Measuring the Economic Effects of Companies Collaborating with the University of Copenhagen
The Value of a Research-intensive University

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1 Executive summary

This economic impact analysis measures the effects of R&D collaboration with the University of Copenhagen. The effects are measured at company level in terms of increased value added in companies and behavioural additionality in terms of additional increase in private R&D investments. Thus the analysis only focuses on a part of the total value the University of Copenhagen creates for the surrounding society. As such, effects from education and other activities at the University are not a part of this analysis.

Universities play a crucial part in society. They are a social and cultural backbone as well as an economic lighthouse. A recent Danish study suggested that universities play a significant role in creating growth by collaborating with companies located in Denmark¹. Yet there is only limited knowledge about the evidence-based impact assessments of universities. Universities have many different effects on society in terms of building up knowledge, education of thousands of academics, construction of societal infrastructure, gaining insights into democracy, generation of knowledge for public authorities in general as well as specific settings etc.

This report conducted by DAMVAD, on behalf of the University of Copenhagen, analyses the effects of collaboration between the university and companies. The economic effects are measured at company level and focus on the value added the collaboration contributes to. The results are based on extensive use of micro level data from registers at Statistics Denmark. These registers are supplemented with data from the University of Copenhagen’s own registers of company collaboration as well as DAMVAD’s unique co-operation database and research database.

The analysis is based on econometric modelling and by applied methodologies used in academic research and pinpointed among international organisations as best practice for measuring effects of R&D collaboration².

The main conclusions from the analyses are:

- We find strong evidence of a positive causal link between companies entering into R&D collaboration with the University of Copenhagen and the development in productivity per employee for the companies. More specifically, companies entering collaboration increase their productivity per employee by an annual average of 6.5 per cent

- The positive causal link to increasing productivity corresponds to a net gain of € 7,000 per employee on the bottom line for each company year on year as an effect of collaborating with the University.

- On average this corresponds to an improvement on the bottom line of each collaborating company by € 2.43 million, as the average company size is 350 employees. With 625 unique companies in the analysis this adds up to a total economic impact on of €1.5 bn.

- As many as 1,537 different companies have had a formal collaboration with the University of Copenhagen from 1998 till 2009. In that timeframe the number of collaborations has increased year by year. In 1998 the number of formal collaborations was 227. In 2008 this fig-

¹ Companies based in Denmark are companies with a Danish VAT-number. The VAT-number is a unique identification number for legal entities in Denmark.

ured peaked at almost 800 individual formal collaborations between companies and the university.

- Whereas the econometric analysis shows that formal R&D collaboration generates higher productivity, the qualitative case studies indicate that such formal collaboration often rests on a much broader and often informal set of interactions between the collaborating partners. This has important policy implications, as it is not enough to stimulate formal R&D collaboration. Policymakers and the university itself must also stimulate and facilitate other forms of interaction between companies and universities.

The University of Copenhagen does play a significant part in creating value for companies located in Denmark. The economic impact figure of € 1.5bn is merely a minimum estimate of the total value that the university creates for its surroundings. This analysis does not identify informal R&D collaborations, the direct impact of alumni, or the indirect effects of alumni creating efficient public institutions, general increase of the knowledge stock and others.

Despite the substantial effects and knowledge provided through the cases, it is still largely unexplained how the effects occur. As such, there are still questions concerning how and why there are the identified effects. What triggers the effects and are the triggers different between different areas of science? What is the time span from the first initial informal contact to a more formal collaboration to an eventual effect? How does the knowledge transferred from the university to the company affect the company as an entity, as well as the individual employee engaged in the collaboration?

1.1 Motivation for the analysis

University – industry collaboration is by no means a new phenomenon. It has long been recognised that universities are important for driving knowledge production and innovation. As such, partnerships between universities and companies have gained increased focus from policymakers and universities.

Even so, we do not know much about the effects of research and R&D collaboration from individual universities. Apart from a range of universities in the US and Canada, e.g. MIT, University of British Colombia and Princeton, there is only limited tradition for evidence-based impact assessments.

This analysis will uncover potential effects of the University of Copenhagen. The analysis is based on econometric modelling. The models used have been pinpointed among international organisations as best practice for measuring effects of R&D collaboration.

1.2 The scope of collaboration

The university participates in an increasing number of collaborations with companies. This is in particular driven by an increase in collaboration with foreign companies. In 2009 there were almost 900 formal collaborations with both Danish and foreign companies.

Collaboration is executed through different channels but largely by common publication, formal R&D collaboration projects and projects based on

public R&D schemes. In total 2,283 formal collaborations have been identified through the University of Copenhagen’s registers.

The companies collaborating with the university are characterised by being larger, more R&D-intensive and more international. E.g. almost half of their revenue stems from exports.

Furthermore, the companies are scattered in many different sectors. Though some sectors are more over-represented. It is in particular knowledge-intensive sectors such as high-tech manufacturing (which includes biotech and pharmaceuticals) or knowledge-intensive business service.

1.3 The effects of collaborating with the University of Copenhagen

This central part of the analysis focuses on the quantitative effects companies experience from their collaboration with the University of Copenhagen.

We find strong evidence of a positive causal link between companies entering into R&D collaboration with the University of Copenhagen and the development in their productivity per employee. More specifically, companies entering collaboration increase their productivity per employees by an annual average of 6.5 per cent.

The positive causal link to increasing productivity corresponds to a net gain of € 7,000 per employee on the bottom line for each company year upon year as an effect of collaborating with the university.

The net gain of € 7,000 per employee improves the bottom line of each collaborating company by € 2.43 million, as the average company size is 350 employees. With 625 unique companies in the analysis this adds up to a total economic impact on of € 1.5 bn.

On the other hand, we have not been able to find valid results from the analysis on spill-over effects. The lack of validity is due to a lack of proper data and information about investments in R&D.

1.4 University/company collaboration; who, when and why

The collaborations have several benefits for academia and companies. Among these, some of the benefits for academia are the practical application and utilisation of research, valuable input to research and publications and access to funding, while the benefits for companies include access to highly specialised expertise, technology and research results.

Across the cases we see changed R&D behaviour in academia as well as in the business sector, innovation effects in the shape of development and commercialisation of new products, as well as economic effects through generation of annual turnover. On a societal level, several examples of collaborations have led to significant and important effects for society by addressing important societal issues - and by creating jobs in the Copenhagen area.

However, the case studies also show that successful university/company collaboration builds on a number of key enablers. Among these is a mutual understanding of the different goals of the research and business worlds. While companies ultimately keep their eyes on the bottom line, academic researchers are focused on generating scientific publications; successful collaborations are collabo-
rations where both parties respect and support the goals of the other party.

