

Career paths for Industrial PhDs



When a potential PhD chooses the type of PhD education that is most attractive, the choice principally depends on a large number of factors that have short term as well as long term effects. In the short term, it could for example be the prospects for the professional environment and the guidance they can receive, in the long term the employment rate and salary trends may influence the choice.

This chapter examines Industrial PhD career paths to shed light on the characteristics of the Industrial PhDs who successfully completed the programme. It is primarily the prospects for finding employment, but also the type of job function the candidates who successfully complete the programme will have and the salary trends that will follow. The basis for comparison will be all other PhDs to create as stable a benchmark as possible.

The general profile of the career paths of Industrial PhDs is very positive:

- ✓ *Industrial PhD candidates have an employment rate of 96 percent.*
- ✓ *66 percent of Industrial PhD candidates still work directly in the research area*
- ✓ *8 percent of Industrial PhD candidates hold a top management position*
- ✓ *The pay increase rate among Industrial PhDs is high*
- ✓ *Industrial PhD candidates are very mobile in the labour market*
- ✓ *A total of 80 percent find employment in private enterprises*

4.1 Career paths

One of the main goals of the Industrial PhD programme is for the candidates who successfully completed the programme to become attractive to future employers. One indication of this is the employment rate where the Industrial PhD programmes can be deemed very successful, also in comparison to all other PhDs. Statistics from 2003 show a high employment rate for Industrial PhDs which even slightly exceeds all other PhDs.

Table 4.1 contains statistics from Statistics Denmark which followed the employment trends over time for Industrial PhDs and all other PhDs. The table shows the employment rate of Industrial PhDs increases with the passage of time after they successfully complete the programme. The same applies to regular PhDs, but the employment of Industrial PhDs is approximately 5 percent higher for all of the years.

Industrial PhDs who successfully complete the programme thus have very good prospects for finding employment⁸.

The unemployment rate for PhDs is not included in the table as it stays relatively constant and fluctuates between 1-2.5 percent unemployment for both Industrial PhDs and all other PhDs. It is thus significantly below the regular unemployment rate. The reason the employment rate and the unemployment rate do not add up to 100 percent is that a number of the candidates are outside of the Danish labour market, primarily due to residing abroad, switching between two jobs, etc.

⁸ The total is not 100% because the remaining percentage covers those unemployed. The total population does not include the category "unknown job status" to ensure consistency with the sampling method

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Table 4.1. Employment among Industrial PhDs and all other PhDs

Number of years after completed education		Industrial PhDs	All other PhDs
Employed	1 year	90.1%	84.4%
	3 years	93.4%	88.7%
	5 years	95.7%	90.9%
	7 years	95.5%	91.7%
	9 years	96.1%	91.5%

When the total population is the number of people for which information is provided, e.g. the category "no information available" is not included. The category "no information available" includes people who are registered as outside of the labour market, emigrated or dead.
Source: Statistics Denmark

Examination of the gender division in the employment rate among Industrial PhDs does not show a large difference. For the men the share is 96.6 percent employed and 2.2 percent unemployed. For the women, 93.1 are employed, while a higher share (6.2 percent) are unemployed. For other PhDs there is no great difference between the employment rates for men and women, either. The unemployment rate is marginally higher for women (2.4 percent) than for men (2.0 percent) and the employment rate is correspondingly a little lower for women (93.92 percent) than for men (95.05 percent).

Industrial PhDs continue their career in research

The Industrial PhD programme strives to educate Industrial PhDs who have insight into the business-world aspects of research and innovation. One question may be whether Industrial PhDs are increasingly choosing not to take on research-related work tasks in their employment and are focusing on other work areas of the business world instead.

This does not appear to be the case when looking at the work functions of Industrial PhDs. Table 4.2 lists, in order of priority, the most important work functions of Industrial PhDs.

Table 4.2 shows that 65.6 percent of Industrial PhDs are directly employed in R&D activities. In addition to this, the share of Industrial PhDs in management positions, consulting functions and production may well have research-related work tasks. In general, a large number of Industrial PhD candidates appear to maintain their engagement in research throughout the course of their careers.

Table 4.2: Work functions for Industrial PhDs 1992-2004

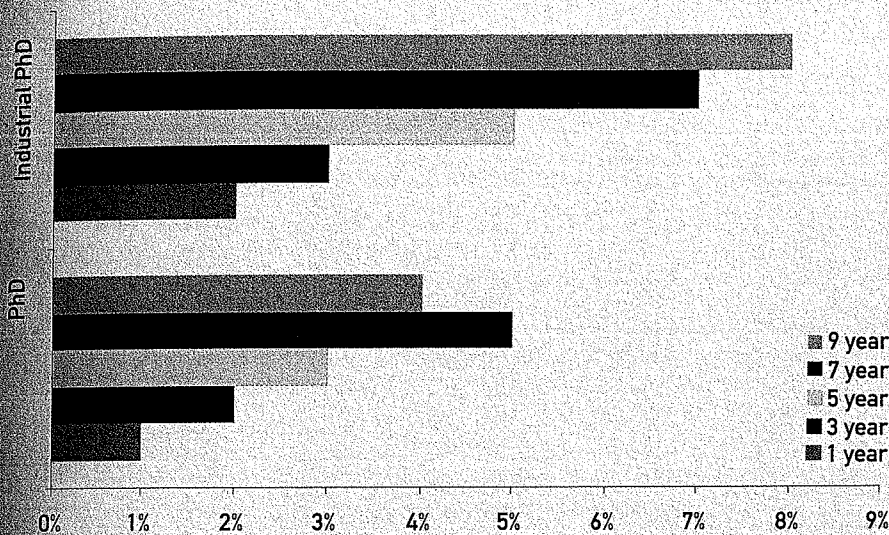
What is your work function today?	Share
R&D activities	25.7%
Research and education	21.1%
R&D management	18.8%
Consultant/advisory	13.5%
Other management	10.2%
Production	5.6%
Case handling/management/ administration	2.6%
Executive general manager	2.0%
Sales/marketing	0.7%
Note: n=304.	
Source: Kvistgård Consult	

A relatively large share of Industrial PhD candidates are employed in management. Examination of the trends over several time intervals after the education, 1, 3, 5, 7, and 9 years respectively, shows that the number of people in top management positions is increasing steadily among the group of Industrial PhD students. It is to be expected that several will reach a management position over time. No statistics are available for time periods beyond the 9 years, but the number of top management positions is expected to rise steadily.

