Copenhagen Business School
HANDELSHØJSKOLEN

Effects on academia-industry collaboration of extending university property rights

By Finn Valentin* & Rasmus Lund Jensen

*) Corresponding author
fv.ivs@cbs.dk
Tel. +45 3815 2551

Biotech Business Working Paper 2005 - 01
Oct - 2005

JEL classes: I23, L65, O31, O34, O38

research centre on biotech business

Abstract

Studying the contribution from university scientists to inventions patented by Danish and Swedish *d*edicated *b*iotech *f*irms (DBFs), we examine effects of the *L*aw on *U*niversity *P*atenting (LUP) implemented in Denmark in January 2000, transferring to the employer university rights to patents on inventions made by Danish university scientists alone or as participants in collaborative research with industry. Sweden so far has refrained from reforming academic property rights along the lines of LUP, leaving Swedish academic property rights much the way they also were in Denmark prior to the reform. Consequently, systematic comparison of Danish and Swedish research collaboration before and after LUP offers a quasi-controlled experiment, bringing out effects on joint research of regulation affecting its IPR framework.

Using original data on all 3589 inventor participations behind the 976 patents filed by Danish and Swedish DBFs during 1990-2004 we model quarterly shares of university inventors in each country as time series to test event effects of LUP on Danish academic participation rates. Whereas this rate remains significantly stable in the Swedish data, a trend of increasing Danish academic participation is identified through the 1990s, turning into a steeper decreasing trend after LUP. Concurrent with this post-LUP decline a notable increasing trend in non-Danish academic participations is identified, substituting for and finally becoming larger than the shares of domestic academic participations.

Examination of possible mechanisms by which LUP could have induced the substitution of domestic with non-Danish academics, indicate as the most likely cause that academic-industrial collaboration in this area typically addresses issues at so early stages of drug discovery that their eventual value cannot be assessed, hence precluding rational contracting of shared or transferred property rights.

The outcome implies a loss for industrial biotech research in Denmark, as well as for university scientists, for whom the focus on early and more fundamental issues in joint discovery made the collaboration attractive on pure scientific criteria. Observed trends are inconsistent with LUP's declared objectives of "…ensuring that research results produced by means of public funds shall be utilized for the Danish society through commercial exploitation".

The authors gratefully acknowledge useful comments received from Henrik Lando of CBS

ISBN 87-91549-08-6

1 Introduction

Advanced economies are giving increasing attention to the *direct* contributions from universities to industrial competitiveness. As an important part of this trend a number of countries, inspired by the American Bayh-Dole act of 1980, have been giving their universities a more active role in taking out patents emerging from academic research, and in pursuing their commercialisation.

While more countries are adopting Bayh-Dole inspired policies and developing the administration for their implementation (Technology Transfer Offices, special venture capital programs etc.) an increasing body of research is beginning to question the consequences of the added emphasis on university property rights (Cohen 2004) (Mowery, David, Nelson, Richard R., Sampat, Bhaven N., and Ziedonis, Arvids A.2004; Jaffe and Lerner 2004; Leaf 2005). While this literature largely has focused on the role of universities as patentees, less attention has been given to *effects on academia-industry collaborative research*. This paper confirms previous findings that academia-industry collaborations, typically focusing on exploratory front-end research, is a more important and widespread mechanism for transferring contributions from university science into industrial competitiveness than is the mechanism by which universities pursue their own patenting for subsequent licensing to industry. Biotechnological capabilities developed by firms and by public science are important for both Denmark and Sweden. In the further development of these capabilities, an important role is played by the segment of firms specialised in biotech research, which has emerged particularly over the past 10-15 years. Denmark and Sweden each have about 45 such firms specialised in research aimed at discovery of new pharmaceuticals, commonly referred to as Dedicated Biotechnology Firms (DBFs). They constitute one of the most intensive fields for joint academic-industrial research, and the paper uses this DBF segment as a window on trends in industry's use of public science.

The paper examines the contribution of academic research to inventions patented by Danish and Swedish biotech firms. Specific focus is put on the Danish *L*aw on *U*niversity *P*atenting (LUP) of January 2000 transferring to universities ownership of patents on inventions made by Danish university scientists, be it as a result of their separate effort or as an outcome of joint research with industry. Sweden so far has refrained from reforming academic property rights along the lines of LUP, leaving Swedish academic property rights with the academic inventors much the way they also were in Denmark prior to the reform.

Consequently, systematic comparison of Danish and Swedish research collaboration before and after LUP offers a quasi-controlled experiment, bringing out effects on joint research of regulation affecting its IPR framework, reformed in one case, maintained in the other. These effects have implications not only for understanding the impact of LUP on national science-based competitiveness. They also may deepen our understanding of university-industry collaboration per se, recognising its particular significance in the broader science-technology relationship (Agrawal and Henderson 2002) Denmark and Sweden are attractive cases to compare because regulations of university IPR uniformly affects practically all academic research in each of the two countries, unmodified by country-internal differences between e.g. private vs. public universities or by variations in regulation at lower levels of government (länder or states).

The main objectives of the paper are: 1) To characterise the university-industry collaborations through which academic scientists have contributed to inventions in Danish and Swedish biotech firms, so as to distinguish it more clearly from the type of research which university scientists themselves may take all the way through to the point of patenting. 2) Based on data from the last 15 years to test if systematic trends appear in academic contributions to collaborative inventions, and whether any significant shifts in trends is associated with the implementation of LUP. 3) To consider factors relevant for explaining empirical findings.

The data presented in the paper refer to the most straightforward form in which this use takes place. We study *direct involvement of university scientist in projects* resulting in the inventions claimed by DBFs as their most important advances, as reflected in subsequent patent filings. In its concluding section the paper links its main argument to the additional mode of transfer in the form of university spin-offs. Other more indirect mechanisms of transfer are not considered in the paper, which should be noted particularly in the case of the recruitment, which companies make of university graduates, Ph.Ds or post docs. Studies of the industrial use of academic science highlight this transfer via the labour market as generally playing the larger role (Salter et al 2000). But they also clarify that pharmaceutical research precisely is one of the areas in which *direct* transfer is particularly important (Klevorick et al 1995).

The paper is structured as follows: The next section briefly reviews the reasons behind the increase in collaborative R&D, presents the methodology with which we study these trends, and summarises findings from the few previous studies which have applied similar methods. Section three gives empirical observations on the inventors in patents filed by Danish and Swedish DBFs, while Section four tests models of trends. Section 5 interprets results from the models, discussing mechanisms by which LUP might be related to trends observed in the data. The final section considers implications of our results.

2 Industry-university collaboration: Trends and metrics

Direct relationships between private and academic science is part of a broader trend of increasing inter-organisational collaboration in R&D. Over the previous two decades strategic alliances and collaborative arrangement have come to play a growing role in the organisation of R&D in all high-tech industries (Hagedoorn and van Kranenburg 2003; Calvert and Patel 2003).

This increase in inter-organisational R&D collaboration has been brought about by a confluence of several underlying forces. Technological opportunities have expanded as a result of maturation of basic science-driven inventions (e.g. materials technologies) (Grupp 1998) and of new, general purpose technologies (like software or the internet) (Helpman and Trajtenberg 1998). As a result, individual companies often experience increase in opportunities (or threats) beyond what they can accommodate in internal R&D. At the same time competition intensifies as a result of globalisation and new more effective tools for design and product development (Thomke 2003; Dodgson et al. 2005). Collaborative R&D has emerged as a response to these conflicting pressures, allowing firms to access a much broader pool of skills and to respond to competitive pressures faster and across a broader frontier of opportunities (Chesbrough 2003). Nowhere is this confluence of trends more apparent than in biotechnology. The number of collaborative arrangements has grown steadily through the 1980-90s (Allansdottir et al 2002), and the particular significance for biotech firms of collaboration with, and direct knowledge transfer from, academic science has been documented in a number of studies (Santos 2003; Powell 1998; Liebeskind et al 1996; Fuchs 2003).

For the issues addressed in this paper the key implications from this large body of research is that collaboration with university research for DBFs is anything but an optional add-on. Rather, it plays a key role in their performance, and the possibilities of specific nations or regions for effective networking into academic science will substantially affect the competitiveness of their biotech sectors.

