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Trade

It is interesting to examine whether it is primarily specific branches that are interested in hiring Industrial PhDs after they have successfully completed their education. The immediate expectation would be for Industrial PhDs, as a result of their educational profile and company affiliations, to be mainly employed in trades that focus on research and innovation. This can initially be illustrated by examining Industrial PhD divisions among different trades as shown in Table 3.2:

Table 3.2: Trade divisions		
Trade	Industrial PhDs	Other PhDs
Finance and business services	39.6%	25.7%
Industry	35.9%	12.4%
Public sector services	14.9%	58.7%
Transportation, mail and telecommunications	3.1%	0.8%
Trade, hotels and restaurants	2.7%	1.6%
Energy and water supply	1.3%	0.3%
Agriculture, fishing and raw material extraction	0.2%	0.5%
Building and construction	0%	0.1%
Note: For Industrial PhDs n=449, and for other PhDs n=7327		
Source: Statistics Denmark		

Table 3.2 shows that Industrial PhDs are primarily employed within three trade areas, two of which clearly stand out: “Finance and business services” and “Industry”.

Not surprisingly, finance, business services and industry employ approximately 90 percent of the Industrial PhDs as they are relatively large trade categories that include many of the large Danish enterprises that participate in many Industrial PhD projects.

There are also 3 primary trade areas where regular PhDs find employment. But the division is different. The most important area is clearly “Public sector services”. Only approximately 12 percent are employed in industry, which illustrates a marked difference between the two types of PhD education.

To gain a better impression of the trade division, the trends were examined over time. This is shown in Table 3.5, where Industrial PhDs and PhDs are divided according to trade one, three, five, seven and nine years respectively after successfully completing

their PhD education. It is based on the three most important trade areas as described in Table 3.2:

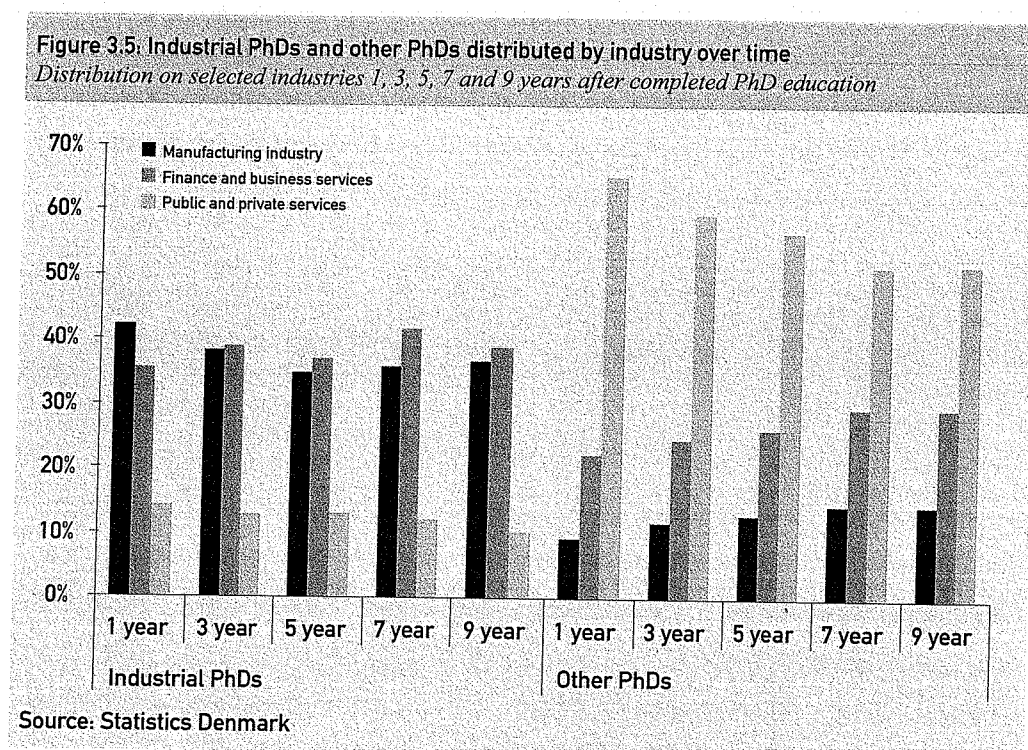


Figure 3.5 shows that over time, there is no significant difference in trade division for Industrial PhDs. The trade division is relatively stable between the three main areas for the period.