Finally, the study points to a number of barriers for university/company relationships. Among these are high transaction costs spent on working out the legal framework for the collaboration, and differences between an academic culture focused on long-term goals and a business culture with a more short-term focus. On the whole, the study shows that successful collaborations often require long-term relationships, where the parties build trust, develop insight into each other’s competences and goals, and find ways of mitigating barriers to fruitful collaboration.

These findings hold important policy implications, namely that in order to generate positive effects from R&D collaboration between universities and industry, it is not enough to simply stimulate formal R&D collaborations; policymakers and universities themselves must also stimulate and facilitate other forms of interaction between public and private science, notably the establishment of long-term relationships between scientists in companies and in universities.

1.5 The structure of the report

The remaining part of the report is structured as follows.

- **Chapter 2** presents the background and introduces the mind-set behind the impact assessment.
- **Chapter 3** establishes a definition of the central terms used in this report.
- **Chapter 4** presents the methodology of the analysis. Thus it runs through the creation of a unique set of data and explains the ideas behind propensity score matching, difference-in-

difference analysis as well as fixed effects models with cluster adjusted error terms. Finally, the chapter explains the methodology behind the cases.
- **Chapter 5** conducts the quantitative impact assessments focusing on both the economic effects (in terms of productivity and employment) and behavioural effects in terms of additional investments in R&D and presents the results.
- **Chapter 6** focuses on why and how there are effects or no effects of collaborating with the University of Copenhagen. This is done through comprehensive case interviews and case studies.
- **Chapter 7** rounds up the report by discussing the results and their implications.
Universities play a significant role today. Historically they have played a crucial role as the backbone of society, a role they still fulfill by educating excellent skilled citizens, but also by conducting basic and cutting-edge research. They are an important engine for knowledge production and innovation. Thus, the universities are a determining factor in the global knowledge-based economy.

As such, universities have many different activities with different impacts on society: Building up knowledge, developing new insights, education, collaboration with external partners etc. The activities vary between many disciplines, and the impact on society therefore takes many different forms.

One of these many activities refers to the relationship between the universities and knowledge spill-over through research and R&D collaboration with companies. This topic has in the Danish context as well as in international research policy debates been subject to increasing demands.

A recent Danish study among companies located in Denmark shows that having R&D collaboration with universities creates growth in companies. More specifically, the R&D collaboration with universities gives a 9 per cent increase in growth in productivity per year. Even so, we do not know much about the effects of research and R&D collaboration from individual universities.

Apart from a range of universities in the US and Canada, e.g. MIT, University of British Colombia and Princeton and the University of Cambridge in the UK, there is only limited tradition for evidence-based impact assessments, though these studies are more descriptive than analytical. This is so despite the fact that more and more demands are put forward in terms of evidence of the effects from funds invested in research.

One reason for the lack of tradition in terms of conducting quantitative and evidence-based impact assessments of universities is the difficulty of identifying the effects and linking potential effects to activities, research and R&D collaboration with companies.

This analysis will uncover potential effects of the University of Copenhagen. The analysis is based on econometric modelling and on applied methodologies being used in academic research as well as being pinpointed among international organisations as best practice for measuring effects of R&D collaboration.

The following chapters provide an in-depth introduction to and scope of the analysis.

### 2.1 Scope of the analysis

The effects of a university are multiple. The universities are important contributors to cutting-edge knowledge, solutions to the challenges of society, to educating people that will keep society in balance and running, in establishing a culture of mutual respect and diversity and as an important

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**Notes:**

4 See: DAMVAD (2011): The impact on company growth of collaboration with research institutions.

5 One can argue whether these economic impact studies are in fact measuring the effects of the universities. Measuring effects and impacts implies setting up a counter factual situation; see OECD, EUROSTAT, The World Bank Group and NBER. Setting up a counter factual situation is setting up a situation without the particular university. Sudmant (2009) denote this approach as ‘.. an extreme approach to economic impact’. Even so it is the ambition of this analysis to conduct an economic impact assessment setting up a counter factual situation and thus measuring the value added created through collaboration with the University of Copenhagen.

source to new knowledge and innovation in companies.

This analysis focuses solely on the value created through interaction between the university and companies and the value it creates in companies in terms of productivity and employment growth.

On the other hand, this implies that a lot of the value a university is creating for the surrounding society will not be covered. Figure 2.1 provides a view of examples on how a university creates value for the surrounding societies. The examples are divided into effects that are quantifiable and those which are not. Furthermore, the general increase in knowledge stock can to a certain extent be quantified. The value can be in terms of:

Non-quantifiable effects:
- Sound Supreme Court judges to enforce the laws of the country and thus creating the institutional stability of the country that is crucial for economic stability and development.
- Skilled economists in order to prevent the country from running with large deficits on national accounts, which either will lead to national bankruptcy or strong austerity measures leading to unemployment and economic stagnation and recession.
- Setting social norms and cultures, e.g. through theology, which has played a crucial part in the development of society and norms throughout the last centuries.
- Skilled doctors enabling treatment of the population, providing wellbeing of the work force and improving the mortality rates with increasing population as a consequence.

Quantifiable effects:
- Gains from knowledge spill-over between university and companies. Knowledge and especially cutting-edge knowledge have proven to

| FIGURE 2.1 |
| Examples of the effects a university creates to society |

<table>
<thead>
<tr>
<th>Quantifiable effects</th>
<th>Non-quantifiable effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic effects of research collaboration</td>
<td>Setting social norms and developing the society</td>
</tr>
</tbody>
</table>
| Economic effects of companies hiring alumni’s from the university | The value of skilled individuals e.g.:
  - Supreme court judges
  - Upper secondary school teachers
  - Doctors
  - Economists
  | Skilled civil servants securing national and institutional stability |

General economic growth through increasing knowledge stock

Source: DAMVAD 2012
Note: The list is by no means exhaustive
To be a crucial competitive parameter for nations, regions and at individual companies.

The figure is divided into effects that are quantifiable and those which are not. Whereas gains from knowledge spill-over related to collaboration between company and university can be assessed, it is somewhat more difficult to quantify the value of setting cultural and social norms of having skilled civil servants to secure national and institutional stability.

It is beyond doubt that skilled doctors, civil servants, high court judges etc. have a massive economic impact on society. However, this is not the focus of this analysis.

### 2.2 Why measure the effect of university research?

The University of Copenhagen is a large generator of economic activity. Focusing on the sheer size of the university it is without doubt that the university is important to its surroundings.

Some basic figures for 2011 are:

- Employed 9,185 full time equivalents.
- Revenue of more than € 1bn.
- 37,869 enrolled students.

