods or services and/or the performance of biotechnology R&D" (OECD, 2005).

they join forces with a large pharmaceutical firm acquiring (parts of) subsequent exploitation rights, thus generating revenues for the DDF for further research.

Excluded from our segment of DDF, in other words, are the much larger Danish pharmaceutical firms, e.g. Novo and Lundbeck, because they operate value chains including other significant components *in addition to* the biotech aspects of their R&D. That is the key reason why both employment and performance indicators reported in the present study differ markedly from previous studies of the Danish biotechnology, which have delimited the sector by different criteria (e.g. Ernst and Young, 2006). To enhance comparison of findings reported in this paper with previous studies on Danish biotechnology, Appendix 1 offers an overview of differences in delimitations.

Fig. 1 visualises the criteria for delimiting biotech firms, clarifying definitions in the present study, as they differ from standard OECD definitions.

Fig. 1: Visualisation of defining criteria for biotech firms



Definitions present trade-offs: OECD's broad definition of "biotechnology active firms" includes all firms with at least some involvement in biotech, at the cost of leaving the intensity and the nature of that involvement quite unclear. At the other end of the spectrum, the very narrow definition of Drug Discovery Firms applied in this study includes firms which do very little else than biotech research. That greatly enhances homogeneity in the segment we study, and brings clarity on its involvement in biotech. We apply this definition, however, at the cost of focusing on relatively few Danish firms (currently around 50) with a limited volume of employment (currently around 1000 employees).

In addition to preferences for distinctness and homogeneity in the object studied, there are additional reasons behind our focus on DDFs. A key element in the methodology of the present study is the comparison of Danish with Swedish biotech firms. A broad definition of biotech firms implies ambiguity about which types of biotech activity would be included in this comparison. With our restricted focus on DDFs, on the other hand, we obtain a more robust comparison of same type of biotech firms in the two countries.

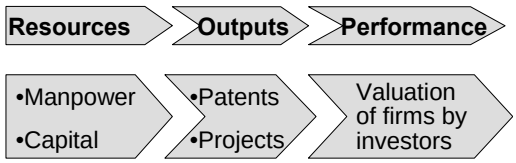
The last, and perhaps most important, reason for focusing narrowly on DDFs is that this definition best reflects why the World so intensely is observing the performance of commercial biotechnology. Put simply, this segment of biotech research firms is one of the best indicators on how economies perform in the transition towards knowledge and science-based competitiveness. That is so because DDFs to an unusual extent depend on the ability of their surrounding framework to perform as an *innovation system*, by which we refer to advantages growing out of interactions and complementarities between e.g. universities, firms and venture capital (McKelvey, Rickne, Laage-Hellman, 2004; Valentin and Jensen, 2004). As compared to larger firms with much broader portfolios of technologies and strategic assets, the exclusive focus of DDFs on fairly long-term

research render them far more sensitive to critical inputs from outside the firm. E.g. without competent venture capital they will not get started nor move far ahead (Audretsch, 2001; Niosi and Banik, 2005). Without rich interaction with academic science they lack the access to skills, spill-overs and talents which is critical for both their key inventions and their day-to-day problem solving (Liebeskind, Oliver, Zucker, Brewer, 1996; Valentin and Jensen 2006). Therefore DDFs to an extreme extent are "extrovert" firms. Precisely that quality turns them into an informative indicator of the ability of their host systems to handle the transition into tomorrow's knowledge- and science-based economy. What makes careful observation of the evolution and performance of 50 DDFs a worthwhile exercise, at the end of the day, is their role as "seismograph" for this more fundamental ability in Danish society.

1.4 Structure, data and reporting formats

This report begins by giving, in the next section, an overview of the entry of new DDFs since 1997, along with changes in employment for different firm-sizes. Section 3 examines changes in employment associated with shifts in investment levels, focusing particularly on the investment decline in 2001. Patents and projects taken into clinical trials are major outputs of DDFs. Sections 4 and 5 analyse these outputs and their associated levels of productivity. As illustrated in Fig. 2, these outputs play an important role for the financial performance of firms. Multiple additional factors, omitted in this report, should be included in a more exhaustive attempt to explain financial performance of firms. Important resource inflows for DDFs consist not only of the factors of manpower and capital, but also of e.g. recruitment of scientific and managerial talent, in-licensed technologies and spill-overs of academic research. Outputs could also include e.g. number of deals with big pharma in the form of out-licensed projects or other indications of successfully traded research results.

Fig. 2: Conceptual framework



This study draws on data extracted from SCANBIT (Scandinavian Biotech), a proprietary database developed and maintained by Research Centre on Biotech Business at Copenhagen Business School[4]. Using the firm as its unit of analysis SCANBIT, for all Danish, Swedish, and Norwegian biotech firms, integrates data on employment, patenting, project pipeline, investments, financial performance and a range of additional variables. Data are updated on a yearly basis and in most cases have been reconstructed for all years since the firm was established.

Firms are grouped by size into 4 categories as follows:

	Number of employees
Micro	≤ 9
Small	10-49
Medium	50-199
Large	≥ 200

Data are reported for the time span 1997-2004. The year of 1997 is taken as the point of departure, because that is when the Danish DDF segment becomes visible. Prior to that only 5 DDF were active in Denmark, but in 1997 that number doubles, and steep growth follows until 2001. Reporting ends with 2004, which is the final year for which we have full coverage for the various indicators included in our presentation.