The difference is more pronounced over time for the regular PhDs. Thus, the share in “Public sector services” drops a little over 15 percent over the nine years. At the same time, there is an increase within “Finance and business services” and “Industry” where more PhDs find jobs over the course of their career.

Thus there is an indication that there is less “trade manoeuvring” for regular PhDs during the course of their career while Industrial PhDs are well represented in these trades from the beginning.

Enterprise size

The enterprises participating in Industrial PhD projects must be in a position to guide an Industrial PhD student at the highest level and contribute to formulating relevant research topics, which means that the enterprise must have some research experience.

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All things being equal, one would expect that several large enterprises would have the necessary capacity to participate in an Industrial PhD project.

Table 3.3 shows that an increasing number of enterprises are also using the Industrial PhD programme. The table lists an enterprise only once even if it has several Industrial PhD projects in a given year.

Table 3.3: Industrial PhD enterprises divided according to size, for the years 2002-2005

Enterprise size	2002	2003	2004	2005
Large enterprises (over 250 employees)	17	18	30	28
Medium enterprises (50 to 250 employees)	8	7	9	9
Small enterprises (less than 50 employees)	10	16	11	16
Total number of enterprises	35	41	50	53

Note: Number of different enterprises calculated according to size that have had approved Industrial PhD projects from 2002-2005.
Source: DASTI

While the number of enterprises stayed relatively constant at approximately 30-35 enterprises in the 1990s, by 2005 this had increased when 53 different enterprises participated. The preliminary statistics for the first half of 2006 show that the growth will apparently continue. In general, the Industrial PhD is spread among all types of enterprises, regardless of size. It has also become more widespread, so the types of enterprises that are hiring Industrial PhD students are more varied than in the past.

An evaluation of the enterprises' share based on their size for specific years does not give the full impression of whether the Industrial PhD projects are spread among a few or several different enterprises. This can be examined by dividing the enterprises according to the number of projects over a period, as shown in Table 3.4 below:

Table 3.4: Division of enterprises according to number of projects from 2000 to the first half of 2006

Number of projects	Number of enterprises
1 project	130
2 projects	29
3 projects	10
4 projects	7
5 projects	3
More than 5 projects	11
Total	190

Note: Statistics of enterprises that have had approved Industrial PhD projects for the period 2000 to the first half of 2006

Source: DASTI: Enterprises 2000 to the first half of 2006

Table 3.4 shows that 190 different enterprises have been affiliated with Industrial PhD students between 2000 and the first half of 2006. Of these, 130 enterprises had one project. The rest of the enterprises had a minimum of 2 projects.

Among this group, there are 11 enterprises that made up 37.6 percent of the 418 projects. It is a group of trend-setting enterprises in Danish research circles, which together have research budgets that can measure up to the total public research budgets.

It is interesting that the large research enterprises also use the Industrial PhD programme and thus actively contribute to the education of new young researchers in Denmark through co-financing and guidance.

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Box 3.1. List of the most active enterprises in the Industrial PhD programme

The list shows the 11 enterprises with more than 5 Industrial PhD projects for the period 2002 to the first half of 2006. The enterprises make up 37.6 percent of the total number of projects.