Various methods have been introduced to assess, across large numbers of innovations, the relative size of contributions to industrial inventions coming from academic science. Previous approaches have brought advances in this direction by using citations to academic research in the patenting of inventions (Narin et al 1997) or using survey data (Mansfield 1995). However, additional information may be achieved by building on the identification, recorded on each patent front page, of its key inventors. That approach is applied in the present paper and it may be explained briefly as follows.

While inventors are recorded on patent front pages by name and nationality/region only, this information may be used as a starting point for identifying the partners who collaborated to bring about each patent. Supplementary information on inventors may be retrieved from other sources, particularly for patents in research intensive-fields, where scientists play a key role in inventive activity. Compared to other professions, scientists are comparatively easier to identify through a number of web-based sources. On this basis the organisational affiliation of the inventor, at the time of patent application, may be established with considerable accuracy[1]. Patents based on bio-scientific research often involves multiple inventors, and each inventor team now may be characterised by the composition of organisations collaborating in specific inventions, e.g. by shares of inventors coming from academia or from industry. While this methodology for enriching patent-based inventor data is time consuming, it offers considerable advantages for systematic observation and analysis. Entire technology areas, or countries, may be characterised by their inventor compositions. Or each inventor team may be expressed as a small network with nodes representing host organisations of inventors, allowing networks to be constructed, representing the broader patterns of collaborations in specific fields. For an example see (Valentin and Jensen 2004)

Furthermore, important information is reflected in the status as inventors vs. assignees, the latter being the party to whom ownership of the patent is granted by the authority issuing the patent. Assignee status normally reflects a leading role in the collaboration behind the patent, either in terms of initiating the invention process, taking a larger share of its costs, or supplying problem solving capability required to bring the invention about or to make it commercially valuable. The inventors listed on the patent may, or may not, be part of the organisation having this leading role, since their inventor status only signifies a problem-solving contributions to the novelty. A key advantage of a methodology based on inventor identification is that it allows a mapping of individuals and organisations on these different, only partially overlapping roles in the overall invention process.

The time consuming procedure required to enrich inventor data along the lines described above has led to its application in a few studies only. They provide consistent and somewhat surprising findings on the role of university scientist as contributors to inventions, as distinct from their role as owners (assignees) of patents.

One study focuses on biotechnological analysis and modification of a micro-organism of particular significance in food processing (lactic acid bacteria). Analysis of 180 key patents in this field reveals that it develops through the 1980-90's largely through university-industry research collaboration (Valentin and Jensen 2003a). The 200 assignments and the 320 inventor participations found in this body of patents reveal that firms and universities balance these two roles in very different ways. Companies, in no case contribute inventor capacity without also being assigned the patent. Scientists from universities and Government Research Institutes (GRI), on the other hand, contributed 198 inventor participations, for which they earned 46 of the total of 200 assignments, in other words operating as co-inventors four times as frequently as they obtain assignee status.

A recent large scale study (Crespi et al 2005) identifying one inventor in each of 9000 EPO patents across 6 European countries demonstrates that inventors, as a whole, in nine out of ten cases were involved only in patents subsequently assigned to their employer organisation. However the sample also comprises a small segment of 294 inventor contributions from university scientists, from which they generated only 85 assignments, again producing almost four times more contributions than assignments.

The consistent message from these studies is *first* that the contribution from academic scientists to technological invention cannot be assessed directly from the number of patents assigned to them or to their host university. Using the assignee status of universities on patents is the most common practise for identifying academic contributions to technology, simply because the assignee in this case is identified by the name of an organisation, which is directly retrievable from patent databases. However, this easier approach leads to a sizable underrating of the contribution of academic scientists. Their actual *direct* contribution, in their role as co-inventors, seems to be 3-4 times higher than what is indicated by assignments. To this we may add their much wider, but probably also less intensive, impact on inventions attributable to their academic papers, conference presentation, consulting, and training of graduates and Ph.D.s (Agrawal and Henderson 2002)

[1] In previous studies of various delimitations of biotech patents the authors applied this procedure and obtained identification of 85 – 90% of inventors. Subsequent validation, based on direct confirmation from inventors, reveal identification errors for less that 5% of inventors.

Second, the highly uneven assignment to companies and to university scientists of patents to which both parties have contributed as inventors indicate that academics do not collaborate on inventions motivated by the wish to obtain patent rights. Their other motives are discussed in Section 5.

3 Danish and Swedish academic inventors in biotech

As part of its ongoing monitoring of the biotech sector CBS' *Research Centre on Biotech Business* carries out inventor identification for all patents filed by Danish and Swedish DBFs. This patent information is brought together with a large number of other metrics and indicators in the *Scanbit Database*, which has each biotech firm in Denmark and Sweden as its unit of analysis.

Denmark has 51 DBFs, of which 48 have filed patents. In Sweden 41 of the total of 44 DBFs have filed patents. Quite similar number of patents - 495 Danish and 481 Swedish - were recorded, representing 1731 resp. 1846 inventor participations. Table 1 breaks participation down by employer organisation. Table 2 shows the composition of employer organisations represented by the inventor teams behind each patent, while Table 2A gives descriptive statistics on the two distribution. The Share of Academic Scientists of inventors will be referred to as SAS.

Table 1: Frequency of inventors affiliated with different types of host organisations

Number of inventor participations From different host organisations		Danish affiliations		Swedish affiliations	
		N	Share of total	N	Share of total
Assignee company		1052	60,77 %	527	28,55 %
Other companies		111	6,41 %	329	17,82 %
*PRO**	*Universities*	325	18,76 %	726	39,33 %
	Government research institutes	59	3,41 %	66	3,58 %
Not identified		184	10,63 %	198	10,73 %
SUM		1731	100,00 %	1846	100,00 %

*) Public Research Organisations, including also non domestic organisations
Source: Scanbit Database

Table 2: Configuration of inventor teams in single patents

Number of patents with	Danish patents		Swedish patents	
	N	Share of total	N	Share of total
Only company inventors	302	61,01 %	166	34,51 %
Only PRO inventors	48	9,69 %	164	34,09 %
Mixed PRO and company inventors	128	25,86 %	133	27,65 %
Not identified	17	3,43 %	18	3,74 %
SUM	495	100,00 %	481	100,00 %

Source: Scanbit Database

Table 2.A Distribution of inventor participations

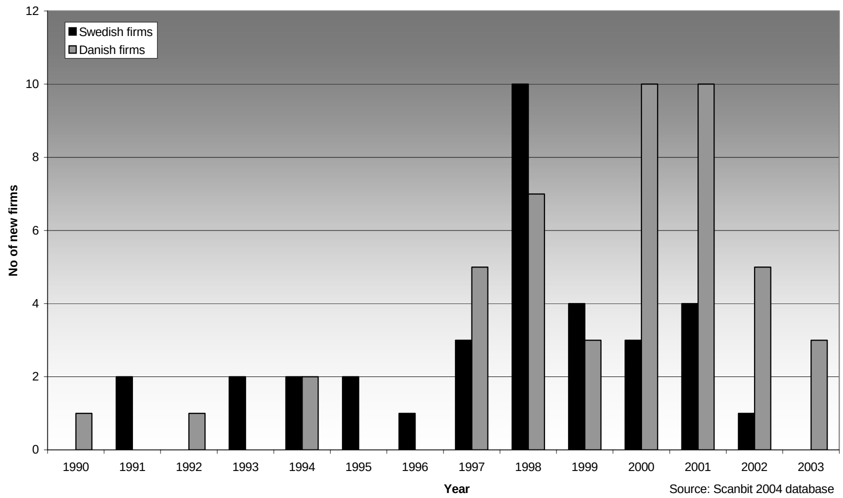
Participations	N	Mean occurrence in single patents	Std Dev	Minimum	Maximum
Danish	1731	3,4969	2,0734	1	12
Swedish	1846	3,8586	2,4691	1	12

Source: The Scanbit Database

Key characteristics from the three tables can be summarised as follows 1) Danish DBFs invent in a comparatively more "introvert" style, the Danish share of inventors coming from the assignee company (61%) being more than two timer higher than its Swedish parallel. 2) Danish inventor teams also have a smaller average size. 3) On the whole, SAS is considerably higher in Sweden, 39% as compared to 9 % in Denmark. 4) The higher Swedish presence of academic inventors appears in the form of 34% of patents being invented by university scientists *only*, more than three times higher than the corresponding share of 9,69% in Danish inventor teams. of. 5) In both countries mixed PRO and company inventors are behind a quarter of all DBF patents.