Figure 4.1 shows the division in the management function over time for both PhD groups.

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Figure 4.1. Industrial PhD share of top management (n=450) compared to other PhDs (n=7336)
Management level for Industrial PhDs and other PhDs by number of years after completed PhD course



Note: Total population comprises everyone in employment
Source: Statistics Denmark

Comparison of similar circumstances for all other PhDs shows differences between the two groups of PhDs. For other PhDs the number of top management positions also increases the longer the candidate has been in the labour market, but the progress does not appear to continue after 7-9 years. There is more clarity in the difference between top managers within the two types of PhD education.

Twice as many Industrial PhD candidates reached a top management position (8 percent) after 9 years in the labour market than other PhDs (4 percent).

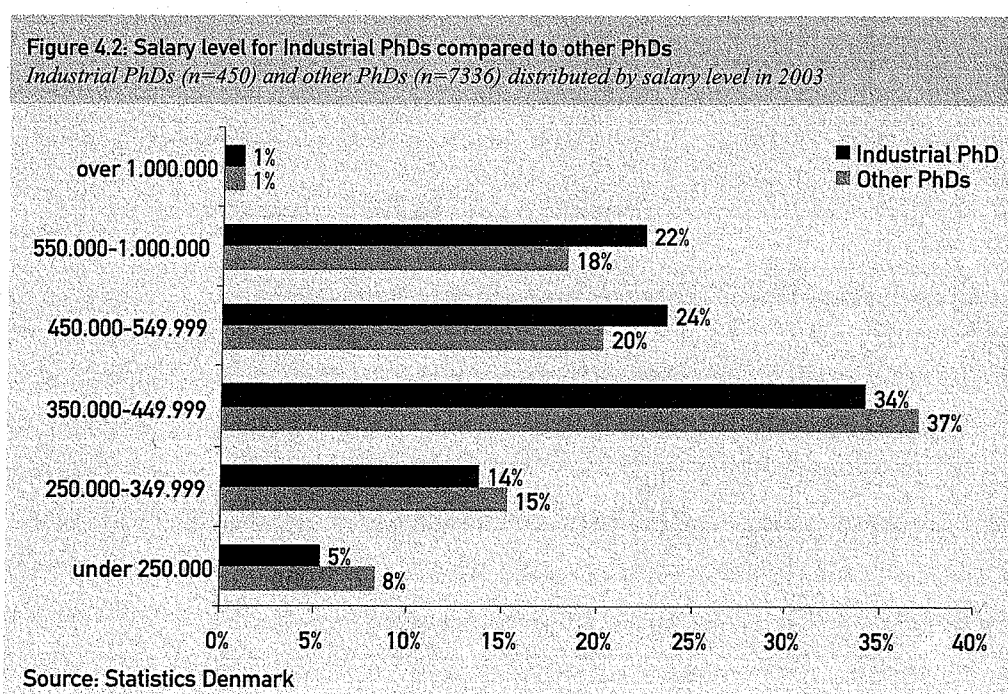
This indicates that the combination of the theoretical and business-oriented elements of the Industrial PhD process is attractive to and promotes the careers of the candidates.

It can be expected that potential PhD students will find it attractive that Industrial PhD candidates have significantly better chances of reaching top management positions. It also shows that students who acquired qualifications from having taken a research education with the main focus on the needs of the business world and have gained insight into the commercial application of research.

4.2 Salary trends

In addition to the employment rate and job title, the pay rate must be included as an indicator of how Industrial PhD careers progress over time. The following analyses the pay rate for Industrial PhDs on a general level and then by gender, trade, public/private sector and job changes.

Figure 4.2 shows the pay rate for Industrial PhDs and other PhDs:



As shown in Figure 4.2, the largest group of Industrial PhDs (34 percent) are in the DKK 350,000-449,999 pay bracket. But almost half (47 percent) have an annual salary that exceeds DKK 450,000, and slightly over every fourth candidate earns more than DKK 550,000 annually. Industrial PhDs generally make good salaries.

Comparison of salaries for the two groups of PhDs show that the trend is for an increasing share of other PhDs to be at the lower end (up to DKK 449,999), while there tends to be more Industrial PhDs at the higher pay rates (DKK 450,000-1,000,000). The share for the two PhD groups that earn more than DKK 1,000,000 are relatively equal, which constitutes a group of 1 percent of the candidates.

Table 4.2 shows that Industrial PhD candidates, all things being equal, have a higher average income than the group of all other PhDs.