- Novo Nordisk A/S: 65 projects
- H. Lundbeck A/S: 19 projects
- Novozymes A/S: 16 projects
- NeuroSearch A/S: 10 projects
- Danfoss Drives/Sauer Danfoss: 8 projects
- Haldor Topsøe A/S: 8 projects
- Vestas Wind Systems A/S: 7 projects
- Birch & Krogboe: 6 projects
- Oticon A/S: 6 projects
- Danish Technological Institute: 6 projects
- Grundfos Management: 6 projects

Source: DASTI (period: 2002 to the first half of 2006)

Geographical location

One of the goals of the Industrial PhD programme is to have a geographical spread across the participating enterprises. To this end, a goal was set for 30-40 percent of the enterprises to be located outside of the Greater Copenhagen area³.

³ Source: Guidelines for the Industrial PhD programme, May 2006

Figure 3.6: Geographical location of Industrial PhD projects distributed by university from 2002 to first six months of 2006 (n=305)

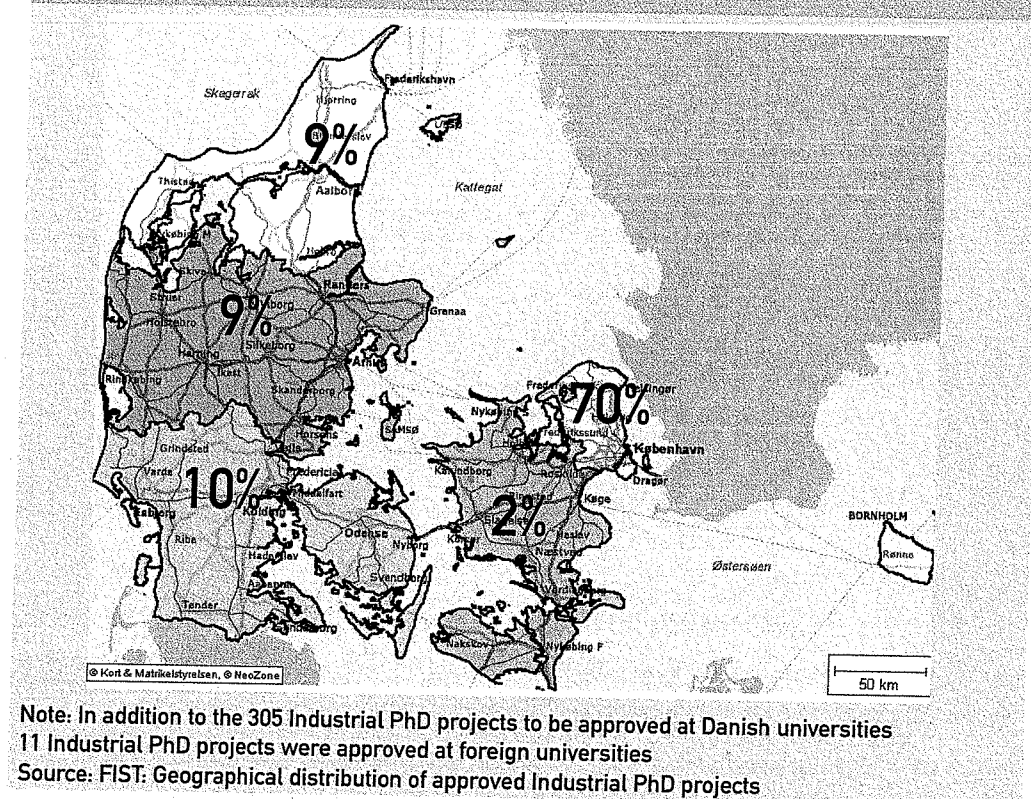


Figure 3.6 shows there is a relatively large difference in the extent that Danish universities use the Industrial PhD programme. The Greater Copenhagen area dominates with 70 percent of all approved Industrial PhD projects for the period 2002 to the first half of 2006.

The figure also shows that the goal of a 30-40 percent share of the Industrial PhD projects outside of the Greater Copenhagen area has been met.