Numbers are presented with "," as 1000 separator and "." as decimal point.

[4] See further www.cbs.dk/biotech and www.biotechbusiness.dk

2 Overall development in number of firms and employment

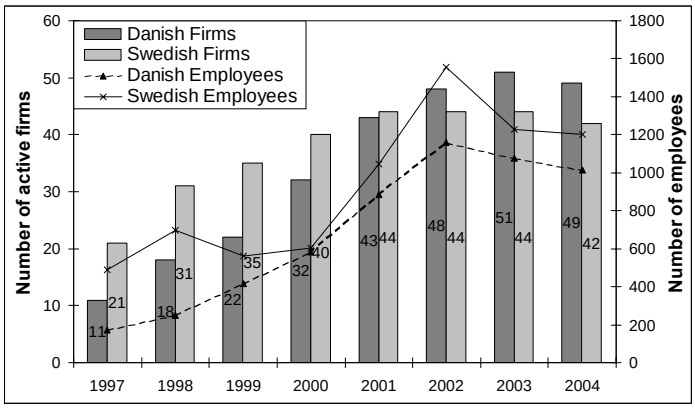
In 1997 the Danish DDF segment consisted of 11 firms with a total work force of less than 200 employees (Fig. 3). The segment grew five-fold over the next 8 years, particularly steep increases occurring 1999-2001. Effects of declining investments after 2001 did not entirely prevent establishment of a few additional firma in 2003, but employment took a modest decrease from 2002 onwards.

The Danish DDF segment, in other words, as a whole emerged fairly abruptly over a very short span of years. More detailed information behind the trends in Fig. 3 shows that 5 of the 11 firms recorded for 1997 in fact were established that year, and the remaining half was only a few years old. Neurosearch, established in 1988, is the oldest Danish DDF. Growth of the segment levelled off after 2002, but on a positive note that also implies a fairly robust survival rate of firm and employment in a climate of declining investments

The Swedish DDF segment in 1997 was about twice the size of its Danish counterpart. Information behind the figures shows that 7 of the 21 Swedish firms recorded for 1997 were established through the 1980'es. Two firms were established decades earlier, and shifted into modern biotechnology during the 1980s. Compared to its Danish counterpart the Swedish segment entering the investment boom at the turn of the millennium consists of more mature firms, and even of some sizeable veterans.

By year 2002 Sweden is overtaken by Denmark in terms of number firms. Sweden maintains, however, a higher level of overall employment, not least because of its steeper increase during the investment boom up till 2001, and even beyond, before a more drastic decline occurs from 2002 to 2003. By 2004 the overall profiles in terms of number of firms and employment of the two segments are remarkably similar. But behind that similarity are notable differences between the DDF segments in the two countries in terms of *maturity* of firms, and in terms of the *technology generations* during which they came into existence.

Figure 3 Number of firms and employees*) in DK and SE



**) The average number of employees in a given year comes from annual reports.*
Source: Scanbit

Further insights into the structure and evolution of the two segments is offered by Tables 1 and 2 which for 4 size categories[5] examine number of firms and total employment 1997-2004. The two tables present figures not only for the first and final years of that period, but also for the height of the investment bubble in 2000 and for the following years (2002 and 2003). The most interesting points appear when each size category is characterised using figures from both tables.

[5] Size for each firm is determined by its number of employee in any given year. I.e. a firm may shift size category between 1997 and 2000.

Table 1 Number of firms in five selected years in the 1997-2004 period by size and by country

DK	≤ 9		10-49		50-199		≥ 200		Total	
Year	N	% of total	N	% of total	N	% of total	N	% of total	N	% of total
1997	8	72.73%	2	18.18%	1	9.09%	0	0.00%	11	100.00%
2000	15	46.88%	15	46.88%	2	6.25%	0	0.00%	32	100.00%
2002	24	50.00%	18	37.50%	6	12.50%	0	0.00%	48	100.00%
2003	27	52.94%	19	37.25%	5	9.80%	0	0.00%	51	100.00%
2004	26	53.06%	18	36.73%	5	10.20%	0	0.00%	49	100.00%
SE	**≤ 9**		**10-49**		**50-199**		**≥ 200**		**Total**	
Year	N	% of total	N	% of total	N	% of total	N	% of total	N	% of total
1997	15	71.43%	4	19.05%	1	4.76%	1	4.76%	21	100.00%
2000	33	82.50%	5	12.50%	1	2.50%	1	2.50%	40	100.00%
2002	27	61.36%	12	27.27%	4	9.09%	1	2.27%	44	100.00%
2003	28	63.64%	11	25.00%	4	9.09%	1	2.27%	44	100.00%
2004	28	66.67%	9	21.43%	4	9.52%	1	2.38%	42	100.00%

Table 2 Employment in five selected years in the 1997-2004 period by firm-size and by country