A central part of the strategy and objective of the University of Copenhagen is to create value added to companies and the surrounding society. As such, the university has launched several initiatives in order to support the strategy, e.g. “Science City North” where health science, pharmaceuticals and natural science are physically integrated with the aim of creating new synergies between the university, the city and businesses.

The ideas in the strategy of the university are in line with the political trends in many European countries in recent years. European governments emphasise the need of transforming the funding of the universities into the knowledge economy in order to strengthen the competitiveness in the global economy. The Danish government platform focuses on creating new partnerships linking companies to universities. As such, they try to utilise university research for the benefit of society as a whole.

There are several reasons for the increased focus on the value created by universities:

- Knowledge is a central competitive parameter. Universities are a key producer of new and valuable knowledge. Therefore it is important to spread the knowledge created at universities into companies and the surrounding society.
- The annual turnover of universities has increased throughout the last decade. This is also the case for the University of Copenhagen. In 2011 the annual turnover of the University of Copenhagen was € 1bn. The increase in annual turnover stems from a significant increase in external funding. As such, external funding has increased from 93m in 2005, 183m in 2007 to 247m in 2009 and finally 308m in 2011. The figures are not in fixed prices but even when correcting for price movement, they are still a very significant increase. With the increased amount of external funding there will also be an increased demand for documenting effects. This is relevant for activities financed by external resources as

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well as basic funding and research based consultancy.

University/industry collaboration is by no means a new phenomenon. It has long been recognised that universities are important for driving knowledge production and innovation. As such, the partnerships between university and company have gained increased focus from policymakers and universities themselves.

But still there is a substantial lack of empirical and quantitative evidence of the effects of university/company collaboration. As stated by Belderos et al. (2004): “Surprisingly, the key question whether cooperative R&D has the expected positive impact on companies’ performance has remained largely unexplored.”

2.3 The importance of universities’ collaboration with companies

Universities are important engines of knowledge production and innovation. Their key contribution to industry and society in general comes from the education and training of graduates (Salter et al. 2000). They also create value through a broad range of heterogeneous and often indirect mechanisms such as adding to the stock of useful knowledge through original research, assessing new knowledge through peer review, disseminating that knowledge and making it widely and freely available.\(^8\) Universities often also develop scientific instrumentation and new research techniques in connection with their research.\(^9\)

\(^8\) However, the contribution of much university research, especially basic research, is often indirect and may emerge long after the research has been undertaken (see e.g. Salter and Martin 2001; Rosenberg 1994; Salter et al. 2000).


Another important means by which universities create value is through direct interaction and collaboration with industry.

University/company research collaboration is by no means a new phenomenon (e.g. Lee 1996; Rosenberg and Nelson 1994; Tether 2002); however, it has gained increased attention from policymakers in recent decades (e.g. Martin 2003), partly as a result of a growing dissatisfaction with the direct and measurable returns from investments in public science, which in turn has led to a demand for greater practical relevance and industry orientation in academia (Pavitt 1991, 2001).

The emphasis on university/company interaction has also been boosted further by the fact that while public funding for universities has decreased, costs associated with scientific research have increased, forcing universities to seek external funding (Genuna 1999, 2001).

Policymakers’ interest in stimulating university/industry research collaboration is however also motivated by recognition of the importance of problem solving at the technological frontier as an enabler of technological development and as a vital source of inputs to basic science (e.g. Brooks 1994; Rosenberg 1994; Vincenti 1990). This has engendered a growing focus on research within specific application contexts, performed in collaboration between public and private science; this focus is reflected e.g. in the literature on “mode 2” knowledge production (see Gibbons et al. 1994) and “triple helix” collaboration between academia, industry and government (Etzkowitz and Leydesdorff 1997, 2000).
Concerns have been expressed regarding possible negative unintended effects of a growing orientation towards and collaboration with companies in academia on the long-term progress of science and technology. However, research also indicates that university/industry interaction can have many valuable effects for academia, for companies and for society (e.g. Brooke 1994; Meyer-Krahmer and Schmoch 1998; Rosenberg and Nelson 1994). For example, public-private research collaboration can play a vital role in advancing scientific and technological progress through joint problem-solving and by opening up new avenues for research (e.g. Meyer-Krahmer and Schmoch 1998; Rosenberg 1990, 1994; Rosenberg and Nelson 1994). This is especially true in the science-based sectors (Pavitt 1984) where technological innovation is closely linked to scientific advances (Feller 1990; Meyer-Krahmer and Schmoch 1998), e.g. the pharmaceutical sector.

2.4 Why do companies and universities collaborate?

According to prior research, collaborating with companies may be beneficial to academic scientists by for example providing additional funding and other resources to bolster university research, by opening up two-way exchanges of scientific and technological knowledge that provide vital inputs to academic research (see e.g. Brooke 1994; Kline and Rosenberg 1986; Lee 1996; Meyer-Krahmer and Schmoch 1998; Rosenberg 1994).

Indeed, according to Lee (2000), the most important benefits that academics realise from collaboration with industry are funding for PhD students and equipment, and new insights into their own research. Academic scientists also enter into collaborations with companies in order to test practical applications of their research and to develop prototypes (Lee 2000; Balconi and Laboranti 2006).

In addition, several studies find strong complementarities between the scientific performance of academic researchers on the one hand and various forms of industry involvement or orientation in academia on the other, for instance patenting, receiving funding from industry, or collaborating with companies (e.g. Agrawal and Henderson 2002; Azoulay et al. 2006; Breschi et al. 2007; Fabrizio and DiMinin 2005; Godin and Gingras 2000; Gulbrandsen and Smeyb 2005; Lowe and Gonzalez-Brambila 2007; Van Looy et al. 2006).

Meanwhile, companies use collaboration with industry to gain access to ideas, knowledge and technology as well as skilled labour (e.g. Feller et al. 2002; Balconi and Laboranti 2006) and to engage in exploratory research and/or technical problem-solving, to design prototypes (Lee 2000).

Collaboration also allows companies to create and maintain learning options on future scientific and technological developments (Caloghirou et al. 2003) by providing access to new research and discoveries in academia (Lee 2000). Interaction with academia helps companies anticipate future research issues, and to translate the complex nature of scientific research (Hall et al. 2003).

In view of this, it is not surprising that companies are more likely to collaborate with universities when they engage in the development of innova-

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10 These concerns will not be reviewed in this report, but for more information, please see e.g. Behrens and O’Gray 2001; Dasgupta and David 1994; Feller 1990; Florida and Cohen 1999; Henderson et al. 1998; Larsen 2011; Lee 1996; Metcalfe 1998, Nelson 1989, 2001, 2004; Stephan et al. 2007.
tions that are “new to the market” rather than just “new to the company” (Tether 2002). Moreover, companies are also most likely to collaborate with academia on very early-stage or very uncertain research, as the results of such research are more difficult to appropriate; because of the lower likelihood that the results will be patented, the opportunity costs of working with academia are equally lower (Panagopoulos 2003).