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Gender – men have the highest salaries

In Table 4.3, the genders are divided according to Industrial PhDs and all other PhDs respectively, making it possible to compare the division of the two genders at the different pay rates:

Table 4.3: Pay rates divided according to gender in 2003				
Units DKK	Industrial PhD		Other PhDs	
	Men	Women	Men	Women
Less than 250.000	3.5%	9.6%	6.4%	11.9%
250.000-349.999	11.4%	19.2%	12.7%	20.0%
350.000-449.999	31.4%	40.7%	36.8%	37.5%
450.000-549.999	26.3%	17.0%	21.5%	17.7%
550.000-1.000.000	26.4%	13.3%	21.5%	12.5%
More than 1.000.000	1.0%	0%	1.2%	0.4%
Total	100%	100%	100%	100%

Note: For Industrial PhDs n=315 for men and n=135 for women. For other PhDs n=4770 for men and n=2566 for women.
Source: Statistics Denmark

Table 4.3 shows that among Industrial PhDs, there is a greater share of men than women at the highest pay rates and the reverse is true for the lowest pay rates. The same division applies in general among all other PhDs, yet with the difference that the predominance of men at the pay rates of DKK 450,000-1,000,000,000 is not as great. It should also be noted that for men there is a greater share of Industrial PhDs at the higher pay levels than other PhDs, while the share of women at the higher income groups is almost identical in the two PhD groups.

The conclusion is that for men there is a greater share of Industrial PhDs at the higher pay levels than other PhDs, while the share of women at the higher income levels is almost identical in the two PhD groups.

For all PhDs, regardless of the type of PhD, the statistics show that women on average follow a significantly lower salary trend than their male colleagues.

4.3 Mobility in the job market

As previously discussed, Industrial PhD students are characterised by a high degree of mobility between the candidate and the Industrial PhD university. It is interesting to examine whether Industrial PhD graduates possess the same degree of change readiness. These statistics are compiled in this section based on job changes among Industrial PhDs, including over time, and compiled based on public and private sectors.

A first indicator of the mobility of Industrial PhDs is the number that are employed at a location other than the one where they completed their Industrial PhD project.

This division appears in Figure 4.3. The table does not take into account the number of years that have passed since the Industrial PhDs successfully completed their education.

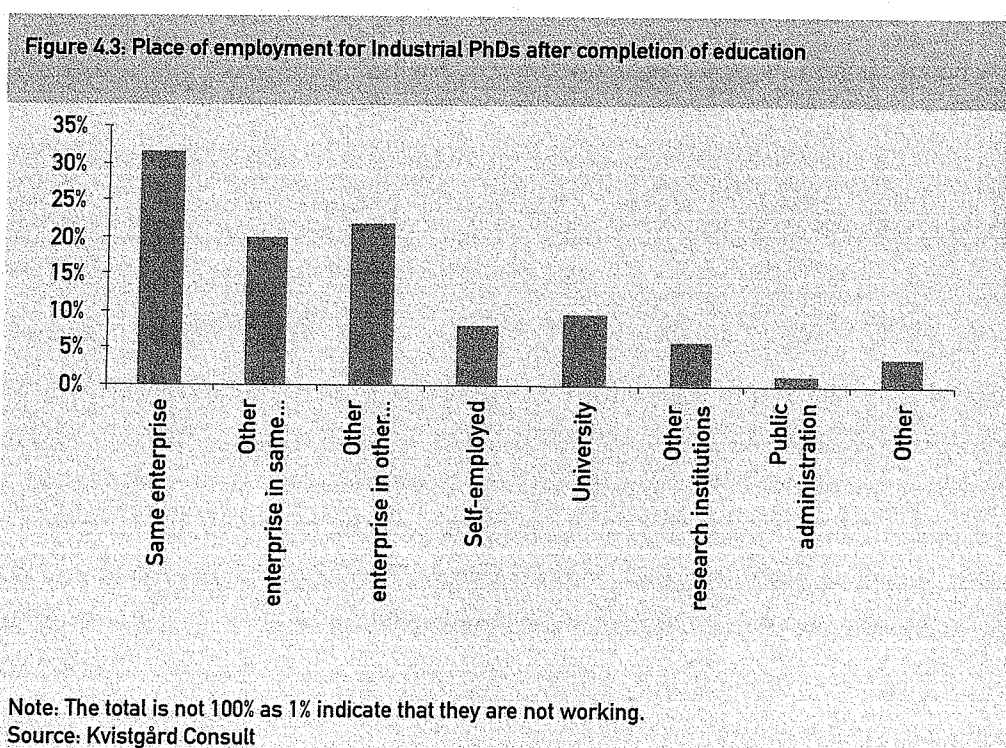


Figure 4.3 shows that slightly more than one third are employed in the same enterprise, which indicates that an Industrial PhD project is a good way for the student to create contacts with a future employer. Conversely, the statistics show that Industrial PhDs are also mobile, as the remaining two thirds have found employment elsewhere. This illustrates that they are an attractive labour force and not necessarily bound by either their Industrial PhD project or one particular trade.

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Thus more than one out of five Industrial PhD candidates have switched trades compared to the trade where they completed their Industrial PhD project. There is also good mobility back to the public sector where, after successfully completing their education, a little over one out of every five Industrial PhDs found employment either at a university, research institution or in public administration. Finally there is a notably high number of Industrial PhDs who strike out as self-employed (8 percent). Entrepreneurship and the Industrial PhD education apparently go well together.

In general, Figure 4.3 shows that the focus the Industrial PhD candidates place on the business world carries over to their future employment as a total of 82 percent find employment in the private business world (the first 4 categories).

Considering the number of job changes, there is no great difference between regular PhDs and Industrial PhDs. Table 4.4 shows a division according to the number of job changes for Industrial PhDs and other PhDs who successfully completed their education between 1993-2003:

Table 4.4: Job changes for Industrial PhDs and other PhDs 1993-2003
in percentages

Number of job changes	0	1	2	3	4	5	6	7
Industrial PhD (n=398)	33.2	28.9	19.8	12.1	3.5	2.0	0.3	0.3
Other PhDs (n=8666)	30.7	27.1	23.1	12.1	5.0	1.5	0.5	0.1

Source: Statistics Denmark

Table 4.4 shows, as expected, that a decreasing number are changing jobs. The majority of Industrial PhDs change jobs 1 to 3 times during the period (60.8 per cent.), which is at a level with other PhDs (62.3 percent). Less than 10 percent of the candidates are "frequent job changers" with 4-7 job changes during the period, and in this case there is no difference in the type of PhD education they took.