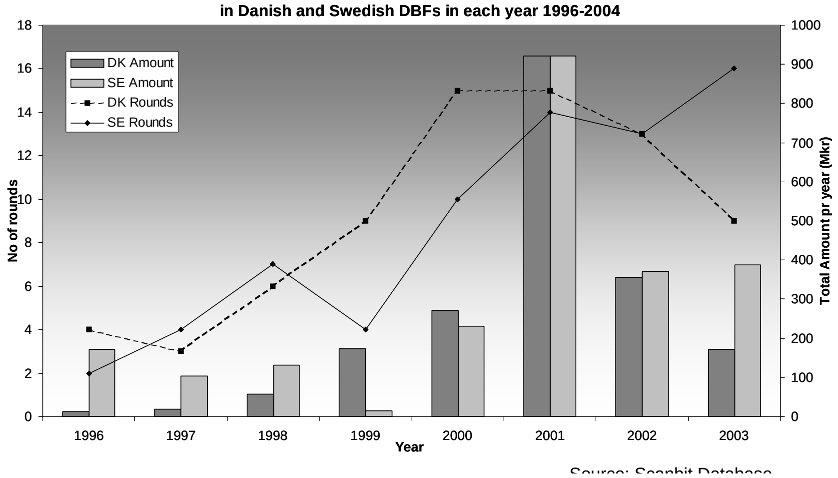
Turning to developments in inventor compositions over time, two factors at the industry level provide an important context. First, the patents examined in this paper come out of firms which emerged as an industry from the early 1990s onwards. Fig 1 presents yearly entry of new DBFs in each of the two countries, showing a higher Swedish entry until 2000, when Danish entries grow to a level two times higher than in Sweden. As a whole the Danish DBF sector has grown slightly larger than the Swedish counterpart, but consists of notably younger firms.

Fig. 1: Number of DBFs established in Denmark and Sweden in each year 1990 – 2003



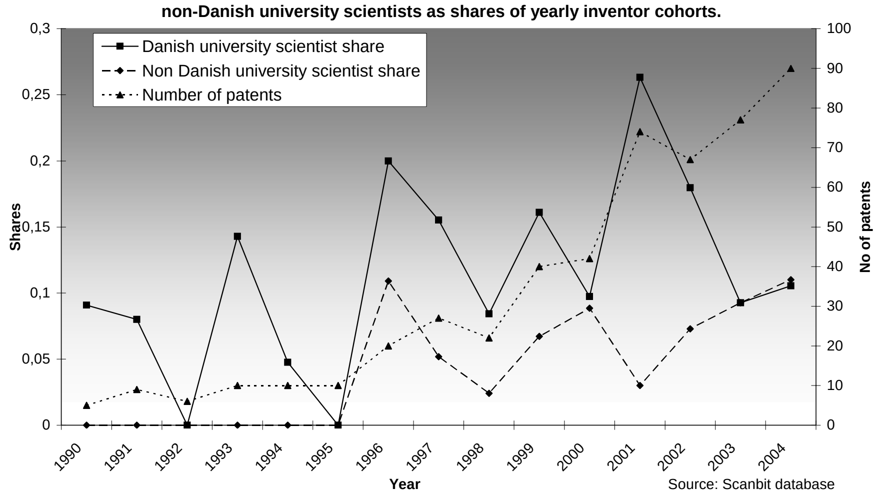
Second, establishment of new DBFs declines steeply following the crisis in venture capital financing in 2001, which spread from the bursting IT bubble to all high-tech sectors. This crises is clearly brought out in Fig 2, giving for each of the years 1996-2004 the total number of Danish Kroner invested in DBF in the two countries, along with the number of investment rounds by which infusion of new capital took place. Invested sums drop dramatically after 2001, whereas the decline in investment rounds is comparatively moderate. Investors, in other words, rather than bringing DBFs to a complete halt, put less money into each investment round, i.e. inducing a reduction of activities, subject to tighter investor control.

Fig. 2: Invested Danish kroner and number of investment rounds in Danish and Swedish DBFs in each year 1996-2004



Figures 3 and 4 present time series on patenting for the years 1990 – 2004, separately for the two countries, reporting both on the total number of patents per year and on national and non-national SAS [2].

Fig. 3 Number of patents filed by Danish DBFs each year 1990-2004 and Danish and non-Danish university scientists as shares of yearly inventor cohorts.

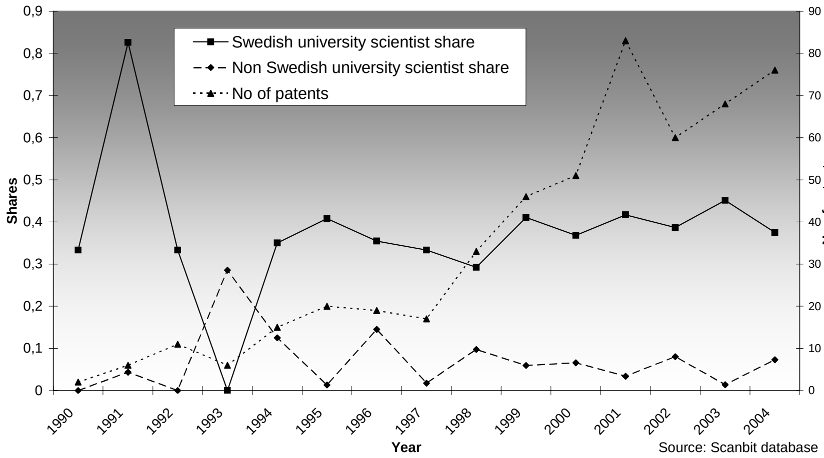


Reflecting its earlier establishment of firms, Sweden maintains a lead in patenting, until Denmark catches up around 2000. The decline in pat-

[2] Patent data is accessible with a delay of about 18 months after application, so that data for 2004 were incomplete when they were identified in the spring of 2005 for use in the present analysis. In Figs. 3 and 4 the numbers of patents from 2004 are extrapolated with the trend calculated from quarterly figures for 2000-2003. Inventor shares are based on observed values only.

enting, induced by the steep drop in investment after 2001, is less pronounced in Denmark than in Sweden.

Fig. 4 Number of patents filed by Swedish DBFs each year 1990-2004 and Swedish and non-Swedish university scientists as shares of yearly inventor cohorts.



The two countries also differ in SAS levels across time. In both countries the large fluctuations up until the mid 1990s come out of very small numbers of patent filings per year. From the mid 1990s, as the numbers of patents increase, fluctuations contract to a range between 30-45% for Swedish SAS and to 1-15% for non-Swedish SAS. No increase in fluctuations is detectable around 2001. The Danish SAS levels in the latter half of the 1990s have larger fluctuations than their Swedish counterparts but clearly increase compared to the first half of the decade. Non-Danish SAS appears from 1995 only and then runs parallel with domestic SAS until 2000. From 2001 a new pattern seems to emerge, beginning with a steep increase in domestic SAS combined with a notable decrease in foreign SAS. Subsequently domestic SAS drops to lower levels, accompanied by a compensating increase in foreign SAS. For several consecutive years the two SAS indicators move in opposite direction, until the non-Danish level in 2004 exceeds national SAS.
The next section tests if underlying trends are present in SAS, and if year 2001, in the Danish case, represents a statistically significant change in the pattern of these trends.

4 Shifting trends

We test for trends by breaking down to quarterly observations the SAS time series presented on a yearly basis in Figs. 3 and 4. This breakdown reveals the first quarter of 2001 as a pronounced peak in Danish SAS, suggesting itself as a natural date for an *event* affecting a possible shift in trends. The time series we examine consequently has 45 observations before and 12 observations after the "event date" of the first quarter of 2001 (2001:1). Danish data are extracted from a total of 495 patents, while 481 patents were used in the Swedish case, representing respectively 1547 and 1648 positive identifications of inventor participations.

Tests are made with OLS regression models with successive quarters as independent variable and domestic and foreign SAS for Denmark and Sweden as dependent variables. Each dependent variable is tested separately, with the event introduced as a 0-1 dummy-variable. A significant estimate for the dummy-interaction with SAS values signifies systematic changes in trends subsequent to the event. Table 3 offers a summary of the data and labels for the variables used in the regressions, while descriptive statistics are presented in Table 4.

Model 1 in Table 5 identifies an increasing pre-event trend in SAS in Danish patents for Danish scientists. The trend is significant at the 5% level, and has a moderate upward slope of 1,35% per quarter, (equivalent to a yearly increase of 5,39%). The post-event trend develops much steeper, at a *declining* rate of 7,2% per quarter (significant at the 5% level). Together the two trends form a model explaining 18% of total variance, significant below the 1% level.