The Greater Copenhagen area's position is probably due to three reasons:

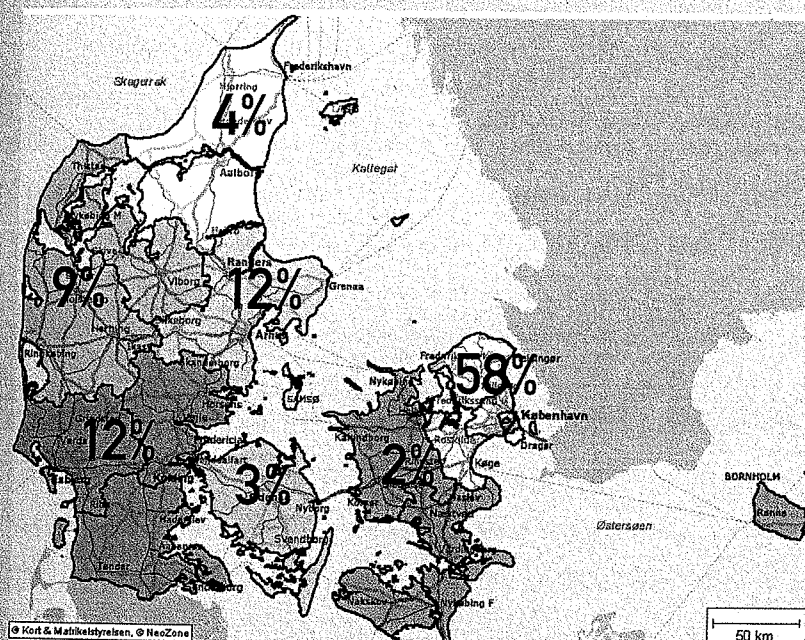
1. The Greater Copenhagen area has a significantly higher share of research-intensive enterprises than the other regions, which is confirmed in Figure 3.7. It can be expected that the more research-active an enterprise is, the more capacity it has to participate in Industrial PhD projects.
2. There is also a large difference in the extent that the universities use the Industrial PhD programme. Universities in the Greater Copenhagen area, the Technical University of Denmark in particular, have used the programme and collaborated with many enterprises in this manner⁴.

⁴ A more thorough analysis of how the universities use the initiative is detailed in section 3.3

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- In addition to this, 8 out of the 11 enterprises with more than 5 Industrial PhD projects are located in the Greater Copenhagen region. The high percentage of Industrial PhD projects is thus partially due to the fact that the majority of the enterprises that actively use the programme are located in this region.

Figure 3.7: Innovation activities by Danish enterprises
 Figures from 2004 distributed by region and shown in percent



Source: The Danish Centre for Studies in Research and Research (2006)

As Figure 3.7 shows, northern Jutland's share of the total private investments in innovation activities is only 4 percent, while 10 percent of the country's Industrial PhDs are educated in that region. This indicates that enterprises from northern Jutland use the Industrial PhD programme more than one would expect.

On the other hand, the Mid-Jutland region is under represented in the Industrial PhD programme where 14 percent of Industrial PhDs are educated but the total innovation costs are higher than 20 percent⁵. This indicates that enterprises and universities in this region use the Industrial PhD programme to a lesser degree compared to the general innovation expenses. More potential could be expected here for Industrial PhD projects, which could likely be realised through a more pro active effort from the

⁵ Please note that the figures used in Figure 3.7 are based upon the previous demarkation of municipalities in Denmark. The Mid-Jutland region now encompasses the whole of the previous Århus municipality, and parts of the previous municipalities of Ringkøbing and Vejle. It is estimated that this region constitutes 20 percent of national innovation activities.

universities in the area. One explanation for this circumstance could be that Aalborg University has traditionally had close collaboration with the local business world.

Research-intensive enterprises are the most active

The purpose of the Industrial PhD programme is to educate researchers with insight into the business aspects of research and development. Thus it is directed towards enterprises that can provide professional support to a 3-year, business-directed research and development project⁶. On that basis, it is interesting to examine the extent that the initiative has primarily been used by enterprises qualified for research.