Finally, prior research also suggests that collaboration with academia enables companies to develop or maintain personal networks, e.g. to academic scientists (Balconi and Laboranti, 2006).

2.5 The effects of university/company collaboration

Despite the growing interest and focus on the importance of university/industry collaboration there is still little empirical evidence on the quantitative economic effects.

There is an increased focus on quantitative and evidence based measures on the effects of research and innovation activities, which among others is stated in the OECD, Science, Technology and Industry Outlook (2008). They state that research policy and research funding to a much greater extend should be based on quantitative evidence.

Furthermore, there is an increasing need for universities to demonstrate their value as an attractive partner for collaboration in order to attract more external funding because public funding is relatively decreasing.

Even so, we do not know much about the effects of research and R&D collaboration from individual universities. Apart from a range of universities in the US and Canada, e.g. MIT, University of British Columbia and Princeton, there is only limited tradition for evidence-based impact assessments.

Moreover, the analyses conducted are more or less descriptive and do not analytically respond to the question of how much added value the university creates for the industry. See e.g. Robert & Eesley (2009) where they focus on the entrepreneurial role of MIT. They state that MIT entrepreneurs employ 3.3 million people and have annual revenue of $2,000 bn. Those are quite substantial figures. The effects are attributed to MIT because of their focus on entrepreneurship programmes.

But there is little evidence that the effect presented can actually be attributed directly to MIT. These entrepreneurial persons have been attracted to MIT because of its excellent reputation. As Robert & Eesley state; “MIT acts like a magnet for foreign students who wish to study advanced engineering, science and management.” But what would have happened if MIT was not an option for these students? Would they have created a company anyway? Would they have succeeded on the same scale? And if they had turned to another university, would they have experienced the same effects? As such, the study lacks an analytical dimension to the question of how much value MIT has created.

Table 2.1 below shows three examples of economic impact assessments with the individual university in focus. The common denominator of the three studies is that they are more or less descriptive and do not analytically relate to how much additional value the university creates. One can argue in several of the analyses that the effect would have been roughly the same if the study concerned a hospital instead of a university. Furthermore, the three examples show that economic im-
pact is measured as the volume of the university, not the additional value the university creates.

What is common for the examples is that they show that universities with a huge number of employees and students have a (regional/local) economic impact. This would probably also have been the case for big companies or other entities and organisations with more than 30,000 employees and receiving $1bn. in national or state funds.
### TABLE 2.1
Examples of known economic impact assessments of universities.

<table>
<thead>
<tr>
<th>Source</th>
<th>Effect of university</th>
<th>Data</th>
<th>Comment</th>
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<tbody>
<tr>
<td>Roberts and Eesley (2009) “Entrepreneurial Impact: The Role of MIT”</td>
<td>Entrepreneurs from MIT create significant effects. They have created an estimated 25,800 companies, employing some 3.3 million persons and earning a revenue of $ 2,000 bn.</td>
<td>Based on survey with 2,059 unique respondents. The survey results are multiplied by a factor to meet the gross population of the 105,928 living alumni from MIT. This factor is used to multiply the results from the 2,059 unique respondents in order to meet the gross population.</td>
<td>The results point at MIT as a significant contributor to the economy. Generally, there are two concerns regarding this kind of approach. 1. Bias among the respondents – are they representative? 2. Using a multiplication factor to reach the gross population may accelerate the bias in the results.</td>
</tr>
<tr>
<td>Sudmant (2009) “The Economic Impact of the University of British Columbia”</td>
<td>The impact of the University of British Columbia is $ 10 bn. The government funding is $ 1bn. As such the university multiplies government funding by a factor 10.</td>
<td>The economic impact is measured through direct spending in the local economy. Furthermore, spending not directly connected to the university, the impact of an educated work force and the impact of new knowledge created by the university are included.</td>
<td>This study focuses on the economic impact of the university but does not tell a story about added value from the university. The figures and amount of economic impact could just as well have been from a hospital subsidised by $ 1bn. a year.</td>
</tr>
<tr>
<td>Tripp Umbach (2009) “The Pennsylvania State University Economic Impact Statement 2008”</td>
<td>The net direct and indirect impact of Pennsylvania State University is $ 8.48bn, supporting more than 67,000 jobs.</td>
<td>Using the ACE-based methodology employing linear cash-flow modelling.</td>
<td>This study shows the economic magnitude by the cash-flow the system and activities around the university generates. This included sporting and cultural activities, conferences, tourism and regional spending by students and employees at the university. Still it could be interesting to see what alternative investments could have brought to Pennsylvania.</td>
</tr>
<tr>
<td>Libery House (2007) “The Impact of the University of Cambridge on the UK Economy and Society”</td>
<td>The net direct impact is £21.2bn. In regional GDP supporting 11,700 people directly and more than 77,000 jobs indirectly.</td>
<td>Using the Higher Education Impact Model for the analytical structure. Further using the REMI model to estimate the regional impact by multiplying the expenditures of the university.</td>
<td>The report covers many aspects of an impact assessment. Both impact of the university’s expenditure, the impact of education, patenting and spin offs. Still, the question related to creating a counterfactual situation remains unanswered. The report states the consequence if the university did not exist. But still it would leave room for alternative investments and the effects of these investments should be excluded in order to report an economic net contribution of the university.</td>
</tr>
</tbody>
</table>

Source: DAMVAD, 2012
Collaboration between a company and the university concerning research, development and innovation produces several advantages covering both exploitation of cutting-edge knowledge, enhancing private R&D and innovation, putting theory into practice and reducing barriers in complicated R&D projects.

The following presents how collaboration between a company and the university is defined. Furthermore, it presents the magnitude of collaboration between the University of Copenhagen and companies located in Denmark and finally the potential effects of such collaboration are presented.

3.1 Channels of collaboration

In order to transfer knowledge from university to company there has to be some kind of interaction. Interaction can be through different channels of collaboration. Thus, identifying and quantifying individual collaboration can be rather difficult.

Firstly, the level of collaboration is plural. There are several channels of collaboration, both formal and informal and the channels are executed at several levels, e.g. through the individual researcher, at faculty level or at the institutional level. Thus it is difficult to delimit and to quantify.

Secondly, the collaboration between the university and its surroundings is indeed a complex process. In order to measure the effects of the different channels of collaboration it is important to include as many different types of collaboration as possible. As such, we want to focus broadly on collaboration and its different channels. In the analysis we focus on the following types of collaboration:

- Buying R&D from the university (e.g. based on a contract).
- Co-financed R&D projects (e.g. financed through company budgets and basis funding at

![Diagram of Channels of Collaboration](source: DAMVAD 2012)
the university).