In Table 5, Model 2 presents a parallel test for non-Danish SAS in Danish DBF-patents. Pre-event shares show a strongly significant trend with a slow increase of less than 1% per quarter. Post-event shares shift into a significant trend with an increasing slope three times steeper compared to the pre-event pattern. Together the two trends in Model 2 explain 27% of total variance, significant below the 1% level.

Table 3 Variables and data applied in regressions

Variable label	*Data*
Share of Danish inventors	Danish university scientist’s share of total inventor participations in all patents in each quarter filed by Danish DBFs
Share of non-Danish inventors	Foreign university scientist’s share of total inventor participations in all patents in each quarter filed by Danish DBFs
Share of Swedish inventors	Swedish university scientist’s share of total inventor participations in all patents in each quarter filed by Swedish DBFs
Share of non-Swedish inventors	Foreign university scientist’s share of total inventor participations in all patents in each quarter filed by Swedish DBFs
Quarter	Quarterly time dependency of each observation
Event dummy	Takes values = 0 for application dates until first quarter of 2001, and val-ues = 1 thereafter.

Table 4: Descriptive statistics

Variables	**N**	**Mean**	**Std dev**	**Minimum**	**Maximum**
Share of Danish inventors	57	0,1036	0,1073	0,0000	0,3619
Share of non Danish inventors	57	0,0445	0,0671	0,0000	0,2581
*Share of Swedish inventors**	41	0,3868	0,1689	0,0000	0,7000
*Share of non Swedish inventors**	41	0,0719	0,0957	0,0000	0,3333

*) The Swedish dataset is reduced due to missing values in the first years and further in a reduced period of 1994:1 to 2004:1

Table 5: Regression of the shares in total inventor participations of Danish university scientists (Model 1) and non-Danish scientists (Model 2) as a function of time by quarters.

Dependent variable : Share of Danish and non-Danish inventors in quarters 1990 :1 to 2004 :1		
Independent Variables	*Danish inventor shares*	*Non-Danish inventor shares*
	Model 1	Model 2
Intercept	0,00433 (0,03242)	-0,02187 (0,01912)
Quarter	0,01349*** (0,00446)	0,00864*** (0,00263)
Event Dummy in 2001-1¤§	0,92010** (0,44505)	-0,54908** (0,26248)
Quarter x event dummy	-0,07054** (0,03282)	0,03933** (0,01936)
Pr > F **Adj R-sqr** ***Df***	0,0036 0,1795 56	0,0002 0,2708 56

Standard errors are given in parentheses for each estimate.
Levels of significance as indicated by * = 10% level, ** = 5% level and *** = 1% level.

Both models were tried out in further versions, using a variation of event dates other than 2001:1 to examine if another timing of the event would produce similar or improved results. All variations of the event date produced inferior models. Since the event-date of the first quarter of 2001 represent a dramatic increase in Danish SAS, we tested and confirmed that the model in Table 5 is sufficiently robust to tolerate removal of this single observation.

SAS levels in the Swedish patent data were subjected to parallel tests, the results of which are presented in Table 6. Significant trends for the entire period remained absent in all models testing both domestic and foreign SAS. The graph in Fig. 2 shows initial strong fluctuations in domestic SAS, undoubtedly caused by the small numbers of patents filed during the first 5-year interval 1990-1994. We therefore tested for a trend in the 41 quarters in the 1994-2004 interval of domestic and foreign SAS in Swedish inventor teams. The variation in quarterly figures for Swedish SAS is considerable so in this case a square-root transformation is applied. Model 3 in Fig. 6 confirms an almost horizontal trend, significant at the 10% level, for the Swedish SAS. Similarly a significant, almost horizontal trend emerges in non-Swedish SAS (in Model 4). Tests for a variety of event dates gave no significant results in two Swedish time series.

Table 6: Regression of the shares in total inventor participations of Swedish university scientists (Model 3) and non-Swedish scientists (Model 4) as a function of time by quarters.

Dependent variable : Share of Swedish and non-Swedish inventors in quarters 1990 :1 to 2004 :1. Square root transformation (N = 41)		
Independent Variables	*Swedish inventor shares*	*Non-Swedish inventor shares*
	Model 3	Model 4
Intercept	0,44173*** (0,08642)	0,14886*** (0,05196)
Quarter	0,01592* (0,00829)	-0,00934* (0,00490)
Pr > F	0,0620	0,0637
Adj R-sqr	0,0631	0,0620
Df	40	40

Standard errors are given in parentheses for each estimate.
Levels of significance as indicated by * = 10% level, ** = 5% level and *** = 1% level.

To summarise: 1) Tests confirm the existence of significant trends in the composition of Danish inventor teams. 2) The share of Danish academic inventors has an increasing trend up to the 2001:1 event, after which it reverses into a notable decline. At the same time, non-Danish inventors, having had a lower and more moderately increasing trend up to the event, enter a steeper increasing trend after the event. 3)In other words there are systematic trends in the way foreign academic inventors, subsequent to the event, substitute for the decline in Danish academic inventor shares. 4) No similar shifts appear in domestic and foreign academic inventor shares in Sweden. Instead, from 1994 onward both domestic and foreign SAS reveal significant horizontal trends, demonstrating steady shares for both groups of academic scientists.

5 Interpretations

5.1 Causes unrelated to LUP

Before examining LUP's relationships to the shifts in Danish SAS trends in 2001, a few other possible causes will be considered.

The bursting investment bubble in IT also brought a steep decline in investment and stock values for biotech firms (Fig. 2), and its effects on the extent to which DBFs link up to university science should be considered. One hypothesis could be that firms trim their project portfolios by deprioritising long-term research, expectedly involving more academic collaborations than do short-term projects, hence producing the decline after 2001:1 in Danish SAS identified in Model 1. It is not supported, however, by the observation in Figs. 3 and 4 that, whereas project volumes (as indicated by resultant patents) in Swedish DBFs actually to some extent follow the contraction of investments, Danish patenting merely levels out before resuming an increasing trend. Nor would a shortage of funds explain the substitution of Danish SAS with a corresponding increase in non-Danish SAS, which, ceteris paribus, is more difficult and costly to access. And while Swedish firms are affected by the same international trend of decreasing biotech investments, no similar substitution effect appears here between domestic and foreign SAS (Fig. 4). In short, the Danish shift in SAS after 2001:1 appears to be unrelated to the concurrent decline in investments.

The steep increase in the formation of new DBFs in 2000-2001 (Fig. 1) also should be considered as a possible cause, unrelated to LUP, for shifting SAS trends. The argument behind this conjecture would be that this particularly steep increase in start-ups involved a migration of university scientists to the role of start-up founders to such an extent that a significant part of the inventive potential at this juncture moved from academia to industry. The conjecture, in other words, would be that a particularly inventive segment of scientists maintains a high rate of participation throughout the period, but that after 2001, they produce a decline in SAS shares simply because they move from academia to industry.

We examined this conjecture by identifying all Danish academic scientists who appeared as inventors prior to 2001 and who also spun out as founders of firms in the wave of entries in 2000-2001. That turned out to be only 3 academics, and they delivered only 2,5% of academic inventor participations before they became founders of start-ups, and a similar share of 2,5 % afterwards. In other words, the migration of inventive talent from academia to start-up founder teams specifically associated with the 2000-2001 wave of entries is much too small to be attributed any significant role in explaining the shifting trends in Danish SAS[3].

Comparative deficiency of public funding of Danish university science is a third possible cause for the Danish shift in SAS trends. Denmark has declining public spending on research as a share of GNP since the mid-90s, whereas increasing shares are observed in the EU average and specifically in countries with strong national science bases in the life sciences, such as USA, UK and Sweden (Lauridsen.Per S. and Mortensen 2005). Fast moving fields, like the life sciences in their current state, require increasing funding, and deficiency in this respect may gradually have rendered Danish university science less attractive for biotech firms as partners in joint research. As a case in point Novo Nordisk, Denmark's foremost pharmaceutical company, recently presented the elaborate network into academic science with which it will pursue a leading position in the stem-cells research now emerging as a key agenda within the core therapeutic field of the company. Danish university science plays a negligible role in this major research orchestration of pharma discovery at its most fundamental level[4]. In interviews (undertaken during the spring and summer of 2005 as part of the research for this paper) managers of research in Danish pharma and biotech firms pointed to the accumulating deficiency of public science funding as a factor in their increasing reliance on non-Danish university science. The role of this factor is consistent with he opposite trend in inventor composition identified above in Model 4 (Table 6) for Sweden, consistently amongst leading countries in terms of public research investments, not least in the life sciences. While the role of deficiency in Danish public research funding seems plausible as one of the factors behind the trends identified above, it does not correspond well with the event effects of 2001:1. The divergence in public research spending between Denmark and high spending nations began considerably earlier than that; and while a lagged effect is expectable, there is little reason why it should appear as a fairly abrupt substitution between Danish and non-Danish academic collaborations in 2000:1. In short, the substitution actually observed could very well be a combined effect of funding deficiency plus an event- related mechanism.