DK	≤ 9		10-49		50-199		≥ 200		Total	
Year	N	% of total	N	% of total	N	% of total	N	% of total	N	% of total
1997	20	11.63%	53	30.81%	99	57.56%	0	0.00%	172	100.00%
2000	23	3.94%	361	61.82%	200	34.25%	0	0.00%	584	100.00%
2002	66	5.69%	522	45.00%	572	49.31%	0	0.00%	1160	100.00%
2003	79	7.34%	518	48.10%	480	44.57%	0	0.00%	1077	100.00%
2004	63	6.23%	504	49.80%	445	43.97%	0	0.00%	1012	100.00%
SE	**≤ 9**		**10-49**		**50-199**		**≥ 200**		**Total**	
Year	N	% of total	N	% of total	N	% of total	N	% of total	N	% of total
1997	23	4.71%	80	16.39%	57	11.68%	328	67.21%	488	100.00%
2000	73	12.07%	113	18.68%	82	13.55%	337	55.70%	605	100.00%
2002	74	4.76%	239	15.38%	391	25.16%	850	54.70%	1554	100.00%
2003	65	5.30%	208	16.97%	395	32.22%	558	45.51%	1226	100.00%
2004	77	6.40%	182	15.13%	367	30.51%	577	47.96%	1203	100.00%

Source: ScanBit

Large firms (≥ 200): Denmark has no firms in this category at any point during the 8 years. Sweden has 1 firm recorded throughout the period, accounting for about half of all employment (even two thirds in 1997), substantially affecting the *relative* position of all other size groups. Behind this one observation we actually find two firms, Active Biotech until 2002, when its employment dropped below 200, while Biovitrum at the same time took its place in this category. Active Biotech after 2002 accounts for about half of all employment in medium sized DDFs. Both firms trace important parts of their origin to the fully integrated pharmaceutical firm of Pharmacia. Active Biotech was established in the early 1980s, but the firm of today primarily originates in the 1997 merger of Pharmacia and Upjohn when a research project was spun out, involving transfer to Active Biotech of about 165 researchers. Biovitrum was formed as a spin-off when Pharmacia in 2001 changed its therapeutic focus. In 2004 Biovitrum registered 577 employees.

Medium sized firms (50-199): Neither of the two countries at any point have more than 6 firms in this size category. But this category is more important in the Danish case, accounting during 2003-4 for 44% of all Danish DDF employment, as compared to about 31% of Swedish DDF employment.

Small firms (20-49): During 2002-4 this category in Denmark comprised 37% of the firms and 45 – 50% of its employment. During the same years, in the Swedish case this category included 21-27% of the firms and 15-17 % of employment.

Micro firms (≤ 9) during 2002-4 in Denmark included 50-53% of the firms, and 61-67% of the firms in the Swedish segment, in both cases accounting for about 5% of employment.

Summary:

- Danish DDFs by 2004 consists of 49 firms and 1012 employees. Most of these firms came into existence in the four-year period 1999-2002. Overall reduction in employment and in number of firms was modest in response to the investment decline after 2001. The entire Danish segment is comparatively younger than its Swedish counterpart.

- In 1997 the Danish segment was only half the size of the Swedish counterpart, but by the end of the period slightly outnumbered the Swedish segment regarding number of firms. Danish employment throughout the period remained below the Swedish level.

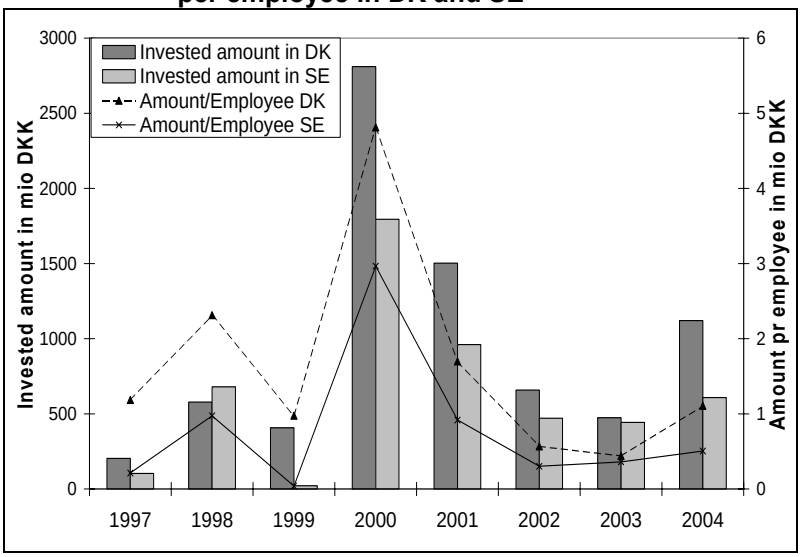
- When comparing the size structure of the Danish and Swedish segments quite similar profiles are observed for the number of micro firms and their employment. The key difference lies in the strong concentration of about half of all employment in the Swedish segment in one large firm, whereas Denmark has almost all its employment equally divided between firms in the two size categories of 10-49 and 50-199 employees

3 Investment and employment

This section examines fluctuation in investment and effects on employment, with an emphasis on the influence of the investment bubble on both job creation during its upswing and employment reductions after the steep decline in 2001. (See Appendix 2 for a brief account of the global investment bubble and the pattern by which it affected Danish biotech.)

For each of the two countries Fig. 4 shows Danish Kroner invested each year as equity in DDFs both through public offerings and through private investments. Both total amounts and DKK per employee are shown. In almost all eight years total investments are higher in Denmark, the difference to Sweden being particularly large 1999-2001, and again in 2004. Swedish investments are particularly modest in 1999. Until 2001 invested DKK per Danish employee was about two times higher than the Swedish level. Following the drastic decline in investment levels from 2001 onwards the two countries converge, until Denmark in 2004 again invests at intensity two times above the Swedish level.