- R&D collaboration based on public R&D schemes (e.g. The Danish Council for Strategic Research or the Danish Innovation Consortia).
- Joint publications and patenting.

From a company point of view, the different channels of collaboration are linked to different internal processes related to knowledge production and R&D activities. Whereas buying R&D mostly consists of knowledge inflow to the company, co-financed R&D projects and formal R&D collaboration on the other hand are related to knowledge interaction between the different collaborators. Figure 3.1 shows different types of collaboration channels between the company and the university. There are more channels especially informal ones and channels related to alumni, however, these are not part of this analysis.

It is also possible to quantify the economic impact for companies from hiring alumni from a university. This report does not focus on the effects from hiring alumni from the university. Thus, the analysis solely focuses on the effects from research collaboration between universities and companies.

3.2 The magnitude of collaboration

The aim of this chapter is to highlight the magnitude and level of university/company collaboration between the University of Copenhagen and companies. The results show that:

- The university participates in an increasing number of collaborations with companies. This is in particular driven by an increase in collaboration with foreign companies. In 2009 there were almost 900 formal collaborations.
- Collaboration is executed through different channels but largely by common publication, formal R&D collaboration projects and projects based on public R&D schemes.
- Companies collaborating with the university are characterised by being larger, more R&D intensive and more international.
- Furthermore, the companies are scattered in many different sectors. Though some sectors are more over-represented. It is in particular knowledge-intensive sectors such as high-tech manufacturing or knowledge-intensive business service.

The results are further elaborated in the following:

3.2.1 Multiple channels of collaboration

The University of Copenhagen has a broad inter-

<table>
<thead>
<tr>
<th>TABLE 3.1</th>
<th>Number of collaborations with Danish and foreign companies on different channels of collaboration</th>
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<tbody>
<tr>
<td></td>
<td>Danish</td>
</tr>
<tr>
<td>Projects registered at the University of Copenhagen</td>
<td>1,634</td>
</tr>
<tr>
<td>Public R&amp;D and innovation schemes</td>
<td>360</td>
</tr>
<tr>
<td>Joint publication</td>
<td>3,671</td>
</tr>
<tr>
<td>Patenting</td>
<td>16</td>
</tr>
<tr>
<td>Total (by nationality)</td>
<td>5,681</td>
</tr>
<tr>
<td>Total</td>
<td>6,338</td>
</tr>
</tbody>
</table>

Source: DAMVAD 2012
face with companies. Table 3.1 shows that companies have been participating in 6,338 collaborations with the university in the time span from 1998 to 2009. 1,537 companies have been involved in the collaborations whereas 1,020 of these are Danish and 517 are foreign companies. This means that several companies have more than one collaboration with the university and that it is in particular companies located in Denmark that have several collaborations with the university.

Furthermore, table 3.1 shows the different channels of collaboration and how many collaborations that have in fact been identified. As such, the table shows that for companies located in Denmark, the most common form of collaboration is through joint publication. On the other hand, the most common channel of collaboration for foreign companies is through a formal collaboration with the university.

Furthermore, 255 companies located in Denmark have participated in publicly financed R&D and innovation schemes with the university. In total the 255 companies have participated in 360 projects with the university.

The fundament for later analysis of effects concerns two different collaboration channels. That is the collaboration projects registered at the University of Copenhagen, as well as the collaboration projects based on the public R&D and innovation schemes. In total that includes 2,651 collaborations.

**Definition of collaboration:**

In this analysis, collaboration is defined as the formal collaboration between a company and the University of Copenhagen. The formal collaboration involves a financially-binding agreement between the two parties and typically involves participation in a formal project e.g. financed through public R&D schemes or where the company buys access to research or technical help from the university.

**FIGURE 3.2**

Number of collaborations per year, 1998-2009

![Number of collaborations per year, 1998-2009](image)
3.3 Increasing level of collaboration

The total number of collaborations has increased constantly since 1998, though there is a small decline in the number of collaborations from 2008 to 2009. In 1998 the number of identified collaborations was 227. The figure has increased to 736 in 2009 and initially peaks in 2008 with almost 800 collaborations.

The increasing number of collaborations is driven by more joint publications, as well as more participation in publicly financed schemes. Furthermore, projects registered at the university are also increasing. As such, the number of joint publications increased from 190 in 1998 to 436 in 2009. Moreover, the number of collaboration projects registered at the university increased from 32 in 1998 to 201 in 2009 and participation in public schemes increased from 4 in 1998 to 99 in 2009.

Furthermore, the increase in the number of collaborations stems from both Companies located in Denmark and foreign companies. As such, figure 3.3 shows that the number of collaborations with Companies located in Denmark has increased 3 times since the point of origin in 1998. Furthermore, the number of collaborations with foreign companies has increased 5 times since the point of origin in 1998.

3.3.1 Collaboration with knowledge-intensive companies

The companies that collaborate with the University of Copenhagen are more knowledge-intensive
than other Companies located in Denmark. Table 3.2 shows that the R&D intensity is way higher in the companies that collaborate with the University of Copenhagen than other companies. In general, the R&D intensity of companies located in Denmark is 11 per cent. This is measured as the share of full time equivalent R&D employees relative to the total number of employees measured as full time equivalent. The same figure for companies collaborating with the University of Copenhagen is 40 per cent. Furthermore, companies collaborating with the university are more likely to have their own R&D department. Thus, 38 per cent have their own R&D department compared to 12 per cent in general.

Moreover, companies collaborating with the university have higher productivity per FTE. The average labour productivity in companies that collaborate with the university is € 171,000 compared to € 100,923 in general.

### TABLE 3.2
Key figures for treated companies

<table>
<thead>
<tr>
<th></th>
<th>Companies collaborating with the university</th>
<th>Companies located in Denmark in general</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue per FTE (€)</td>
<td>374,165</td>
<td>280,443</td>
</tr>
<tr>
<td>Value added per FTE (€)</td>
<td>100,035</td>
<td>89,365</td>
</tr>
<tr>
<td>Exports per FTE (€)</td>
<td>171,441</td>
<td>100,923</td>
</tr>
<tr>
<td>Export intensity</td>
<td>42 %</td>
<td>27 %</td>
</tr>
<tr>
<td>R&amp;D intensity</td>
<td>40 %</td>
<td>11 %</td>
</tr>
<tr>
<td>Share with R&amp;D department</td>
<td>38 %</td>
<td>12 %</td>
</tr>
</tbody>
</table>

Source: DAMVAD2012 based on register data from Statistics Denmark

Note: The average figures are corrugated for sector as well as the time of collaboration with the University of Copenhagen. The figures are measured in 2011 prices.