---

[3] A related conjecture could be that firms established 2000-2001 gradually would *employ* particularly those academics who, through their prior participation in inventor teams, had demonstrated skills of specific interest to firms. This conjecture would rest on the general assumption that steep increase in entries of new firms produces a level of depletion of academic inventive talent sufficiently large to reduce domestic SAS the next few subsequent years. Visual comparison of Fig. 1 with Danish and Swedish SAS levels in Fig. 3 and 4, gives no support to this conjecture. Nor does a recent systematic study indicate that this particular effect would be strong enough to explain the decline in Danish SAS after 2001:1 (Crespi et al 2005).

[4] Information provided by Hagedorn Research Institute at Novo Nordisk. Se also (Frank 2005)

5.2 LUP and its implications

LUP remains the most likely explanation of this event-related substitution. To assess the role of LUP in this context ideally we should have systematic data of the way university- industry research collaboration was arranged prior to the reform. In the absence of such data, we rely on information from the interviews with research managers referred to above, indicating that collaboration typically would be based on contractual allocation of ownerships rights to the firm and publication rights to involved academics. As part of, or related to this contract, the industrial partner would make resources available in the form of e.g. PhD funding or give access to the firm's research capabilities for purposes specified in the contract[5]. It was up to the two parties to assess if this package of exchanges and joint activities would justify the commitment required for the collaboration, and property rights rarely were a high priority issues for the academic partners.

Largely these are still the conditions for collaborative research operating in Sweden, which so far has refrained from introducing Bayh-Dole inspired reforms of the 1949 act on the "rights to inventions of employees", granting to university teachers the property rights to the results of their research[6]. The strong relationship between Swedish academia and biotech firms in several sources is argued to benefit particularly from this right given to Swedish university scientists (McGguire 2004).

Effective in Denmark as of Jan.1st 2000 LUP was implemented with the purpose (§1) of "…ensuring that research results produced by means of public funds shall be utilized for the Danish society through commercial exploitation" [7]. Its key instrument lies in allocating to universities ownership of an invention made as part of the work of employees (§7). That also pertains to inventions resulting from collaborative work with third parties (e.g. firms), but in these cases the university may (§9) "….upon prior agreement with the party concerned, renounce, in full or in part, the right to the inventions made by the project". It is in other words and option to be decided upon by the university.

The relevance of LUP for understanding the shifts in Danish collaboration patterns identified in this paper does not come out of the regulation of academics in their role as assignees, which obviously is the centre of attention in the law, but which rarely has been the outcome of joint university-industry research. LUP becomes relevant for the shift in university-industry collaboration by transferring to universities, albeit in optionalised form, also the rights to the outcomes from collaborative projects[8].

From the perspective of industrial partners LUP affects the terms of collaboration primarily by giving rise to critical *uncertainties*, not least in the following three respects: 1) Prior to establishing a collaborative relationship with academia the firm will not know whether or not the university in this particular case will exercise its optional rights to IPR. 2) In most cases Danish universities often conclude their deliberations on this option by renouncing their rights, but doing so in ways that unpredictably may disadvantage the firm. Disadvantages may be caused either by slow decision-making on part of TTOs, which may be hazardous in patent racing research, or may be caused by the firm being called upon to inform these procedures in conflict with its concern for confidential aspects of its knowledge and expectations. 3) Finally, research is difficult to contract on, not least because a spe-

[5] These terms corresponds well the typical set-up for industry sponsorship of academic life-science research as identified in more comprehensive surveys, when we correct for their inclusion also of more short-term research issues (Blumenthal et al 1996)

[6] Lagen om rätten till arbetstagares uppfinningar, LAU 1949:345. This specific exception to employer's ownership to their inventions is currently under consideration for reform See e.g. (Sellenthin 2004)

[7] The "Act on inventions at public research institutions" of June 2nd 1999 may be accessed at http://www.videnskabsministeriet.dk/cgi-bin/doc-show.cgi?doc_id=14206&leftmenu=LOVSTOF. An English translation is available at http://www.videnskabsministeriet.dk/cgi-bin/doc-show.cgi?doc_id=20047&doc_type=22&leftmenu=1 .

[8] The implementation of LUP respects terms of collaborative projects commenced prior to the reform, the results of which were filed as patents subsequent to its implementation. A delayed effect of about a year, as observed in the Danish SAS peak in 2001:1 is a plausible timeframe for such a lagged relationship.

cific project may give rise to findings and insights not explicitly covered by, but still derived from, activities and objectives specified in its contract. Whereas such derivations previously were considered part of the residual rights of the company funding the collaboration, LUP turns them into residual rights for the university. Now firms unexpectedly may be met with property claims to results derived from projects which they initially conceived and subsequently funded. These uncertainties are not of a kind precluding collaboration altogether, but they restrict the scope for joint research to agendas amenable for contractual anticipation and solution. And precisely that scope may not necessarily coincide with the agendas offering the most productive synergy for joint university-industry research. That brings our focus of attention to the question of the nature of the research addressed in such joint research.

Before we turn to that issue let us briefly consider if firms after LUP pull out from collaborations with academia for the more mundane reason, that they are unwilling to pay[9] for the contributions from university scientists, which they used to get for free, insisting, as it were, either on free-riding or on opting out.

The main weakness of this free-rider argument is that biotech firms buy and sell intellectual property almost as a matter of routine. Pharmaceutical research, including the sector of biotech research firms, provides what is probably the most intensive and sophisticated market for IP (Arora et al. 2001). Concurrent with the mapping of inventor activities presented in this paper, *Research Centre on Biotech Business* undertakes also a complete mapping of all alliances involving the same population of Danish and Swedish DBFs. These data show Danish and Swedish DBFs contracting into alliances at a frequency exceeding their collaboration with university scientists. To an unusual extent biotech firms are open and receptive to formal contracting and acquisition of IP. It is far from obvious why they should be less open to similar arrangements with university Technology Transfer Offices (TTOs). That is all the more so, since in this particular context they would be contracting about research in which they are involved on a collaborative basis, substantially mitigating the hazards of asymmetrical information which otherwise complicate research contracting. Nor is it likely that collaborations after LUP decline because a considerable part of joint research all along were only marginally useful and hence easily deselected when their indirect costs were driven up by LUP. Notoriously short on scientific resources, DBFs are highly unlikely in the first place to have allocated resources to projects that were not substantially useful to them. The free-rider argument, in short, appears to have little going for it.

The free-rider argument also could be combined with a specific conjecture on timing, arguing that firms up to Jan. 2000 initiated an unusually large amount of collaborations with universities to reap as many benefits as possible before LUP would redefine the rules of the game. This increase arguably could deplete inventive potential to such an extent that collaborations necessarily would subsequently decline. However, the patterns in the 384 academic participations identified in Table 1 above are such that most academics have collaborated one time only, indicating that firms continually renew their collaborative relationships. In the case of multiple participations, for some academics they are concentrated within a few years, for others widely dispersed in time. In short, they are mobilized for collaboration in a form that makes an argument on “temporary depletion” quite untenable.

5.3 The nature of joint university-industry research

If Danish DBFs withdraw from arrangements requiring them to negotiate with TTOs the rights to this particular value, whereas in other contexts they buy and sell IP on research on a regular basis, an obvious question appears: Is there anything specific about the research DBFs undertake with academic scientists which renders it valuable but at the same time vulnerable to requirements that IP rights should be negotiated ex ante?