Figure 4 **Private and public equity investments and amount per employee in DK and SE**

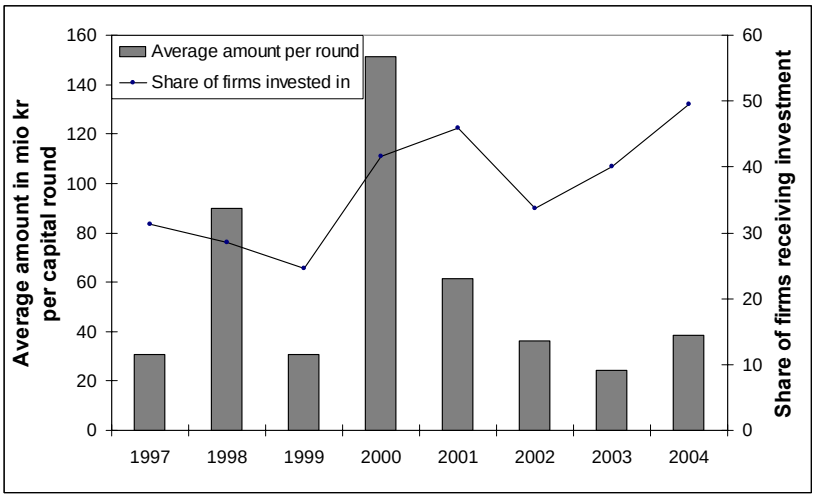


Source: ScanBit

Fig. 4 also brings out the uniqueness of year 2000 when investments soared to twice the level of what they have been in any other year. The early parts of 2001 brought overall investments for that year also notably above subsequent years. The crisis, which became apparent during that year, meant several years of declining investment, bringing 2003 below the level from 1998.

The nature of this cutback in investments is brought out in Fig. 5, where columns indicate average sums, in Mio. DKK, mobilised in investment rounds for each year. The curve shows the pct. share of all firms going through capital rounds or IPOs per year. For the entire period 1997-2004 this share varied in the range of 25-50%, and was particularly high in 2000-2001 before it dropped close to 30% in 2002. Notably more dramatic shifts

Figure 5 **Average amount per investment round and share of firms raising investments**



Source: ScanBit

occur in the invested *amounts*, which in 2000-2001 on average was above 100 mio. DKK per round, but dropped in 2003 to about 20 mio. DKK. The decline in investments, in other words, only to a moderate degree was about capital injections disappearing altogether. It was a lot more about each injection making radically less resources available to the recipient DDF.

Table 3 shows how DDF employment in the two countries responded to the investment bubble. Unlike the previous tables, figures in Table 3 do not refer to employment as per each year. Instead figures refer to *changes* in employment associated with *four different phases* of the investment cycle, i.e. net difference in employment from the first to the last year of each phase. Furthermore, this net difference has been broken down by firm-sizes[6].

Table 3 Change in employment by firm-size, by year and by country for four separate phases of the 2001 investment bubble

Year	1997-2000		2000-2002		2002-2003		2003-2004	
Country	SE	DK	SE	DK	SE	DK	SE	DK
	N	N	N	N	N	N	N	N
≤ 9	50	3	1	43	-9	13	12	-16
10-49	33	308	126	161	-31	-4	-26	-14
50-199	25	101	309	372	4	-92	-28	-35
≥ 200	9	0	513	0	-292	0	19	0
Total	117	412	949	576	-328	-83	-23	-65

Source: ScanBit

The following changes should be noted.

Phase 1, 1997-2000, moderate growth: Overall Swedish growth of 117 employees is heavily concentrated in micro firms. The Danish increase in employment is 3.5 times above the Swedish level and is concentrated in the somewhat larger firms categorised as "small firms".

Phase 2, 2000-2002, hyper growth: Swedish DDFs show aggregate growth of almost 1000 new jobs. More than half of this increase is associated with the above-mentioned establishment of the single firm of Biovitrum, but notable increase in employment (of 309) also takes place in medium-sized firms. The Danish aggregate increase of 576 employees corresponds to only 60% of the Swedish growth, but has a similar concentration in medium-sized firms.

Phase 3, 2002-2003, steep reduction: The Swedish decline of 328 jobs is about 4 times larger than the Danish cutback of 83 employees. Still, relative to aggregate employment levels in 2002 (Table 3) this amounts for the Swedish segment to a reduction of 21%, while for Denmark it is 7%. In both countries the cutback predominantly takes place in the largest firms. For Sweden that means its single large firm, while for Denmark it happens in the 6 medium-sized firms.

Phase 4, 2003-2004, adjustment: Reductions almost come to an end in Sweden, and is actually reversed into modest growth for its largest and smallest firms. Denmark takes a further small reduction (65 jobs), quite evenly distributed on all size categories.

To sum up:

- For almost all years included in this study (1997-2004) investments are higher in Denmark than in Sweden. Until 2001 invested DKK per Danish employee was about two times higher.

[6] Firms in Table 3 are categorised by size according to the employment at the end of each phase.