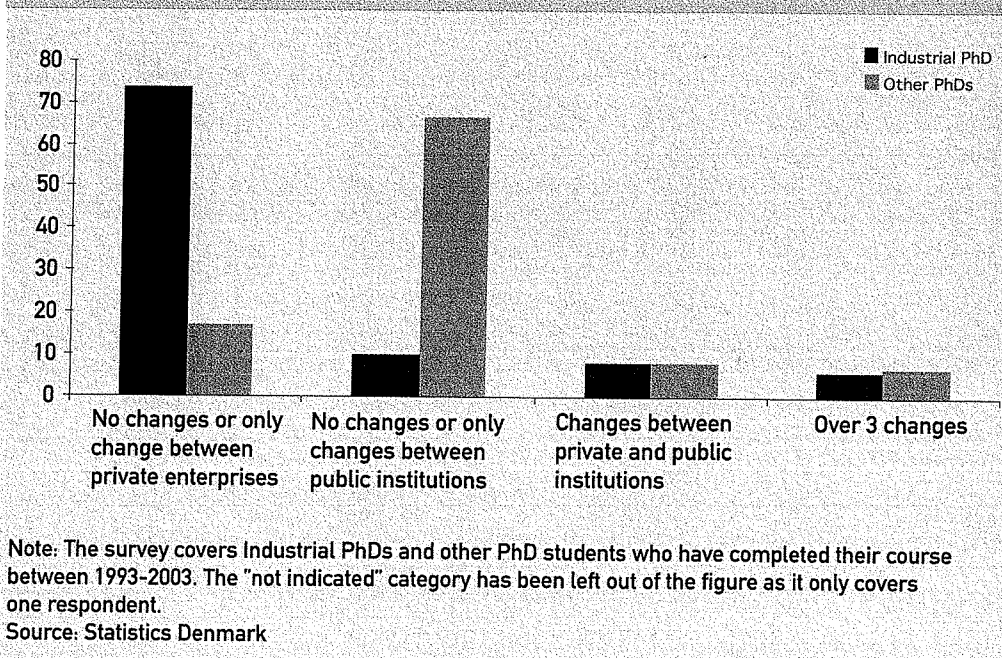
All together this shows that Industrial PhDs and all other PhDs in general are a fairly mobile labour force. There are no clear distinctions between the two types of PhD education in mobility on the job market.

To further document the mobility, it is interesting to study the changes between the public and the private sectors divided into the two types of PhD education. One would

expect that Industrial PhD candidates would change less from the private sector to the public sector and that other PhD candidates would change from the public sector to the private sector more often due to the higher pay rates in the private sector.

However, Figure 4.4 shows that when comparing Industrial PhDs to other PhDs, the career paths are almost parallel. Industrial PhDs have a career with regular job changes within the private sector, while other PhDs have a career with regular job changes between public institutions. Only 15-20 percent change between the two sectors. The rest remain in the sector where they were employed during their PhD education. Conversely one could say that Industrial PhDs, after successfully completing their education, contribute equally to knowledge sharing between the public sector as other PhDs by changing to the public sector. This in itself might be more surprising.

Figure 4.4: Mobility between private and public sectors
Job changes for Industrial PhDs (n=448) and other PhDs (n=8581)



4.4 Network

The Industrial PhD programme contributes to promoting collaboration and creating networks between universities and enterprises. But the individual Industrial PhD also expands their network through the Industrial PhD project. This is shown in statistics from the questionnaire survey where the Industrial PhDs assessed the significance the project had for their professional network.

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Table 4.4 shows the division between the different types of networks created where the intensity in professional networks goes from very permanent, formalised collaboration to informal ad hoc cooperation.

Table 4.4: Network creation for Industrial PhDs

What network effects did the project have?	Share
Permanent, formalised working agreements	3.4%
Long-term, formalised project partnerships	17.7%
Occasional, formalised collaboration	25.4%
Informal cooperation	45.2%
Do not know	11.3%

Note: n=311.
Source: Kvistgård Consult

The Industrial PhDs also create personal networks with their “fellow students”. The Danish Agency for Science, Technology and Innovation ensures the new Industrial PhDs are introduced to the Industrial PhD association. Here the Industrial PhD students and Industrial PhDs that have successfully completed the programme have the opportunity to attend lectures and networking events that can strengthen the reciprocal network and cross-disciplinary aspects of the research.

One important element in this network creation is the Industrial PhD course that is part of the Industrial PhD education. The course is module-based and consists of 3 two-day courses where Industrial PhD students from different academic areas participate in the same classes.

Kvistgård Consult’s questionnaire surveyed the Industrial PhDs on how useful the networks they created during the project were to them after they completed the project.

The response divisions appear in Table 4.5:

Table 4.5: Industrial PhD network activities

How useful do you feel the network you created during the project has been to you after you completed the project?

	Share
Extremely	28.8%
Somewhat	42.8%
Slightly	20.7%
Not at all	4.5%
Do not know	3.2%

Note: n=222.

Source: Kvistgård Consult

Here 71.6 percent state that the network has been “Extremely” or “Somewhat” useful, while only 20.7 of the surveyed Industrial PhDs responded “Slightly”. Additionally, some of the most important network effects they list are access to new knowledge and sparring partners.

In general there is a significant network effect for the Industrial PhDs, who both create networks within the host enterprise and personal networks that they use throughout their career both to find new jobs and to stay updated on new knowledge in public and private research.