One indicator of an enterprise's readiness to do research is their research and development work year (R&D). Table 3.5 shows the participating enterprises' number of R&D work years at the start of the project:

Table 3.5: Number of R&D work years in the enterprises at the start of the project	
Number of R&D work years	Number of enterprises
1-5	21%
6-20	23%
More than 20	52%
Do not know	4%
Note: n=155.	
Source: Kvistgaard Consult	

Table 3.5 shows that about half of the enterprises had more than 20 R&D work years when an Industrial PhD project was initiated. There is an almost even division between enterprises that had 6-20 R&D work years (23 percent) and 1-5 R&D work years (21 percent) respectively. The Industrial PhD projects are thus implemented in enterprises that focus less on research as well as enterprises that focus heavily on research, although the latter is clearly over represented.

Another indication of the enterprise readiness for research is the R&D share of their activities. Table 3.6 shows the R&D share of total enterprise sales from the start of the project:

⁶ Guidelines for the Industrial PhD programme, May 2006

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Table 3.6: R&D share of total enterprise sales

R&D share	Number of enterprises
1-5 percent	29%
6-10 percent	12%
11-20 percent	21%
21-50 percent	10%
More than 50 percent	16%
Do not know	12%
Note: n=155	
Source: Kvistgard Consult	

Table 3.6 shows that there is a more even division between the enterprises. A large number of the enterprises (29 percent) had an R&D share of 1-5 percent at the start of the project, while enterprises with larger R&D shares are also well-represented. Every fourth enterprise (26 percent) had an R&D share of more than 20 percent of their total sales.

To gain an impression of how the large and small enterprises are divided according to R&D share, the number of employees in the enterprise was compared to the R&D share of total enterprise sales. The results for the highest and lowest R&D shares appear in Table 3.7:

Table 3.7: Enterprise size and R&D share

Enterprise size	Low research share*	High research share **
Micro (0-10 employees)	11.8%	41.2%
Small (11-50 employees)	15.0%	55.0%
Medium (51-250 employees)	28.9%	10.5%
Large (over 250 employees)	36.3%	2.5%
Note: n=155		
* Low research share is denoted by: R&D share of total sales: 1-5 percent		
** High research share is denoted by: R&D share of total sales: more than 50 percent		
Source: Kvistgard Consult		

The results show a relatively clear division between the enterprises where small enterprises primarily have a very high R&D share, i.e. 41 percent of micro enterprises and 55 percent of the small enterprises respectively have an R&D share of more than 50 percent.

This is in contrast to the medium and large enterprises that are at 10.5 percent and 2.5 percent respectively. The small enterprises are thus the most research-intensive. If the focus is placed on enterprise divisions in the low R&D share, the table shows that divisions can again be made into large and small enterprises. About one third of the medium and large enterprises have an R&D share of 1-5 percent, while only approximately one sixth of micro and small enterprises have a corresponding R&D share. For the larger enterprises, the research efforts are becoming an increasingly larger portion of a low R&D share.

In general, the majority of the enterprises who focus heavily on research are micro and small enterprises, while medium and large enterprises make up the number of enterprises with a relatively small R&D share.

Enterprise experiences with research activities

As previously mentioned, the Industrial PhD programme is directed towards enterprises that are in a position to provide professional support to the student's project. Thus it is interesting to gain an impression of the enterprise experiences with implementing R&D activities. This was surveyed using different indicators in the questionnaire: The responses were as follows:

The majority of enterprise supervisors (91 percent) had participated in at least one previous, jointly-financed research project with academic and research institutions on the start date, and of these, 68 percent had participated more than once. Only 8 percent had never participated in such activities. The vast majority (74 percent) had hired researchers from academic and research institutions when the Industrial PhD candidate started, while around one-fifth (21 percent) had never hired a researcher before. Thus there are far more enterprises with experience of R&D activities, which can be expected to give them a good foundation for completing the Industrial PhD project.