Following the drastic decline in investment levels from 2001 onwards the two countries temporarily converge, until Denmark in 2004 again invests at intensity two times above the Swedish level.

- Both increase and subsequent decline in employment associated with the investment bubble are heavily concentrated in firms with more than 50 employees. These firms constitute about 10% of each DDF segment in Denmark and Sweden (Table 1).
- The upswing involves notably larger job creation in Sweden, but due to one firm only. Job creation in the upswing is remarkably similar in the two countries if we disregard this single observation.
- The overall decline in employment caused by the reduction in investments after 2001 (Fig. 4) is surprisingly modest. For the two countries combined the total 2002-2003 reduction of 411 jobs represents 21% of the employment recorded for 2002. This reduction breaks down into merely a 7% reduction for Denmark, whereas Swedish DDFs take a three times larger cut of 21%. A likely cause for this difference is the generally higher level of previous investments per employee in Danish firms, which gives Danish DDFs added financial robustness against a turbulent investment climate.

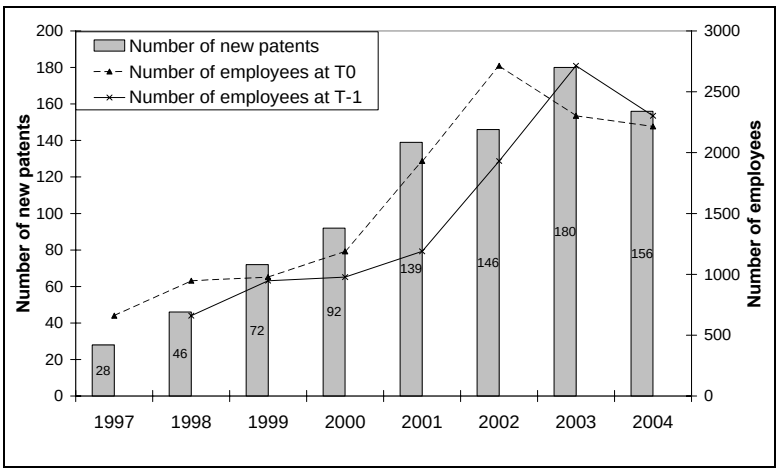
The overall effects of the steep decrease in investments represent what could be termed a "soft shakeout" whereby firms rarely are brought to close down altogether (as reflected also in the aggregate number of firms in Fig 3). Instead they are being maintained in existence, but subjected to a cut-back in resources forcing them into prioritisation and selection of activities and objectives.

4 Patents

Fig.6 shows the steep rise in patenting associated with the increasing entry of new firms and the rise in employment after 1997, until effects of the investment crisis becomes visible in 2002. The number of employees is shown both for the year of patent filing (t_0), and for the previous year (t_{-1}). The t_0 employment curve gives a better fit during the period of steeply increasing patenting (1999-2001), while t_{-1} offers better fit for the decline 2003-4.

These preliminary observations suggest that a closer look at patenting productivity would be useful. Fig. 7 shows numbers of patents per employee (referred to as Patent Employee Productivity - PEP) for the two countries, revealing quite notable differences. Swedish PEP converges towards the higher Danish level and exceeds it in 2000 and 2001, before it again drops to a lower level during the last 3 years. However, the overall effect of the difference is that Denmark on the average for the 8 years have produced 0.08 patents per employee, 1.4 times higher than the corresponding average Swedish level of 0.056.

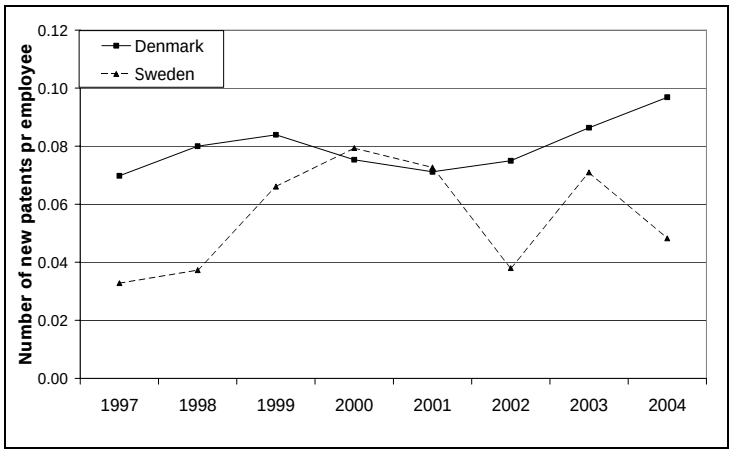
Figure 6 Number of patents filed per year and total number of employees in same and previous year. Danish and Swedish figures consolidated



Source: ScanBit

To examine possible causes for this striking difference between the two countries Fig. 8 reports on patenting productivity, calculated on the basis of number of patents filed in a given year divided by total equity investment (Mio. DKK) in the same year. This measure for "Patent Capital-Productivity" (PCP) sees Sweden soaring to the extremely high value of 1.66 in 1999. In that year a minimum of equity was raised (comp. Fig 4 above.), explaining this divergent figure as the result of patenting being maintained at its normal level during a single year, while investments decline to an all-time low. A higher Swedish PCP level also is observed for 1997.