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Box 4.1: What have the most important network effects been for you?

"They helped me establish my own enterprise." The network connections that were created during the project in Denmark and abroad are the ones I am building upon today."

"They provided insight into other specialist areas and created an interest for new areas."

"As I have remained in the same trade, it has been easy to contact the right people in specialised areas."

"My network created many relevant opportunities to look for employment and that resulted in a job in another department within the enterprise."

"I have built up a network of people from academic circles in Denmark, England and France. People I can always e-mail to bounce ideas off

"I became a co-author of a number of scientific articles through my network."

Source: Kvistgård Consult

Box 4.2: The Industrial PhD Association

The PhD Association is an association of industrial researchers and Industrial PhDs who are currently students or have successfully completed the education. The club currently has 300 Industrial PhDs who are either students or have successfully completed the education.

The purpose of the club is to create the framework for professional inspiration, exchanges of experiences and creation of networks for its members. This is facilitated through lecture afternoons where lectures are held on topics of broad interest to researchers.

In addition, the club, in collaboration with the Research and Innovation Council hold introduction meetings where new students are invited to hear about the Industrial PhD education where the students can get assistance, if needed, and where there is an opportunity to meet other students in their "class".

Source: www.erhvervsphd.dk

Enterprise yield from an Industrial PhD process



In the PhD programme, the enterprise is the applicant for an Industrial PhD project. The application is made in collaboration with the Industrial PhD candidate and the university, but it is important to emphasise that the enterprise is the project owner in the Industrial PhD programme. The programme primarily functions by the enterprise receiving a subsidy from the state to collaborate in educating an Industrial PhD student. But the effect for the enterprises comes through the research project that is formulated in collaboration with the student and the university. In many instances, the Industrial PhD projects lead to new patents, new products, insights or ways of doing things. In short, the Industrial PhD programme helps promote innovation in Danish enterprises. This chapter assesses expected and achieved enterprise effects of participating in an Industrial PhD project. The basis is there are both direct effects, for example in the form of new patents and increased market share, and indirect effects in the form of creating networks and external collaboration.

The chapter shows that Danish enterprises achieve significant positive effects through the Industrial PhD programme:

- ✓ 48 percent of the enterprises expect a larger number of patents
- ✓ 46 percent of the enterprises expect increased market shares
- ✓ 44 percent of the enterprises expect an increase in annual sales
- ✓ 36 percent of the enterprises expect an increase in exports
- ✓ 90 percent of the enterprises feel the project has increased theoretical knowledge
- ✓ 84 percent of the enterprises feel the project has increased practical knowledge

5.1 The Industrial PhD programme sparks innovation

One of the main goals of the Industrial PhD programme is to help promote development opportunities in the business world. To assess the innovation effects, indicators can be divided into quantitative and qualitative categories. The quantitative examines the Industrial PhD programme's production of patents and sales of license rights. Compared to the qualitative innovation effects, the focus is on learning/knowledge and candidate skills.

Quantitative indicators: Good prospects for patents and licenses

Kvistgård Consult's questionnaire surveyed the enterprises on the Industrial PhD project's production of patents and sales of license rights (see Table 5.1). Enterprise supervisors were first surveyed regarding how the project is expected to increase enterprise production of patents, which 48 percent confirmed. Compared against research intensity as stated by R&D work years, the trend is the more R&D work years there are, the more the patent production share is expected to increase.

There is some uncertainty related to these responses, as they were surveyed on expectations. A more precise answer can be arrived at by including candidate responses as they are surveyed on expectations and experiences. Around $\frac{1}{4}$ of the Industrial PhDs state that the project has led to/will lead to attainment of one or more patents (26.7 percent). The difference may be due to the fact that the Industrial PhDs look at whether his or her project resulted in a patent from a narrower perspective, while the enterprise looks at this from a broader perspective in relation to the knowledge it has contributed to the enterprise.

The questionnaire also reveals enterprise expectations that the project will lead to an increase in enterprise sales of license rights. 11.5 percent answered this in the affirmative. Compared with the number of employees, there is a tendency for the small enterprises (micro and small) to have higher expectations than the larger enterprises (medium and large). Compared with R&D work years, there are no differences for the answers in the affirmative.

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If candidate responses are included according to the same argumentation as before, it shows that 12.6 percent respond that it has led to/will lead to sales of license rights or specially developed expertise. This corresponds well to enterprise expectations. In this situation it also applies that even though the actual yield might be less, it is still a high yield compared to other R&D activities.⁹

Table 5.1: Enterprise supervisor and Industrial PhD assessment of patent and license potential

Enterprise supervisors:	percent that respond: Yes
Does the enterprise expect the project to lead to an increase in enterprise production of patents?	48%
Does the enterprise expect the project to lead to an increase in enterprise production of patents?	11.5%
Industrial PhD candidates:	percent that respond: Yes
Has the/will the project lead to application for or attainment of several patents for the enterprise?	26.7%
Has the/will the project lead to sales of license rights or specially developed expertise?	12.6%
Note: For the four questions, the n value is, in this order: n=148, n=139, n=420, n=420	

Qualitative indicator: Good effects for knowledge and learning

Innovation is not only about quantifiable parameters, but knowledge and learning as well that form the basis for developing patents and license rights sales, for example.

The following focuses on the development of business-relevant knowledge within the enterprise, theoretical and experimental learning and finally Industrial PhD candidate qualifications.