It has been very evident that the enterprises are well-prepared for the project. The majority of the participating enterprises had prepared a formal R&D strategy (68 percent) and had a plan of action with operational instructions (57 percent) when the Industrial PhD candidate became affiliated with the enterprise.

One other approach is to examine the extent to which certain enterprise profiles increasingly choose to hire Industrial PhDs and PhDs when they have successfully

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completed their PhD education. This has been carried out in Statistics Denmark's study of PhD employment patterns after their education was successfully completed. This is shown in Table 3.8 where the focus is on how research-intensive the work place is divided according to the number of R&D work years.

Table 3.8: Employment of Industrial PhDs who have successfully completed the programme and PhDs in the private sector listed according to enterprise research intensity

Number of work years	Share of Industrial PhDs	Share of PhDs
1-9	10.1%	12.1%
10-49	15.3%	17.1%
50-99	7.4%	6.8%
100-249	9.3%	7.9%
250 and above	57.0%	54.5%
Number of work years unknown	0.8%	1.5%
Total	100%	100%

Note: For Industrial PhDs n=365 and for PhDs n=2428.
Source: Statistics Denmark

Table 3.8 shows that there are no major differences between regular PhDs and Industrial PhD candidates regarding enterprise divisions according to research intensity. The enterprises who focus most heavily on research are the ones who hire the Industrial PhDs who successfully completed the programme and PhDs. 57 percent of Industrial PhDs are thus in enterprises that have hired more than 250 researchers, while the corresponding number is 54.5 percent for regular PhDs who choose to pursue a career in the private sector. This result may not be so surprising.

What is more surprising is that even very small enterprises hire quite a few people with a PhD background. 32.8 percent of the Industrial PhDs who successfully completed the programme and 34 percent of the PhDs who choose to pursue careers in the private sector are hired in enterprises with less than 100 employees. Of these, 10.1 percent and 12.1 percent respectively are hired in enterprises with less than 10 employees.

The enterprises use the programme to create new R&D projects

In the guidelines for the Industrial PhD programme of 2006, the advantages for the enterprises can be summed up in that it has the potential to promote development opportunities for Danish business and create networks for knowledge sharing between research institutions in Denmark and abroad⁷. It is interesting to examine how this corresponds to enterprise motivation for participating in the programme.

Table 3.9 contains a list of the reasons that the enterprise initiated an Industrial PhD project:

Table 3.9: Reasons for initiating Industrial PhD projects in enterprises	
Reason: The project was initiated to...	Share of enterprises that stated "highly/somewhat"
Promote skills building within the enterprise	99%
Begin new R&D projects	90%
Build up and expand upon the professional network	81%
Promote employee recruitment	65%
Get recommendations from other enterprises	10%
Note: n=152.	
Source: Kvistgård Consult	

Table 3.9 shows that there are three main reasons for initiating Industrial PhD projects. They are: skills building, initiating new R&D projects and expanding the professional network. They also state that a primary motivation is the project gives the enterprise the opportunity to initiate research and development in areas to which they would not normally allocate resources. This corresponds well with the goals for the initiative to contribute to promoting the development and creation of networks in the business world.

Over half of the enterprises also state that they initiated the project as part of employee recruitment, i.e. they consider that project to be part of a long-term recruitment strategy.

⁷ Vejledning til ErhvervsPhD-initiativet, maj 2006.

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3.3 Which universities typically use the Industrial PhD programme?

This section explains the universities' use of the Industrial PhD programme. Analysis of student mobility compared to choice of university in connection with Industrial PhD studies is also covered.