Figure 7 Number of patents per employee separate for Danish and Swedish firms

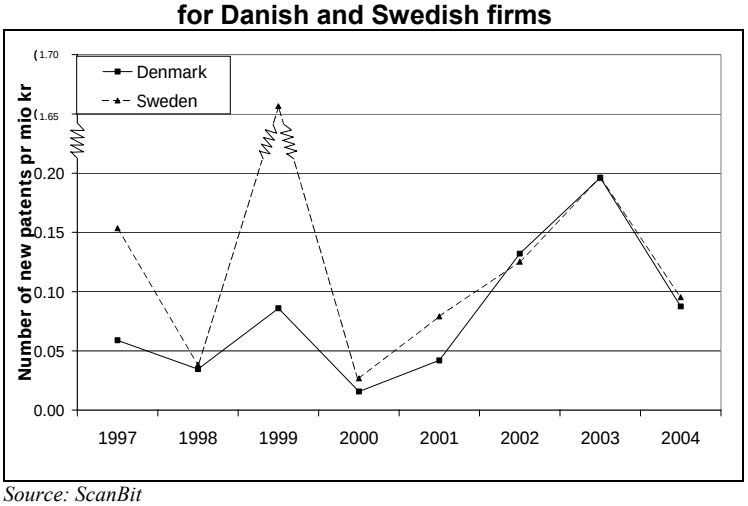


Source: ScanBit

Apart from these two years, the Danish and the Swedish PCP curves virtually overlap, i.e. demonstrating strikingly similar patenting per invested DKK in the two countries. The higher Danish PEP, in other words, comes about largely because of the higher capital-intensity in Danish DDFs.

Such capital advantages could mean many different things, such as access to better research instrumentation. It also would allow for more widespread use of outsourced research activities, allowing firms to focus their internal research on their particular area of expertise. It also would translate into higher medium-term financial stability, and hence a better basis for planning.

Figure 8 Number of patents per mio DKK separate for Danish and Swedish firms



Source: ScanBit

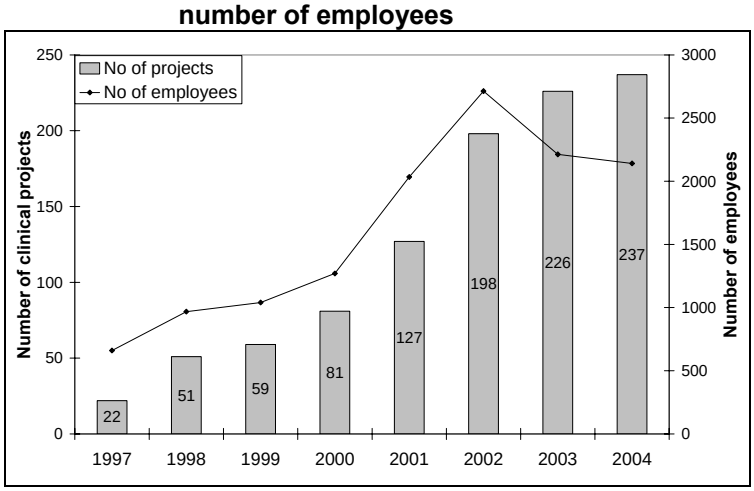
In this interpretation, what could account for the temporary convergence of Danish and Swedish PEP levels around year 2000? The Danish side of this convergence comes in the form of a moderately declining PEP level, conceivably attributable to a steep increase in investments targeting a highly immature DDF segment. Investment precisely at this juncture, we learn from Table 1 to a notable extent went into the establishment of new firms or into small, recently established firms, both of which would entail initial low PEP levels for the firms in question. The Swedish increasing side of the convergence arguably comes out of the same logic, i.e. being based on steep increase in investments which to a comparatively higher extent flow into existing larger firms, better capable of translating notable expansion of their resources into higher PEP.

5 Projects

The second type of output from DDFs to be considered in this report is *projects*, which refer to clinical tests of drug candidates in Stages I-II-III. The value of a drug candidate increases notably when proven feasible for clinical trials, and as it progressively passes the considerable risks of failure during the three stages. Clinical tests also are costly, so DDFs often carry them out in a contractual arrangement with large pharmaceutical firms. The latter in recent years have seen their own internal pipeline of drug candidates declining, increasingly making them dependent on the new projects they can acquire from DDFs. Such project contracts are valuable for DDFs not only in the direct sense of generating revenue (and sometimes also equity), but also by signalling what the DDF has to offer, turning such contracts into assets for further attraction of investments. These attributes make projects a key output from DDFs. They are, so to speak, the meeting point where preceding efforts in pre-clinical inventiveness (as reflected in patents) are brought to bear on the actual commercial potential of the DDF.