⁹ It is very difficult to compare other efforts within innovation politics, but the Danish evaluation of the Research patent law shows figures for patents and sale of licences compared to other public investments into research. Denmark generally has a lower rate than countries like Belgium, The Netherlands, Germany and Switzerland. 2.7 licences for each billion DKK invested in public research and 8.9 patents for each billion DKK invested in public research. If the public investment for each Industrial PhD candidate is estimated at DKK 0.8 million, this equals DKK 336 million for all the Industrial PhDs, who have answered the questionnaire. 112 of these Industrial PhDs believe that the project leads to new patents (26.7 percent), while 53 believe that the project will lead to the sale of licences (12.6 per cent). This indicates a very significant patent and licence return on the public investment in the Industrial PhD education. But such comparison must be carried out with great caution. We need more in-depth analysis in this area.

First an examination of the development of business-relevant knowledge is conducted. The enterprise supervisors are surveyed on whether the framework and structure for the project provide favourable conditions developing business-relevant knowledge – 68.9 percent agree, 27.4 percent partially agree. The very positive responses are mainly attributable to the fact that 70.1 percent agree completely that the enterprise has a great deal of influence on the project and can influence its professional and application aspects (26.6 percent partially agree). i.e., the Industrial PhD programme gives the enterprise a good framework for adapting the projects to its specific needs, and the enterprises make great use of it to develop business-relevant knowledge.

Table 5.2. Supervisor assessments of the Industrial PhD framework and learning effects in percentages

Enterprise supervisors (n=155)		Agree completely	Agree some-what	Disagree completely	
Programme frameworks	Do the frameworks and structures provide favourable conditions for developing business-relevant knowledge?	68.9	28.5	1.3	
	Does the enterprise have a great deal of influence on the project, and it is able to influence the professional and application aspects	70.1	26.6	2.6	
		A great deal	Some-what	Slightly	Not at
Programme learning effect	How has the project contributed theoretical knowledge and learning within the enterprise?	49.0	41.3	7.7	1.3
	How has the project contributed practical knowledge and learning within the enterprise?	31.0	52.9	12.3	3.2
Source: Kvistgård Consult					

It also examines the theoretical and practical learning within the enterprise. 90.3 percent of enterprise supervisors state that the project has contributed substantially/somewhat to theoretical knowledge and learning within the enterprise. An almost identical share (83.9 percent) respond that the project contributed substantially/somewhat to developing practical knowledge and learning within the enterprise.

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In general, the Industrial PhD programme can be said to have very positive effects on the development of learning and knowledge within the enterprises.

5.2 The Industrial PhD programme promotes growth

In addition to innovation, growth is a central goal for the Industrial PhD programme. This section evaluates the effects of growth based on these indicators: increased market share, increased exports, sales and employee recruitment.

Increased market share, exports, sales

Industrial PhD project effects on enterprise growth potential can be evaluated based on the following indicators: market share, exports and sales. Table 5.3 shows enterprise supervisor expectations to the Industrial PhD project for the three indicators:

Table 5.3: Enterprise supervisor expectations for growth (n=145)

Expected effects	Share of enterprises
Increased market share	46.3%
Increased exports	35.5%
Increased annual sales	44.1%
Source: Kvistgård Consult	

The table shows that the enterprises have high expectations for growth. It is not possible to precisely determine the extent that these expectations have been met. But it is an indicator that the Industrial PhD projects contribute to growth.

If the Industrial PhD responses regarding the effect of the project for the enterprise are included, this confirms that the enterprise can apply the acquired knowledge to realise new projects or other types of market improvements. Thus 38.8 percent of the candidates respond that the Industrial PhD project has led to new or improved products (Table 5.4). Slightly over 3 out of 4 projects also led to the enterprise actually applying research project results (71.8 percent).

Table 5.4: Industrial PhD evaluations of enterprise usefulness

Realised effect	Share of candidates (n=418)
Has the project led to new or improved products in the enterprise's product range?	38.8%
Has the project led to the enterprise using results or recommendations from the project?	71.8%
Source: Kvistgård Consult	

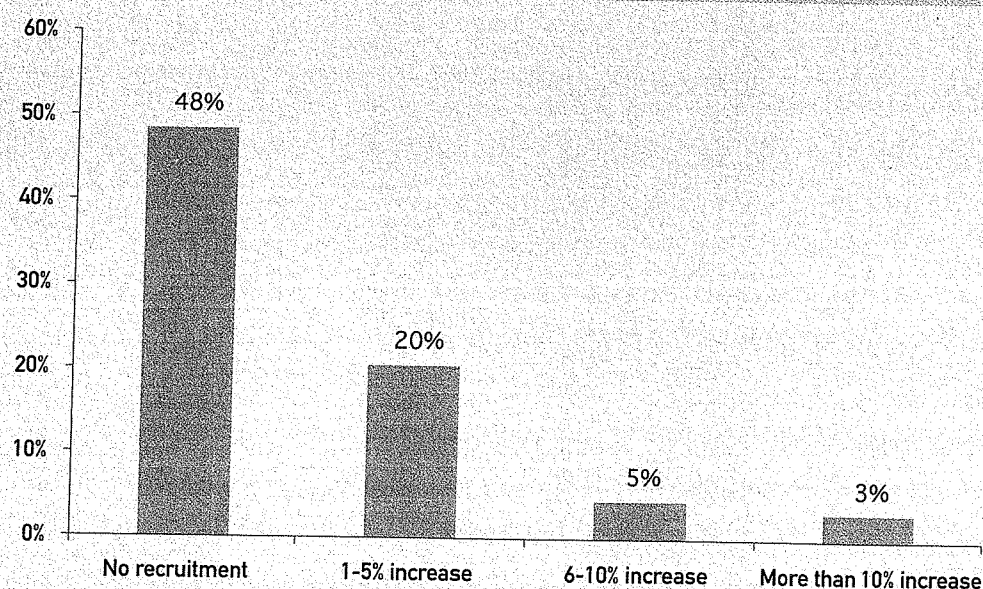
Employee recruitment

Another indicator for how the Industrial PhD products create value for the Danish enterprises is the extent that the project leads to new jobs.