Science-based firms undertake research projects for purposes that differ in the extent and the ways in which external collaboration becomes helpful. Without attempting any exhaustive categorisation, let us distinguish between three types of research projects based on their role in the overall invention-innovation process:

---

[9] i.e. in the form of licensing or fully acquiring patents resulting from collaborations

1) Some research is directly needed for the design of specific technological solutions. To become useful in this type of "design-enabling research" scientists must understand its technical and functional context, which tend to be highly company and product specific, and they benefit greatly from rich firm-*internal* experience addressing very similar bundles of design restrictions. (Iansiti and West 1999) (Fleming 2002). External collaborations therefore play a limited role in design-enabling research

2) Other projects have the objective of understanding and developing the tools and instrumentation of R&D, as exemplified in the many projects set up by firms in the life sciences through the 1990s to quickly internalise skills in combinatorial chemistry or High Throughput Screening. To accelerate the adaptation of such new tools firms collaborate with external partners who typically would not be university scientists but rather vendors or consultancy firms involved in the commercialisation of new tools for R&D, (Malo 2003) (Thomke 2003). This category of projects could be referred to as "tool-enabling research".

3) A third category of projects are undertaken by firms to keep them abreast of emergent scientific insights of relevance for the field in which they operate (Cohen and Levinthal 1990). These project are essential for providing the opportunities for first mover advantages, which are sine qua non in the patenting-intensive regimes in which science-based firms often operate, and in a number of different ways they provide a basis for other, more applied forms for research in the firm (Rosenberg 1990). They are essentially exploratory in nature and quite unspecific in their relationship to issues of detailed design addressed simultaneously elsewhere in the same company. This third type of project could be referred to as "exploratory research", and it is primarily in this type of research that science-based companies particularly benefit from collaborating with academic science (Calvert and Patel 2003; Meyer-Krahmer and Schmoch 1998; Valentin 2000). Some pharmaceutical firms refer to their activities in this very early front-end of the R&D spectrum as "pre-discovery" or "project generating" research, and as a rule of thumb they expect about 1% of such projects to translate into new drugs. That translation goes via a complex sequence of further investments and combinations with subsequent efforts the costs and success of which cannot be foreseen. As a consequence, companies cannot predict the context in which specific pieces of front-end research may become commercialised, nor the costs required to take it that far (David et al 1994). That defines what is probably the core dilemma for firms confronted with LUP regulations: Firms cannot invest in these complex subsequent processes of translation without having secured their patent rights to the earliest stages of the process. On the other hand they cannot with TTOs negotiate acquisitions of single pieces of this front-end research, since their separate values cannot rationally be calculated ex ante. Therefore if firms cannot collaborate with universities without transferring rights to this knowledge, wholly or partially, to the academic partner, or if in advance they do not know whether the university will exercise or renounce their claims, they often will have no choice but to withdraw from collaborations.

It may be useful to recognise the parallel to the many inventions in biotechnology, and in other science-based technologies, left unexploited and undeveloped in the "valley of death", not because they are known to lack potential, but because they are too immature to be assessed by venture capital for their commercial possibilities. This type of market failure undoubtedly also plays a role in the lack of commercialisation which most TTOs, in Denmark and elsewhere, experience for the larger part of their patent portfolios. It is essentially the same type of market failure, which prevents firms from contracting for access to the results from discovery-oriented collaborative research. By the same argument, the pre-LUP framework could be seen as a hybrid mode of governance that actually allows front-end research not only to be carried out but also to be channelled into a subsequent complex selection and translation towards commercial exploitation. The possibility should not be ruled out ex ante, that pre-LUP conditions stimulated the self-organisation of what actually may have been one of the least ineffective modes of governing invention-oriented fundamental research.

An important implication of this argument is that academics, without collaborating with industry, rarely on their own would have defined the same research issues. Nor are universities by themselves fit for taking results from such research all the way through the complex translation via many subsequent investment and projects which eventually may render the initial project valuable. Therefore the joint research aborted by LUP will not appear in stead as knowledge produced and patented by universities. LUP does not provide a substitute mechanism, allowing the same research to be undertaken by academics on their own, the only difference being that the university now will hold rights. If LUP nevertheless incentivizes academics to direct some of their research to patentable technologies, most likely they will be of a different kind requiring much less in term of subsequent translational projects. On the spectrum from simple to complex technologies (Rycroft 1999), university patenting may be expected to gravitate towards the former. In the context of biotech related research that means a comparatively higher share of university patents directed at areas like tests, research tools, diagnostics etc.

The nature of academic-industry research collaborations cannot be understood without also considering what they mean for participating academics. A recent study obtained responses from 4300 UK academics[10] in the UK on their *types of relationships* with industry, including joint research, of the kind considered in the present paper, along with consultancy, conference attendance, joint PhD supervision etc., on a menu of 9 different types of relationships (D'Este and Patel 2005). The first finding to note from this study, is that factor analysis of the 9 types of relationships brings out "joint research" as a separate, highly robust factor. In other words, more than any of the other relational types, joint research is sui generis in the way academics connect to industry. Furthermore academics engage in joint research for purposes that are distinctly and significantly different from the motivations driving them in other types of relationships with industry, say as consultants. Using the response categories from the survey, academics do joint research predominantly for the purpose of "keeping abreast of research in industry"; "increasing the applicability of university research" and "getting access to research expertise in industry". So whereas academics may engage in other relational types for a variety of reasons, they participate in joint research so as to better anticipate the technological frontier, and to access expertise of a kind less easily found within academia. To put it differently: In stead of seeing joint research with industry as a detour temporarily diverting them their core scientific agenda, collaboration is perceived as having intrinsic, i.e. epistemic, value for this agenda.

This understanding is supported by another recent study, which identifies higher overall scientific publication performance of 299 Italian university scientist credited as inventors in EPO patents in the 1978-99 interval, compared to a matched sample of academics without inventor contributions (Breschi, Lissoni, and Montobbio 2005). Superior performance is attributable partly to the well-known phenomenon that a segment of academics delivers a disproportionately high share of publications. So while it is not surprising that this segment has its higher productivity expressed in *both* patenting and publications, it also means that industry recruits its academic inventive potential particularly within this high-performing segment. Higher performance, however, also is a result of the projects in which academics have contributed to patented inventions, because academics in these projects access extra resources. For the same reason the beneficial effects of inventor contributions on subsequent publication rates is much stronger for inventions patented by firms as compared to academic inventions patented by universities. An equally interesting finding in this study is that this beneficial effect on academic performance does not imply a shift towards more applied research. On he contrary, it is particularly strong when it comes to publications in *basic* science journals.

It is perhaps not sufficiently recognized that collaboration with industrial partners may fit into particular stages or issues of academic research in ways that benefits its progress (Rosenberg 2000; Rosenberg 1994). Collaboration sometimes offers an opportunity for the academic scientists to experiment on a larger scale, or under more realistic conditions in ways that may substantially benefit advances in academic research. Those opportunities arise with particular frequency and intensity when industrial research itself progresses on the frontier of science and technology. In a recent paper the present authors demonstrate, that academic scientist exhibit increased presence in industry collaboration precisely during the stage when new agendas emerge for industrial research, arguably be-

[10] Sampled from the total of 25400 university scientists who had received grant from the Engineering and Physical Research Council between 1999 and 2003

cause that is when collaboration with industrial R&D is particularly fruitful for the advancement of scientific knowledge (Valentin and Jensen 2003b).

When combining the two sets of driving forces behind university-industry research collaboration, i.e. those motivating industry as well as those driving academics, we realise that they are not only different. They also offer complementarities and synergies which by themselves may benefit either party. Therefore, when left with sufficient possibilities for self-organising behaviour, university scientists and firms are likely to select issues for collaboration on the criteria that they offer, at one and the same time, opportunities for epistemic and technological advances (albeit technological intensions at this early stage are quite unspecific). The defining characteristic of this collaboration, consequently, is a research agenda representing *a duality of epistemic and technological objectives*.

To understand how the pursuit of this duality has been affected by LUP, it is useful to clarify the underlying rationale for the widespread pre-LUP practise by which technological exploitation (patents) went to the industrial partner, while the university scientists appropriated the academic reputation (through publications). In this arrangement perhaps the most important aspect of the control either party had to their respective outcome referred to their residual rights (i.e. those not explicitly specified in the contract), so that in this context they became "partitioned residual rights". Much hinges on exactly this principle, since partners in joint research do not look upon their collaboration only from a static perspective as an exchange of information and activities. Rather they see the project and its outcome more as a type of good offering *generative* potential, capable of bringing about further benefits when combined with additional activities or assets separately controlled by the partners. Contracts with high tolerance for partitioned residual rights are helpful for joint efforts directed at such generative goods, because they incentivize partners to invest in their creation, at the same time handling their concern that they cannot ex ante specify claims on outcomes.