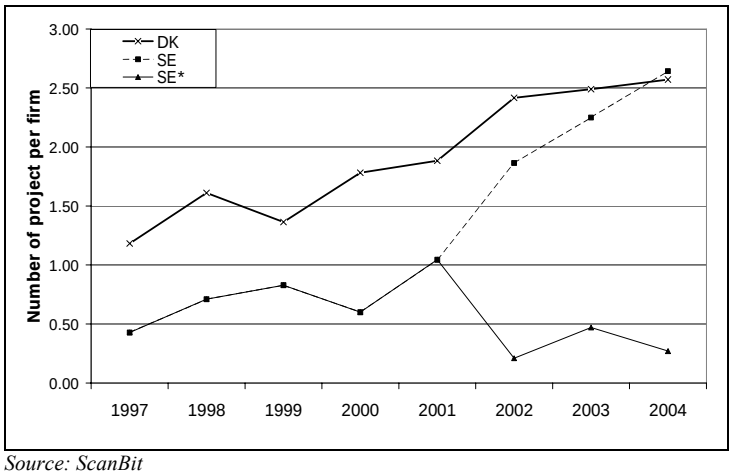
We bring data on the number of active projects, for each year, in Danish and Swedish DDFs. Projects stretching over the turn of year are counted for both years, and projects indeed may also have durations exceeding 12 months. Even though that implies that any one project may enter figures for two consecutive years (or more), for our analytical purposes this may be assumed to be a random attribute. Combining information on both Danish and Swedish DDFs, Fig. 9 shows the moderate increase in projects until 2000, followed by a steeper growth, quadrupling their number over four years. Increases continue also during declining employment after 2002. A clinical project launched by a DDF in 2003 would be based on a large body of research carried out during the preceding 3-4 years, which partly explains how more projects come out of a declining number of employees. Another part of the explanation undoubtedly has got to do with redirection of resources, giving added priority, in times of financial stress, to take projects into clinical trials to generate revenue (from alliances with big pharma) and to better prepare the DDF for the next investment round.

Figure 9 Number of projects in clinical trial and total number of employees



Source: ScanBit

Figure 10 Number of projects per firm, separate for Danish and Swedish DDFs



Source: ScanBit

Fig. 10 compares Denmark and Sweden in terms of the ability of DDFs to generate new projects, showing fairly consistent Danish increases from the 1997 level of 1.18 projects per firm to a level of

2.6 projects in 2004. Swedish firms were at a considerably lower level in 1997 (0.4), increase moderately until 2001, after which they decline to their initial level. Fig. 10 also shows a dotted graph for Swedish DDFs, indicating a steep increase from 2002 onwards. This is the trend for Swedish firms when they include the single firm of SkyePharma. Only in some respects did SkyePharma belong in the category of DDFs when in 2002 it was established as a Swedish subsidiary of SkyePharma PLC, UK[7]. Increasingly it diversified out of this category until its activities in 2005 were transferred to other parts of the SkyePharma group outside Sweden.

To clarify if the Danish higher project productivity has a particular concentration Table 4 gives a breakdown by firm-size for 2004. Swedish performance is higher in micro firms and of course in the largest category (≥200), where Denmark is not represented. So the overall higher Danish performance comes out of firms with 10-49 and 50-199 employees, where Denmark has two times more firms than Sweden (Table 1).

Table 4 Number of projects in 2004 per firm, by firm size and by country

Employees	DK	SE	Total
≤ 9	0.31	1.21	0.78
10-49	3.72	(5.33)* 1.75	(4.26)* 3.12
50-199	10.20	4.50	7.67
≥ 200		11.00	11.00
Total	2.57	1,83	2.23

*) Figure including SkyePharma. *Source: ScanBit*

The higher Danish project-productivity most likely grows out of the same investment-advantage, which also appeared behind the higher Danish *patent*-productivity. A stronger capital basis allows firms not only to deliver more patented inventions but also to push those inventions further into a larger portfolio of projects in clinical trials. What Table 4 adds to this understanding is that the Danish investment advantage appears to be particularly focused in the middle of the size structure, i.e. in firms with 10-200 employees, precisely where the Danish DDB segment has a notably higher concentration of firms compared to the Swedish counterpart.

[7] SkyePharma specialized in drug delivery technologies, developing improvements of existing pharmaceuticals along with some new pharmaceuticals. Its delivery technology was the basis for a high number of collaborations in the form of in- and out-licencing with large pharmaceutical companies. With a staff of 39 the firm in 2002 undertook 40 projects in preclinical and clinical stages. In 2004 the number of employees was reduced to 21 while 34 projects were processed.