Figure 5.1 illustrates enterprise expectations for general recruitment as a result of the project:

Figure 5.1: Expectations to general recruitment

Enterprises' expectation to general recruitment as a result of the project (n=157)



Note: The total is not 100% as 24% answered "don't know"
Source: Kvistgård Consult

As shown in Figure 5.1, approximately 1/4 of the enterprises expect to hire new employees as a result of the Industrial PhD project. Therefore it can be said to have good employment effects.

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Compared to enterprise size, it shows that large enterprises constitute the smallest share with a 1-5 percent increase, that small enterprises dominate with a 6-10 percent increase, and micro enterprises constitute the large share which expect more than a 10 percent increase. The overall impression is that small enterprises generally are the ones who will hire most new employees as a result of the Industrial PhD project.

This corresponds with the expectations, as it is not likely that the Industrial PhD project itself will lead to a large percentage increase in the personnel at enterprises such as Novo Nordisk, Danfoss, Grundfos, Haldor Topsøe and other large Danish enterprises that are frequent users of the Industrial PhD programme. But in these cases, even a small increase of 1 percent could mean several work places.

Compared to R&D work years, there is a similar correlation where the percentage increase in employees (at each interval) declines with the number of enterprise R&D work years.

This indicates the least research-intensive enterprises are the ones who expect to hire new employees the most.

This confirms the impression that large enterprises who focus heavily on research are often not able to attribute specific growth in the number of jobs to one specific Industrial PhD project. It is also interesting that the employment effect of the Industrial PhD programme is significant for non-research-intensive enterprises, which most large Danish enterprises are. This shows great potential if more Industrial PhD projects are done in collaboration with these types of enterprises.

The enterprises were also surveyed as to their expectations for recruitment of R&D employees, to which 28 percent responded that they expected an increase of 1-25 percent. This shows that the project is also very significant to the enterprise's ongoing research efforts.

Compared to enterprise size, it shows that large enterprises constitute the smallest share of the shares of recruitment. Compared to R&D work years, it shows that enterprises with 6-20 R&D work years have the highest expectations to increase their personnel, enterprises with more than 20 R&D work years have the lowest expecta-

tions, while enterprises with 1-5 R&D work years are in the middle. i.e., primarily enterprises that focus on research will hire research employees.

In summary, the results above show that, in regards to general recruitment and hiring R&D employees, small enterprises relatively make up the largest expected share. The small research-intensive enterprises expect the largest general recruitment, while the middle group of research enterprises expect the highest R&D employee recruitment. Thus there is a correlation between enterprise research intensity and the type of employees they are looking for.

5.3 Develops and improves networks

One of the main purposes of the Industrial PhD programme is to contribute to creating networks for knowledge sharing between enterprises and Danish/foreign research institutions. Networks, however, can be viewed as both an effect of the project as well as an intermediary variable, as networking can contribute to creating knowledge, patents and skills building, for example. In this section, networks will be interpreted both ways.

Effects of the extent and depth of networks

Industrial PhD projects' importance for building up a network can be evaluated quantitatively as well as qualitatively. The quantitative element can be illustrated using enterprise estimates of the extent of network building. A total of 95.6 percent of the enterprises that participate in an Industrial PhD project experience an expansion of their existing research network.

Of these, 20 percent call it a large expansion for the enterprise, while 75.6 percent call it a small network expansion. Only 4.4 percent did not experience any expansion of the network. This means that one out of five enterprises experiences a large expansion of the research contact base, while a large group of enterprises experiences a smaller, but positive, reinforcement of the professional networks.

Enterprise supervisors were surveyed on the effects of the depth and expansion of the network with new collaboration partners, and the response divisions appear in Table 5.5:

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Table 5.5: Enterprise expansions of networks

Response category:	Share of enterprises (n=155)
Our network was expanded with new collaboration partners	28.4%
Our network has more depth	27.7%
We have gained new partners and depth in the network	27.7%
No, no network expansion	12.9%
Note: This does not add up to 100 percent as 3.2 percent stated "Do not know"	
Source: Kvistgård Consult	

The responses in Table 5.5 confirm that the enterprises create new working relationships. It also shows that there is also a qualitative expansion of the network as they gain more depth. 56.1 percent of the enterprises state this, and the project can be said to have great qualitative significance for the enterprise networks. In general, 83.8 percent of the enterprises experienced a qualitative and/or quantitative expansion of their network.

The following studies the effects in more detail. The initial focus will be on the type of collaboration that the enterprises achieved as a result of the project. Table 5.6 contains enterprise supervisor responses to the types of effects that the enterprise achieved, listed:

Table 5.6: Achieved enterprise network effects

Network effects	Share of enterprises (n=186)
Informal cooperation without formal working agreements	48.9%
Occasional, formalised collaborations	24.7%
Long-term, formalised project partnerships	22.0%
Permanent, formalised working agreements	1.6%
Note: This does not add up to 100 percent as 2.7 percent stated "Do not know"	
Source: Kvistgård Consult	

Table 5.6 shows an almost equal division between informal and formal collaborations. It should be noted that little over half of the agreements have a formal character of varying lengths. All things being equal, the formal agreements must be seen as having

greater depth and mutual obligations for both parties. A small number of the enterprises have experienced the Industrial PhD project has led to a permanent and formalised working agreement (1.6 percent), while others have permanent agreements of varying lengths (46.7 percent).