R&D intensity states the share of R&D FTE to FTE.

Export intensity states the ratio of export to revenue.

### TABLE 3.3
Examples of sectors that are over-represented compared to companies located in Denmark in general.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Companies collaborating with the university</th>
<th>Companies located in Denmark in general</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific, research and development</td>
<td>18.8 %</td>
<td>0.2 %</td>
</tr>
<tr>
<td>Legal and accounting activities</td>
<td>10.8 %</td>
<td>6.6 %</td>
</tr>
<tr>
<td>Manufacture of food product</td>
<td>6.0 %</td>
<td>0.6 %</td>
</tr>
<tr>
<td>Manufacture of basic pharmaceutical products and pharmaceutical preparations</td>
<td>4.0 %</td>
<td>0.03 %</td>
</tr>
<tr>
<td>Manufacture of chemicals and chemical products</td>
<td>3.0 %</td>
<td>0.2 %</td>
</tr>
<tr>
<td>Manufacture of computers, electronic and optical products</td>
<td>2.4 %</td>
<td>0.1 %</td>
</tr>
</tbody>
</table>

Source: DAMVAD 2012 based on registers from Statistics Denmark.
to € 100,000 for companies in general.

The companies collaborating with the university are more exposed to global competition. As such, the share of their revenue coming from exports is 42 per cent as opposed to 27 per cent in general. This makes companies collaborating with the university more dependent on developing new solutions that are competitive on a global market.

Table 3.3 shows the share of collaborating companies dispersed on different sectors. The figures show the share of companies in each sector out of the total number of companies. As such, comparing the companies collaborating with the university with the general distribution of companies enables us to assess whether there are certain sectors that are over-represented.

Certain sectors are indeed over-represented compared to the general picture. These are sectors such as scientific, research and development, legal and accounting activities, manufacture of food products, manufacture of basic pharmaceutical products and pharmaceutical preparations, manufacture of chemicals and chemical products as well as manufacture of computers, electronic and optical products. E.g. the sector scientific, research and development accounts for 18.8 per cent of the companies collaborating with the university whereas this sector only covers 0.2 per cent of the Danish businesses. Likewise, the pharmaceutical industry (manufacture of basic pharmaceutical products and pharmaceutical preparations) accounts for 4 per cent of the companies collaborating with the university, but the sector only covers 0.03 percent of the companies in Denmark.

3.4 Different effects

The economic effects from research collaboration between the university and the company can be multiple and appear at different times. Figure 3.2 shows the plural effects companies can experience

![Figure 3.2](image-url)

**FIGURE 3.2**
Different effects of R&D collaboration on private companies

- **Impact**
  - Society level
  - Company level
  - Innovation effects (e.g. increased innovation)
  - Economic effects (e.g. increased productivity)
  - Social effects (e.g. solution to challenges of society)
  - Behavioural additionality (e.g. continual collaboration with universities)

- **Time after initial collaboration**
  - 0-2 years
  - 1-5 years
  - 2-10 years
  - 5-20 years

*Source: DAMVAD 2012*
from collaborating with universities at different time levels:

- **Behavioural additionality**, e.g. strategic changes in management, the organisation changes in R&D collaboration with universities.
- **Innovation effects**, e.g. more innovation, increased R&D activity or patents.
- **Economic effects**, e.g. increased productivity or increased employment.
- **Social effects**, e.g. socio-economic growth, new solutions to challenges in the society related to health, environment or energy.

The above levels of effect show that the effects of company collaboration with university underline the fact that collaboration is affecting companies and the surrounding society in many different ways. Furthermore, figure 3.2 shows that one type or level of effect does not exclude others. E.g. innovation effects in terms of increased innovation can lead to economic effects at company level.

Furthermore, figure 3.2 shows the different effects in different time frames. Whereas effects at society level first become present in the long term, e.g. 5 to 20 years or in some cases even longer. The behavioural changes, on the other hand, may be present immediately after the initiation of the collaboration.

This analysis will focus on the economic effects at company level through econometric and quantitative analysis. Furthermore, the analysis will focus on a particular behavioural additionality – that is the effects of increasing private R&D investment in companies collaborating with the University of Copenhagen. Apart from that, the behavioural and innovation effects will be included in the quantitative part of the analysis. Thus, they will be in focus in the case studies.

It is not an easy task to state definite figures for the impact of collaboration with universities. Most analyses focus on the satisfaction among companies related to the collaboration. The results mostly report that companies have been pleased with the collaboration. A recent study published by Universities Denmark\(^{11}\) shows that 97 per cent of the responding companies are pleased with the collaboration with a Danish university. However, this result does not show if the companies have had additional gains in terms of improved economic results, employment etc. that they would not have experienced without this collaboration.

The main focus will be on the following economic effects:

- **Productivity per employee**: Productivity per employee is a measure of how efficient the working force is used to generate value added\(^{12}\). An increase in productivity per employee means that the value added has increased for a fixed number of FTEs. By using this measure it is possible to apply a transverse objective which has the same expression across different industries, sectors and company sizes over time.

Furthermore, the analysis will look at behavioural additionality in terms of R&D investments conducted by the companies. Hence, the analysis will look at to what extent collaboration with the University of Copenhagen has an impact in terms of increasing private R&D in the companies. As such

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11 Universities Denmark is the organisation of the eight Danish universities to enhance their cooperation, visibility and impact.
12 Value added is calculated as the difference between revenue and costs of materials and other services used for production such as rent, energy, consumption of stock goods, salaries etc. Value added is based on Statistics Denmark’s calculations and is defined as the company’s turnover plus other operation annual turnover minus the use of goods and services.
the additionality becomes a question of whether research carried out at the university and transferred to a company will substitute or complement the private R&D.
4  Methodology

This part describes the methodology and data fundament for conducting the analyses. In the following, we will account for creating a unique set of data and how we treat data in order to set up the proper models to do the effects studies. Furthermore, this chapter describes the methodology behind the case studies.

The different phases of data collection, setting models and conducting cases are introduced in figure 4.1. The steps are as following:

- Creating a unique set of data from four different sources of data.
- Identifying individual collaboration between companies and the University of Copenhagen.
- Setting up models to test the effects of collaboration between companies and the university.
- Finally, conducting case studies that allow for elaborating the findings from the quantitative studies.

The following presents in detail the different steps of creating data and setting up the models.

4.1 Creation of a unique set of data

This analysis is based on a unique set of data. The purpose of the unique set of data is:

---

**FIGURE 4.1**

Four central steps in setting up the analysis

1. **Establishing a unique set of data**
2. **Identifying individual collaborations between the university and companies**
3. **Setting up models to test the effects of these collaborations**
4. **Through cases elaborate on the findings**

*Source: DAMVAD 2012*
At first to enable us to identify individual collaboration activities between companies and the university. Furthermore, it is crucial that we are able to identify the year in which the collaboration was initiated.