This rationale for pre-LUP collaborations in several respects is dismantled by the reform. First LUP introduces the university (as represented by its TTO) as an actor looking for potential revenues to the university. That is quite different from the pre-LUP version of university interests, which were represented through academics looking for intellectual synergy combined with industrial funding. Essentially LUP builds a tri-partite contractual space involving the TTO, the academic and the company, and the common denominator interests for all three in many cases will be different from the shared aims of the two latter. Second, from the outset all rights in this tripartite set-up are assigned to the TTO. As discussed above, whether renounced or not, this pre-allocation of all rights causes critical uncertainties for industrial partners, primary because it complicates their utilisation of the generative potential of collaboration, which often would be their key motivation for doing joint research in the first place.

These complications, we submit, are the most plausible reasons why Danish biotech firms, after the implementation of LUP withdraw from collaborations with Danish university scientists, increasingly substituting them with non-Danish academics, presumably operating under less restrictive regulation.

For the same reasons we may expect that university-industry collaboration, not addressing basic, early discovery oriented research, but in stead issues considerable closer to technological innovations in their final form *will be less disturbed* by LUP regulation. In "close to technology-projects" firms more easily can asses the potential market value of specific project results, which in turn allows them to undertake rational market transactions with TTOs on IP to these results. In other words, LUP is not uniform in its effects on joint university-industry research. Ceteris paribus, it will operate best for joint R&D on issues closer to commercial technologies. Whether or not academic engagement in that type of R&D is consistent with the broader rationale and objectives of universities opens a set of issues beyond the scope of the present paper.

6 Discussion

Is it a problem at all that Danish university scientists contribute to inventions of Danish biotech to a considerably lower extent after LUP? Will other mechanisms not compensate for whatever loss may come out of the decline in Danish SAS?

Above we already considered one possible compensatory mechanism in the form of the argument that academic research which under pre-LUP regulation would have been carried out collaboratively with biotech companies and subsequently patented by those companies, now in stead appears as research carried out by and patented by the university on its own. We argued that whereas LUP is unlikely to provide this substitution it may in stead incentivize other types of technology-related research from universities. The extent to which university patents appearing on that basis develops towards real commercial potential is the subject of considerable current controversy (Mowery, David, Nelson, Richard R., Sampat, Bhaven N., and Ziedonis, Arvids A.2004) (Leaf 2005), so it remains to be seen if TTO patenting will compensate for the decline in direct university-industry collaboration. The benchmark for TTO performance in this respect is not if their patent portfolios are growing, and if some of these patents begin to generate license fees. The more relevant criteria compares this income to the large sums so far spent on setting up and running TTOs. And it considers if the inventive potential of university scientists behind TTO-held patents might have generated larger social value if exploited and commercialized by other mechanism, say as inputs to the complex selective and combinatorial processes of science-based firms, i.e. preserving academics in the role of co-inventors without giving to them or to their employer universities the role of patentees.

Finally, let us consider the compensating mechanisms appearing in the form of non-Danish scientists replacing domestic academics as partners for biotech firms in collaborative research? Why should it matter that Danish biotech firms for their university collaborations substitute Danish with non-Danish academics? We shall argue that it matters for both academia and industry in Denmark. Projects offering a combination of epistemic and technological advances are not that frequent, and are likely to offer substantial learning value for both the academic and the industrial partners. It seems inconsistent with concerns for Danish science-based competitiveness to have legislation designed so as to reduce the participation of Danish academia in these learning opportunities.

Furthermore, the decline in Danish SAS after the reform signifies an increasing disengagement between national industrial and academic research actors, implying an erosion of the advantage Denmark has, based not on its individual firms but on the *relationships* between actors by which they become a network. Networks are useful collective assets, for several reasons, one of which is that they provide *search advantages*.

A useful point of departure for appreciating the role of search advantages is offered in findings from multiple studies documenting that research collaborations in biotechnology are established with a strong preference for partners from the same country, even the same region (Allansdottir et al 2002). When it comes to licensing arrangement or procurement of specialized research instrumentation, biotech firms are profoundly international, indicating that proximate partners offer specific types of advantage when it comes to research? The advantage of proximate research relationships is not derived from superior qualities of partners, who just happen to be local. Rather it comes from the fact that proximate relations tend to be embedded in networks in which actors have repeated interactions and learn about each other via multiple channels (Powell 1998; Pyka et al. Pyka, Andreas and Küppers, Günter2003). In this way networks become architectures capable of retaining and transmitting vastly richer information about each actor, as compared to arms-length relationships to partners who are distant (in the sense of not being part of the network) (Reagans and McEvily 2004). That is why networks offer superior search, allowing actors with complex agendas to access the types of complementarity which gives rise to effective research partnering (Valentin and Jensen 2002).

For the issues in the present paper the implication of this argument is that an important part of the value emerging from industry-academia collaborations lies in *the quality of the network* through which either side may undertake effective search so as to identify “the right complementarity at the right time”. Danish DBFs have no advantage above that of DBFs from other countries when it comes to search into the global “market” for academic collaboration. But they do have an advantage in search into the Danish academic setting, since there are strong indications that they are particularly well connected into Danish universities. Concurrent with the inventor mapping reported on above, *Research Centre on Biotech Business* also has undertaken a full identification of the founders and board members that took all Danish and Swedish DBFs through their first year of existence[11]. For both groups, the vast majority of members are recruited from Danish organizations. On that basis Table 7 reports on compositions of founder teams, based on the pre-entry organizational affiliation of each founder, and on board composition, based on the primary organizational affiliation of each board member.

Teams involving Danish university scientists founded more than half of Danish DBFs. Similarly academics were present on more than half of the boards that took firms through their first year of business. These compositions of founder teams and board make them highly effective in subsequent search into the academic potential for research collaboration.

Table 7: Composition of founder team by pre-entry affiliation and of first year board by main organisational affiliation of board members

Types of composition	**Composition of founder teams**		**Composition of boards**	
	N	**Share of total**	**N**	**Share of total**
*Only company**	18	47,37 %	18	47,37 %
Only PRO	10	26,32 %	1	2,63 %
Mixed PRO and Company	10	26,32 %	19	50,00 %
SUM	38	100,00 %	38	100,00 %

*) Including all types of companies
Source: Scanbit Database.

These figures bring out the particular connectivity, which Danish DBFs have into Danish academia. In turn this connectivity brings notable search advantages when scientists either from the academic or from the industrial side go looking for the complementarity of skills and agendas which are so important for making university- industry research collaboration effective and useful for both commercial and scientific objectives.

In a recent paper we demonstrate that precisely this diversity of founders and boards matters for the ability of Danish DBFs to establish the diversity of inventor collaborations which in turn affects their commercial performance (Valentin and Jensen 2005). These observations substantiate that search advantages into a network of *potential* collaborators constitutes a type of social capital with considerable value for inventiveness and competitiveness of firms. It is therefore cause for concern when the trends identified in this paper indicate that Danish biotech firms disengage themselves form the national research network, substituting in stead with search in the global market for academic research partners. It signifies that LUP, as an unintended side effect, seems to have induced an erosion of national networks of considerable value for Danish science-based competitiveness.

[11] Information on founder and board compositions was carried out by Sune Vorre, Peter Bille Krogh from CBS's masterprogram in Innovation Management.

Reference List

Agrawal, A. and R. M. Henderson (2002) 'Putting patents in context: Exploring knowledge transfer from MIT', Management Science, 48(1), 44-60

Allansdottir, Agnes, Andrea Bonaccorsi, Alfonso Gambardella, Myriam Mariani, Luigi Orsenigo, Fabio Pammolli, and Massimo Riccaboni (2002), 'Innovation and competitiveness in European biotechnology', Bruxelles: Enterprise Directorate-General, European Commission.

Arora, Ashish, Alfonso Gambardella Andrea Fosfuri (2001), Markets for Technology and their Implications for Corporate Strategy, Cambridge, Mass.: The MIT Press.