To gain an impression of the players that participate in the new collaborations, Figure 5.2 presents the divisions of the new types of players involved in a network expansion:

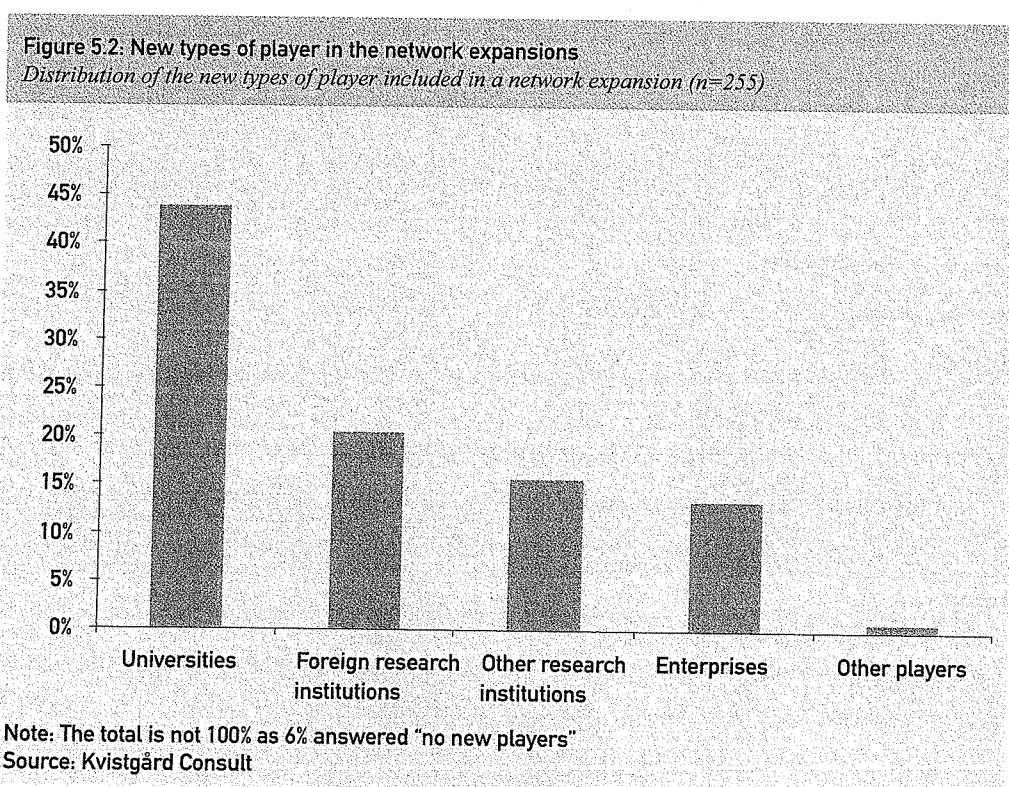


Figure 5.2 shows that the most prominent new player type are the universities. This is not surprising, as the Industrial PhD candidates are specifically affiliated with a university during the course of their education. The Industrial PhD programme thus functions as a link between an enterprise and an educational institution.

The foreign research institutions constitute approximately one fifth of the new players that the enterprises state have become part of their professional network, which is a surprisingly high share. As part of the Industrial PhD programme students are allowed to choose a supervisor from a foreign university, but only 2.6 percent of students are

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affiliated with a foreign university rather than a Danish University (see Table 3.7). This must mean that more Industrial PhD projects are involving a larger contact base than the supervising university, and that the projects are creating an international network. The Industrial PhD programme also pro actively supports this type of activity.

An central element of the Industrial PhD education is subsidies to courses and conferences in Denmark and abroad where the student receives an earmarked subsidy of DKK 75,000 from the Danish Agency for Science, Technology and Innovation. The money must be used for those purposes. This subsidy most likely strengthens a network with foreign universities. Experience has shown that one out of three Industrial PhDs have long stays at foreign research institutions¹⁰. As something new since 2004, they have also been allowed to choose an assistant supervisor from a Danish or a foreign university for the project with subsidies from the Danish Agency for Science, Technology and Innovation.

Effects of network expansion

As mentioned in the introduction, a network can also function as an intermediary variable, e.g. a network expansion can help promote results for the enterprises. Table 5.7 summarises a number of the most important effects that the enterprises have experienced as a result of an expanded network:

Table 5.7: The most important effects of a network expansion for the enterprises

Effects	Share of enterprises (n=269)
General skills building in an enterprise	34.9%
New product development	16.7%
Improvements to existing products	14.5%
Improvements to existing production processes	6.7%
New production processes development	5.6%
Attainment of patents	5.6%
Increased annual sales (in DKK)	4.1%
Increased annual exports (in DKK)	2.6%

Note: This does not add up to 100 percent as 0.7 stated "Sales of license rights or expertise", 1.1 percent stated "Access to new geographical markets" and 7.4 percent stated "Other effects".
Source: Kvistgård Consult

¹⁰ Source: Industrial PhD secretariat in The Danish Agency for Science, Technology and Innovation

Table 5.7 shows that network expansion have real impact in a number of areas. The most important area is the enterprise's general skills building. New products and production processes follow with a total of 22.3 percent, and improvements to existing products and production processes is 21.2 percent. Compared to the previously discussed aspects (attainment of patent and increased sales and exports), they are not assessed as constituting a large share of network effects, but there is a certain effect.

Box 5.1. What have been the most important effects from the Industrial PhD project for your enterprise?

"Better insight into customer perceptions of rights"

"It will be several years before commercial products are realised from the project. On the other hand, the project has had synergies with existing, short-term development projects."

"Goal-oriented effort towards implementing new standards (operational as well as organisational) for transfer of innovation to practical logistics."

"Research and development in areas to which resources are not normally allocated."

"One motivating factor is to contribute to a project that would not normally be financed internally. Ad hoc projects that have great potential, but are regarded as risky can be implemented if external financing is available."

"It is fun and exciting to supervise Industrial PhD projects."

Source: Kvistgaard Consult – enterprise supervisor responses