Secondly, the unique set of data should enable us to set up models for conducting econometric analyses on the economic and behavioural effects for companies that stems from collaborating with the University of Copenhagen.

An overall view of the unique set of data is illustrated in figure 4.2. The following provides a detailed description of the different data sources:

- Registers at the University of Copenhagen
- DAMVAD’s Co-operation database
- DAMVAD’s Research database.
- Register data at micro level from Statistics Denmark.

4.1.1 The University of Copenhagen’s register for economic transactions with companies

The University of Copenhagen collects information on companies’ purchase of R&D conducted by the University of Copenhagen as well as companies’ participation in co-financed R&D projects with the university. The list contains information on the companies which have had collaboration with the university, in which years the collaboration took place and the type of interaction. DAMVAD and the University of Copenhagen have, by using CVR numbers, linked the companies to register data from Statistics Denmark.

4.1.2 DAMVAD’s Cooperation Database

DAMVAD’s cooperation database contains information on which types of projects and means companies located in Denmark, universities (in-
cluding the University of Copenhagen) and organisations etc. collaborate on and can thus supplement the university’s own data with those companies participating in public financed R&D-projects together with the University of Copenhagen.

The foundation of the cooperation database is a complete enumeration of public funded projects within programmes such as Innovation Consortia, Strategic Research, EU Framework programmes, EUDP etc.

Altogether the database contains more than 4,600 different projects which collectively comprise nearly 12,000 Danish actors’ participation. The cooperation database contains VAT numbers (Central Business Register numbers) of the companies and by this means is coupled from the cooperation database to register data.

4.1.3 Publication and patent database
DAMVAD’s research database for joint publishing and patenting is based on “Web of Science” and “Core Patents” at Thomson Innovation and further complements the information from University of Copenhagen. The database identifies collaboration through:

- Joint publications between companies and the University of Copenhagen.
- Patenting

Publications
The data material contains all publications authored by one or more researchers from the University of Copenhagen in the period 2000 to 2011. All publications are downloaded and formatted in order for the data to match DAMVAD’s research database.

The publication number is used in this context as an indicator of whether there has been collaboration between a company and the University of Copenhagen. To indicate the year for interaction between the company and the university, the year of publication for that specific journal number is used.

Since most of the collaborations do not lead to a publication from the first day, we have to make an estimate of the time involved.

Valentin and Jensen (2010) have shown that up to 90 per cent of the knowledge generated on joint publications, is published within the time frame of one year after the year of submission of the patent application. The authors show reason to assume that the duration of a peer review is on average one year. Additionally, the working time of a publication is assumed to be one year on average.

Consequently, this analysis assumes that the knowledge creation that later leads to a publication starts building up two years before the priority date.

Patents
The data material on patents includes all patents that have been taken out during the period 2000 to 2011. All the patents are downloaded and follow the method as described for publications.

Since most partnerships do not lead to a patent from the first day, we assume that on average it takes one year to produce the knowledge underlying a patent.

For both patents and publications it applies that information on these can be coupled to other data by using VAT numbers.

4.1.4 Register data
Through research access at Statistics Denmark, DAMVAD has accessed micro data containing de-
etailed information on specific companies in Denmark.

From the general company statistics, account statistics, DAMVAD has access to information on key economic indicators such as turnover, value added, number of employees, export etc. By using VAT numbers this information can be linked to those companies collaborating with the University of Copenhagen.

Furthermore, DAMVAD has access to micro data for individuals and thus may supplement with information on the employees’ educations.

Through research access at Statistics Denmark, DAMVAD has access to micro data containing detailed information on specific companies in Denmark.

From the general company statistics, account statistics, DAMVAD has access to information on key economic indicators such as turnover, value added, number of employees, export etc. By using VAT numbers this information can be linked to those companies collaborating with the University of Copenhagen.

4.2 Modelling the effects of R&D collaboration

This section describes the method employed to estimate and quantify the company-specific impact of forming R&D collaboration with the University of Copenhagen.

It is always difficult to single out, by no mistake, the real effect of collaboration with a university. In principle, you want to know the impact compared to the counterfactual situation that the same company did not have a collaboration. This is logically impossible. An analysis modelling this counterfactual situation needs to address some fundamental issues:

- Eliminating the impact from other factors by establishing a control group with no systematic differences.
- Trying to ensure logic and time causality
- Trying to eliminate selection bias – the case that some companies are more inclined to participate in collaboration with a university than others

This analysis estimates the average treatment effect on the data treated which can be expressed as the difference between the participants’ outcome with and without treatment:

$$E[y_1 - y_0|\text{treatment} = 1] = E[y_1|\text{treatment} = 1] - E[y_0|\text{treatment} = 1]$$

where $y_1$ expresses outcome in the event of treatment, and $y_0$ is outcome in absence of treatment.

Since only the first term on the left hand side, $E[y_1|\text{treatment} = 1]$, can be observed for the participants we need an approximation to the latter term describing what would have happened to participants had they chosen not to participate, i.e. the counterfactual situation. Taking the mean outcome of non-participants as an approximation is not a promising approach since participants and non-participants are expected to differ systematically even in absence of treatment. The challenge is known as (self) selection bias. The motivation for implementing the PSM approach is to reduce and potentially eliminate the bias arising from selection bias.

Figure 4.3 below illustrates the basic idea behind impact assessment. The two groups of companies
perform similarly before collaboration, where the treatment group enters into collaboration at time 0 and consequently achieves a higher productivity per employee.

The average treatment impact is measured as the difference to the counterfactual outcome. The counterfactual situation is illustrated by a dotted line illustrating the performance path participation would have followed in the absence of collaboration. As shown in the figure, the appropriately selected control group is a good substitute for the counterfactual outcome.

**4.2.1 Underlying assumptions**

An important assumption for identification of the treatment effect is that all differences between companies that collaborate with the university and the control group identified by PSM can be captured by the set of observables including, among others, the pre-treatment productivity of the companies.

The assumption is known as the conditional independence assumption (CIA) and can be formulated as\(^\text{\ref{eq:cia}}\):

\[
y_0, y_1 \perp \text{treatment} \mid p(X)
\]

The CIA implies that selection is based solely on observational factors and that all variables that influence the treatment decision and potential outcomes are simultaneously observed. The CIA is clearly a strong assumption and rules out the presence of unobservable characteristics affecting the treatment decision and potential outcomes.