Bloch,C., 2004, "Biotechnology in Denmark: A Preliminary Report". The Danish Centre for Studies in Research and Research Policy

Blumenthal, D., N. Causino, E. G. Campbell and K. Seashore (1996) 'Relationships between Academic Institutions and Industry in the Life Sciences - An Industry Survey', New England Journal of Medicine, 334(6)

Breschi,S., Lissoni,F., and Montobbio,F., 2005, "The Scientific Productivity of Academic Inventors: New Evidence From Italian Data". CESPRI, Centre for Research on Innovation and Internationalisation, Universita' Bocconi, Milano, Italy, *CESPRI Working Papers* no 168

Brink, Johan, Maureen McKelvey, and Keith Smith (2004), 'Conceptualising and measuring modern biotechnology', in Jens Laage-Hellman, Maureen McKelvey and Annika Rickne (eds), The Economic Dynamics of Modern Biotechnologies, Cheltenham: Edward Elgar Publishing, pp. 20-40.

Calvert, J. and P. Patel (2003) 'University-industry research collaborations in the UK: bibliometric trends', Science and Public Policy, 30(2), 85-96.

Chesbrough, Henry W. (2003), Open innovation -The new imperative for creating and profiting from technology., Boston: Harvard Business School Publishing.

Cohen, W. M. and D. A. Levinthal (1990) 'Absorptive capacity: A new perspective on learning and innovation', Administrative Science Quarterly, 35(1), 128-152.

Cohen, W. M. (2004) 'Patents and Appropriation: Concerns and Evidence', The Journal of Technology Transfer, 30(1-2), 57-71

Crespi, Gustavo, Aldo Geuna, and Lionel Nesta (2005), Labour mobility from academia to business, DRUID Summer Conference Jun 27-29, 2005 at Copenhagen Business School

D'Este, Pablo and Pari Patel (2005), University - Industry linkages in the UK: what are the factors determining the variety of interactions with industry? DRUID Summer Conference Jun 27-29, 2005 at Copenhagen Business School

David, Paul A., David C. Mowery, and W. E. Steinmueller (1994), 'Analyzing the Economic Payoffs from Basic Research', in David C. Mowery (ed), Science and Technology Policy in Interdependent Economies, Boston, Kluwer Academic Publishers., pp. 57-78.

Dodgson, Mark, David. M. Gann Ammon J. Salter (2005), Think, Play, Do: Innovation, Technology, and Organization, Oxford: Oxford University Press.

Fleming, L. (2002) 'Finding the organizational sources of technological breakthroughs: the story of Hewlett-Packard's thermal ink-jet', Industrial and Corporate Change, 11, 1059-1.

Frank, Lone, 2005, "Instrumus": *Weekendavisen*, 17-05-2005

Fuchs, Gerhard (2003), Biotechnology in Comparative Perspective, Routledge.

Grupp, Hariolf (1998), Foundations of the Economics of Innovaton, Cheltenham, UK: Edward Elgar.

Hagedoorn, J. and H. van Kranenburg (2003) 'Growth patterns in R&D partnerships: an exploratory statistical study', International Journal of Industrial Organization, 21(4), 517-531.

Helpman, Ethanan and Manuel Trajtenberg (1998), 'Diffusion of General Purpose Technologies', in Ethanan Helpman (ed), General purpose technologies and economic growth, Cambridge, Mass.: The MIT Press, pp. 85-119.

Iansiti, M. and J. West (1999) 'From physics to function: An empirical study of research and development performance in the semiconductor industry', Journal of Product Innovation Management, 16, 385-399.

Jaffe, Adam B. and Gosh Lerner (2004), Innovation and Its Discontinents: How Our Broken Patent System Is Endangering Innovation and Progress and What to Do About It., Princeton: Princeton University Press.

Klevorick, A. K., R. C. Levin, R. R. Nelson and S. G. Winter (1995) 'On the sources and significance of interindustry differences in technological opportunities', Research Policy, 185-205.

Lauridsen.Per S. and Peter S. Mortensen (2005), 'Offentligt forskningsbudget for Danmark 2005', Århus Universitet: Dansk Center for Forskningsanalyse.

Leaf, Clifton, 2005, "The Law of Unintended Consequences": *Fortune*, v. 152, (6):

Liebeskind, J. P., A. L. Oliver, L. G. Zucker and M. B. Brewer (1996) 'Social networks, learning and flexibility: sourcing scientific knowledge in new biotechnology firms', Organization Science, 7(4), 428-443.

Malo, Stéphane (2003), The Knowledge-based Economy – New Challenges in Methodology, Theory and Policy, The 3rd European Meeting on Applied Evolutionary Economics. University of Augsburg, Germany April 9 -12, 2003.

Mansfield, E. (1995) 'Academic research underlying industrial innovations: Sources, characteristics and financing', Review of Economics and Statistics, 77(55), 65.

McGguire, Stryker, 2004, "Science and Savvy. Sweden: A culture of innovation breeds biotech start-ups": *Newsweek*, 26-07-2004

Meyer-Krahmer, F. and U. Schmoch (1998) 'Science-based technologies: university-industry interactions in four fields', Research Policy, 27(8), 835-851.

Narin, F., K. S. Hamilton and D. Olivastro (1997) 'The increasing linkage between U.S. technology and public science', Research Policy, 26, 317-330.

Mowery, David, Richard R. Nelson, Bhaven N. Sampat, and Arvids A. Ziedonis (2004), Ivory Tower and Industrial Innovation: Univerity-Industry Technology Before and After the Bayh-Dole Act, Stanford University Press.

Powell, W. W. (1998) 'Learning from collaboration: Knowledge and networks in the biotechnology and pharmaceutical industries', California Management Review, 40(3), 228-240.

Pyka, Andreas, Günter Küppers eds. Pyka, Andreas and Günter Küppers (2003), Innovation Networks. Theory and Practice, Cheltenham: Edward Elgar.

Reagans, R. and B. McEvily (2004) 'Network Structure and Knowledge Transfer: The Effects of Cohesion and Range.', Administrative Science Quarterly, 48(2), 240-268.

Rosenberg, N. (1990) 'Why do firms do basic research with their own money?', Research Policy, 19, 165-174.

Rosenberg, Nathan (1994), 'Science-Technology-Economy Interactions', in Ove Granstrand (ed), Economics of Technology, Amsterdam: North Holland, pp. 323-337.

Rosenberg, Nathan (2000), Schumpeter and the endogeneity of technology -some American perspectives., London: Routledge.

Rycroft, Robert W. (1999), Complexity Challenge. Technological Innovation for the 21st Century, London: Pinter.

Salter, Ammon, Pablo D'Este, Keith Pavitt, Pari Patel, Alister Scott, Ben Martin, Aldo Geuna, and Paul Nightingale (2000), 'Talent: Not Technology: The Impact of Publicly Funded Research on Innovation in the UK', University of Sussex: SPRU.

Santos, F. M. (2003) 'The co-evolution of firms and their knowledge environment: Insights from the pharmaceutical industry', Technological Forecasting and Social Change, 70(7), 687-715.

Sellenthin,M.O., 2004, "Who should own university research? An exploratory study of the impact of patent rights regimes in Sweden and Germany on the incentives to patent research results". Swedish Institute For Growth Policy Studies.

Thomke, Stefan H. (2003), Experimentation matters, Boston, Mass.: Harvard Business School Press.

Valentin, Finn (2000), Danske virksomheders brug af offentlig forskning. En casebaseret undersøgelse, Copenhagen: Danmarks Forskningsråd.

Valentin, F. and R. L. Jensen (2002) 'Reaping the fruits of science', Economic Systems Research, 14(4), 363-388.

Valentin, F. and R. L. Jensen (2003a) 'Discontinuities and distributed innovation - The case of biotechnology in food processing', Industry and Innovation, 10(3), 275-310.

Valentin, Finn and Rasmus Lund Jensen (2003b), Pushing the envelope. Self-organised selective involvement of university scientiests in industrial biotechnology, Conference in memory of Keith Pavitt. SPRU, University of Sussex, Brighton, U.K. 13th-15th November 2003

Valentin, Finn and Rasmus L. Jensen (2004), 'Networks and technology systems in science-driven fields. The case of European biotechnology in food ingredients', in Jens Laage-Hellman, Maureen McKelvey and Annika Rickne (eds), The Economic Dynamics of Modern Biotechnologies, Cheltenham: Edward Elgar Publishing,

Valentin, Finn and Rasmus Lund Jensen (2005), Entrepreneurship, networks and strategising in biotech start-ups, 21st EGOS Colloquium - 'Unlocking Organizations' June 30 - July 2, 2005. Freie Universität Berlin in cooperation with Wissenschaftszentrum Berlin