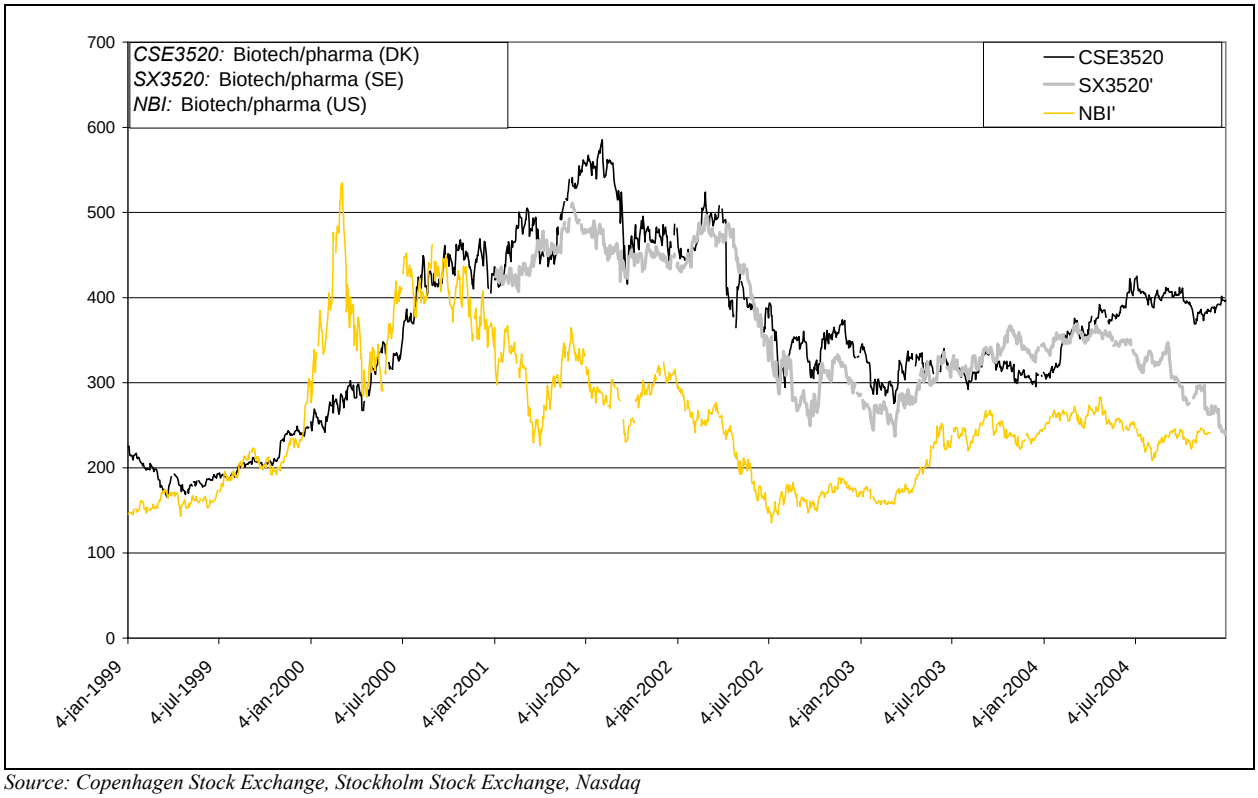
Appendix 1. Delimitation of biotech firms in this and in previous reports

Reports on the biotech industry present diverging numbers and figures when describing the industry in terms of number of firms, number of employees, R&D expenditures etc. Depending on the complex nature of biotechnology and dispersion among several traditional industry categories, which normally are based on industry output classifications, delimitations and concept definitions applied varies. The table below present an overview of differences in delimitations and use of concepts in the present and two previous reports on employment in the Danish biotech industry (Bloch 2004; PLS RAMBØLL MANAGEMENT, 2003)

	The present study	PLS Rambøll (2003)	Bloch (2004)
Geographic boundaries	Denmark	Storkøbenhavn, Frederiksborg, Roskilde, Vestsjælland, Storstrøm labour market regions (DK) and Skåne (SE).	Denmark
Number of firms	54 Danish firms	220 Danish firms and 106 Swedish firms.	267 Danish firms
Number of employees	1077 and 1012 employees in 2003 and 2004 respectively.	In total about 19.000 employees in the region.	4766 employees in 2003.
Definitions	Own definition, similar to but more confined than OECD.	Applies definition similar to OECD.	Applies OECD definitions.
Delimitation	See section 1.3 in the present report.	Broad definition of biotech industry corresponding to OECD definition of "biotechnology active firms", including not only R&D firms (R&D and CRO) but also production firms (both with in-house R&D and CMOs applying biotechnology processes) and suppliers of products and services to the firms mentioned above. Process developers are excluded. - Includes 'Red','Green',and 'White' biotech firms. About 1/3 are 'Red' biotech firms.	Corresponding to OECD definitions of "dedicated biotech firms" and firms with related activities Including 'Red' (pharmaceuticals & diagnostics), 'Green' (agricultural), and 'White' (industrial & environmental) biotech firms.
Employment	Annual average number of employees in each firm.	Delimited to firms with 20 employees or more in industries with a "certain" level of biotechnology firms.	Full time employees. 36 firms are assigned estimated number of employees.
Data and firm identification	Own list of firms gathered from several sources, such as web-sites, industry organizations, news sources and public databases. Classification of each firm's business activities. Data from annual reports.	Own list of firms based on firms with industry codes of biotechnology related activities. Interview with 900 firms to assess relatedness to biotechnology activities. Data from Danmarks Statistik (DK) and SCB (SE), and survey with 39% response rate.	Similar approach as the present study. Own survey and list of firms gathered from various sources, such as industry organizations, venture capitalists, and news sources. Classification of firms based on web-site information and above sources. Data from NewBiz Business Information.

Appendix 2. Effects of the 2000-2001 investment bubble on Danish biotech

The investment bubble in Scandinavian biotech occurs with a time lag of about one year after the US biotech bubble. The US biotech/pharma index reaches its highest peak in the first half of year 2000 followed by a short but steep downturn. In US biotech a short recovery phase takes place until mid 2000, where the index moves downwards, beginning a long-term decline until the beginning of 2003. The Danish and Swedish biotech/pharma indices almost fluctuate in parallel. The indices peak in mid 2001, where the Danish index reaches higher levels and the gap between the Scandinavian indices exhibits the greatest gap. From that period on, both indices slope downwards, with an accelerating pace in 2002.



Source: Copenhagen Stock Exchange, Stockholm Stock Exchange, Nasdaq

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