Technical University of Denmark is the leader

The Industrial PhD projects are spread across all of the universities in the country, but there are vast differences between the extent that the programme is used at universities in Denmark and abroad. This appears in Table 3.10 that shows university shares of Industrial PhD projects from 1993 to the summer of 2006:

Table 3.10: University shares of Industrial PhD projects between 1993 and the summer of 2006

University	Number of Industrial PhD projects	Share of Industrial PhD projects
Technical University of Denmark	292	37.6%
University of Copenhagen	137	17.7%
Aalborg University	81	10.4%
University of Southern Denmark	53	6.8%
Royal Veterinary and Agricultural University	44	5.7%
The Danish University of Pharmaceutical Sciences	41	5.3%
University of Århus	40	5.2%
Copenhagen Business School	37	4.8%
Universities abroad	20	2.6%
Århus Business School	13	1.7%
Roskilde University	12	1.5%
The Danish University of Education	3	0.4%
The IT University of Copenhagen*	2	0.3%
Copenhagen School of Architecture	1	0.1%

*Data for the IT University of Copenhagen only goes from 2002 forward.
Source: DASTI. Gender and university from 1993 to the summer of 2006

Table 3.10 shows that three universities constitute 65.7 percent of all Industrial PhD

projects for the period 1993-2006, of which the Technical University of Denmark in particular leads with a total of 37.6 percent of these. But the statistics mask the significant differences in university sizes. This means that one cannot directly determine the extent that the Industrial PhD programme is used compared to the regular PhD education.

To this end, an index has been calculated in Table 3.11 that compares the number of Industrial PhD students to the general number of PhD students for the period 2002-2004. The index is calculated by making the national average the average division between Industrial PhDs and regular PhDs (=172/3437). Then a similar relationship can be calculated for each university, and this is indexed against the national average.

Table 3.11: Index for university shares of the Industrial PhD projects 2002-2004

University	Number of Industrial PhDs	Total number of PhDs*	(100 = national average)
Copenhagen Business School	13	121	215
Technical University of Denmark	46	500	184
Royal Veterinary and Agricultural University	17	187	182
University of Southern Denmark	22	277	159
The Danish University of Education	2	33	121
Aalborg University	18	329	109
The Danish University of Pharmaceutical Sciences	4	89	90
Århus Business School	2	48	83
University of Copenhagen	36	889	81
Roskilde University	4	106	75
University of Århus	8	581	28
Total	172	3437	

Source: Ministry of Science, Technology and Innovation/DASTI Gender and university from 1993 to the summer of 2006
 *Ministry of Science, Technology and Innovation: "A Public Good - PhD Education in Denmark" - Appendix 5, April 2006

This shows a significant change in the university ranking order. Copenhagen Business School has the highest relative use of the Industrial PhD programme, while the University of Copenhagen, Roskilde University and the University of Århus are at the bottom. Even taking into account that there are relatively few industrial PhD students in the period 2002-2004, Table 3.11 shows the extent that the universities are using the

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Industrial PhD programme to create contacts within research circles and the business world.

If one also considers the division of Industrial PhD students into specialist areas, it is clear that there are vast differences at faculty level (Table 3.12). The University of Copenhagen has a significant share of Industrial PhD projects in the health sciences faculty compared to the university's other academic areas. It is far more concentrated than the University of Århus, for example, where there is a considerably lower share of Industrial PhD students who in turn are more evenly divided into various academic areas.

Naturally, it is not odd that specialised universities such as the University of Copenhagen, Faculty of Life Sciences and Copenhagen Business School have concentrated Industrial PhD projects in their core areas. It is clear that Copenhagen Business School is dominant within the social/mercantile areas, while the Royal Veterinary and Agricultural University mostly has all industrial PhDs in the areas of food and agriculture.

Table 3.12: Faculty division of approved Industrial PhD projects – selected universities from 2002 to the summer of 2006

University	Health	Technical/ natural sci- ences	Social sci- ences and mercantile	Humani- ties	Agricul- ture and food
Technical University of Denmark	17	72	2	0	1
University of Copenhagen	54	1	2	6	1
University of Southern Denmark	13	6	6	3	0
Aalborg University	4	20	2	1	0
Royal Veterinary and Agricultural University	4	0	0	0	20
Copenhagen Business School	0	0	20	0	0
University of Århus	10	5	3	2	0

The remaining universities have between 1-11 Industrial PhD projects

Source: DASTI, "Industrial PhD and university divisions between 2002 and the summer of 2006"

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Aalborg University has a strong position in the technical/natural sciences areas. It is second to the Technical University of Denmark, which has the largest share of Industrial PhD projects. The collaboration with the business world is at the very centre of Aalborg University's instruction methods.

The popular universities with great appeal

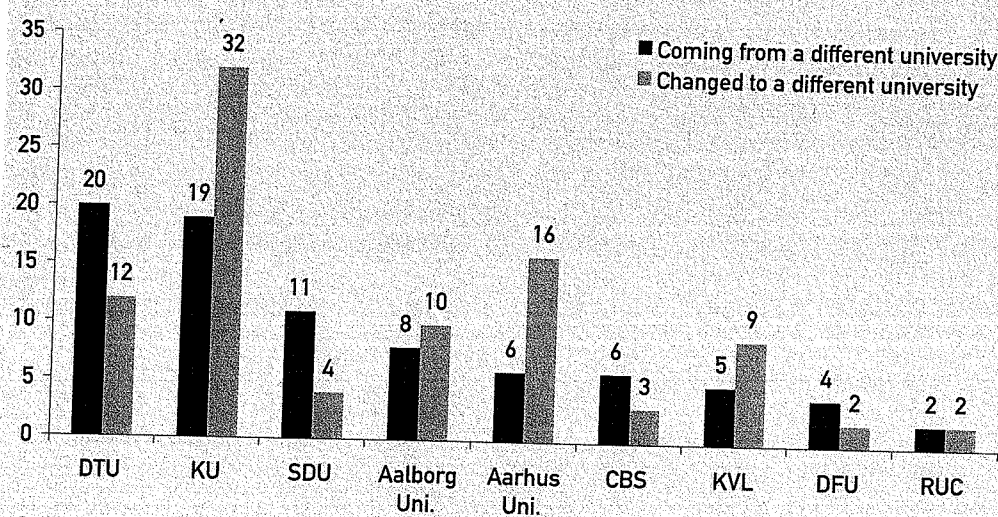
Another perspective on the university shares of Industrial PhD projects can be arrived at by examining where the Industrial PhD candidates completed their Masters degrees compared to where they are studying for the Industrial PhD.

It shows that there are differences in the ability of the universities to attract potential Industrial PhDs. This means candidates who have successfully completed a MA programme choose to take their PhD education at a university other than a Masters university.

Figure 3.9: Mobility among universities 2002-2005

Number of Industrial PhD students who *left* their MA university (n=93)

Number of Industrial PhD students who *arrive* at their PhD university (n=85)



Source: FIST: Mobility from postgraduate university to Industrial PhD university

In Figure 3.9 a green column shows the number of student transfers to specific universities for the period 2002-2005, while a red column shows the number of student transfers that chose to study for an Industrial PhD at another university.

Figure 3.9 shows that the Technical University of Denmark and the University of Southern Denmark attracted the largest net amount of Industrial PhD students with

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+8 and +7 candidates respectively for the period 2002-2005. The University of Copenhagen had several Industrial PhD students, but together with the University of Århus, the two universities lost the most Masters students with -13 and -10 respectively.

This means that while the University of Copenhagen and the University of Århus scored low on the index for Industrial PhD (Table 3.11), the explanation is not that the students did not have the desire to study for an Industrial PhD. It is a matter of the students not choosing these universities and choosing other universities instead. The statistics also show that the Industrial PhD students are very mobile. Of the 267 candidates who had their Industrial PhD applications approved during the period 2002-2005, 93 chose to take their Industrial PhD education at a university other than the university where they completed their Masters.