This analysis draws on a large and high quality micro data which gives reason to believe that all major factors that jointly influence both selections into treatment as well as potential outcomes are observed. However, the presence of unobservable factors cannot completely be ruled out, implying that the results should be interpreted with some caution. Unfortunately, the CIA is an untestable assumption (Gerfin and Lechner 2002).

In addition to imposing conditional independency, this study requires an overlap condition known as common support\(^\text{\ref{eq:overlap}}\) which can be expressed as:

\[
0 < \text{prob}(\text{treatment} = 1|X) < 1
\]

Common support ensures that companies with the same value of covariates have a positive probability of being both treated and untreated. Hence, the treatment effect is identified among the set of par-

---

\(^{13}\) Rosenbaum and Rubin (1983) show that if potential outcomes are independent of treatment conditional on \(X\), independence also holds conditional of \(p(X)\). Consequently the CIA is formulated conditional on the propensity score.

\(^{14}\) Robin and Rosenbaum (1983) refers to the CIA and common support requirements as strong ignorability of treatment.
participants with a propensity score for which a similar non-participant exists. As a final assumption, this study uses the stable unit treatment value assumption (SUTVA), which rules out that treatment indirectly impacts untreated companies (Wooldridge (2002). The SUTVA assumption is likely to hold taking the time frame into consideration, since companies’ individual knowledge of the impact of the collaboration can be considered as private. However, information on the impact of collaboration with the University of Copenhagen will flow to untreated units in the long run contradicting the SUTVA.

4.2.2 Propensity score matching

The basic idea of PSM is to simulate the counterfactual situation by identifying a control group consisting of non-participants who are similar to the participants in all relevant pre-treatment characteristics. Denote the set of characteristics by X.

The propensity score expresses the probability of initiating collaboration with the University of Copenhagen conditional on a set of covariates. This can be expressed by:

\[ p(X) \equiv \text{Prob}(\text{initiate collaboration} = 1|X) \]

More precisely, the participation probability is estimated by formulating a probit model using the following covariates:

\[ \Pr(\text{Initiate collaboration}_{i,t} = 1) = f(\text{size}_{i,t-1}, \text{export intensity}_{i,t-1}, \ln(\text{capital}_{i,t-1}), \ln(\text{productivity}_{i,t-1}), \text{share with ISCED(5B)}_{i,t-1}, \text{share with ISCED(5A)}_{i,t-1}, \text{share with ISCED(5A)}^2_{i,t-1}, \text{share with ISCED(6)}_{i,t-1})^{15} \]

where \( f\{\} \) is a standard linear functional form.

Characteristics that are expected to partially explain the decision to form a collaboration as well as companies’ premise for the potential outcome are the companies’ size, orientation towards foreign markets, capital, productivity as well as the companies’ knowledge adoption compounded by the employees’ educational backgrounds.\(^{16, 17}\)

All factors on the right hand side are expressed at \( t-1 \), i.e. the time leading up to treatment since the decision to form collaboration with the university is based on company specific pre-treatment characteristics. Companies are selected to form part of the control group by employing a matching technique that matches based on the propensity score. The analysis employs the nearest neighbour matching with a matching ratio of 1:10. In other words, the matching procedure for each participant selects 10 non-participations with a similar propensity score. The matching algorithm selects ten control units in the attempt to improve the estimation precision in the control group due to a relatively low number of participants. The matching is conducted for each year to ensure that the control group has similar propensity score at the year of participation.

4.2.3 Assessing the quality of the control group

The quality of the matching procedure is assessed in order to ensure that the estimation of the treat-
The propensity score before matching. Almost all covariates are statistically significant and can thus partially explain the treatment status. This means that there are significant differences in the covariates between the treatment group and the control group before matching. The coefficient on the covariate \( \text{share with ISCED (5B)}_{t-1} \) is negative indicating a positive but marginally declining impact on the participation probability by increasing the share of employees with long-term higher educations.

The columns to the right show that the significantly systematic differences in the observables disappear after the matching procedure. Consequently, the PSM method has resulted in an appropriate balance considering each characteristic. This indicates that the control group is capable of simulating the counterfactual situation and with the CIA in hand we are thus able to identify the average treatment effect for the companies forming R&D collaboration with the University of Copenhagen.


different, the balancing test investigates whether the treatment decision is independent from the set of observables conditional on the propensity score. The propensity scores thus serve as a way to balance the observed distribution of covariates across the treatment and control groups (Lee 2006).

Table 4.1 presents the balance of each covariate for the treatment and control groups before and after the matching procedure. The two columns to the left present the coefficients for the estimation of

| Table 4.1 |
| --- | --- | --- |
| | Before matching | After matching |
| | Coefficient | t-value | Coefficient | t-value |
| Size: 50-249 | 0.47** | (6.75) | 0.04 | (0.33) |
| Size: 250-999 | 0.69** | (6.55) | -0.06 | (-0.34) |
| Size: 1,000-2,499 | 0.89** | (4.94) | 0.07 | (0.24) |
| Size: >2,500 | 1.39** | (5.87) | 0.08 | (0.23) |
| Export intensity\(_{t-1}\) | -0.07 | (-0.89) | -0.10 | (-0.71) |
| \(\ln(\text{capital} _{t-1})\) | 0.11** | (7.48) | 0.02 | (0.67) |
| \(\text{Share with ISCED (4&5A)}_{t-1}\) | 0.82** | (7.57) | 0.10 | (0.44) |
| \(\text{Share with ISCED (5B)}_{t-1}\) | 0.82** | (7.57) | 0.10 | (0.44) |
| \(\text{Share with ISCED (5B)}^{2}_{t-1}\) | 0.82** | (7.57) | 0.10 | (0.44) |
| \(\text{Share with ISCED (6)}_{t-1}\) | 0.82** | (7.57) | 0.10 | (0.44) |
| \(\ln(\text{productivity} _{t-1})\) | 0.01 | (0.12) | -0.02 | (-0.23) |

Note: * denotes significance at a 5 per cent level. Additionally, the model includes year dummies and two digit nace codes.

Company size is measured by FTE. Export intensity denotes the amount of export relative to total turnover.

Source: Calculations by DAMVAD based on micro data from Statistics Denmark.
4.2.4 Difference-in-difference

The difference-in-difference model is implemented in order to estimate and detect whether participants and non-participants perform differently before and after treatment. Since only the treatment status separates the two groups, they are expected to perform similarly before treatment. Any differences in the post-treatment performances can be attributed to the participation in collaboration with the University of Copenhagen.

The difference in difference estimator is given by:

\[ \delta = \bar{Y}_i^T - \bar{Y}_i^C - (Y_i^C - Y_i^L) \]

where \( \delta \) is the participation effect and \( Y_i^T \) captures the performance at time \( t \) for group \( i \) where \( i \) indicates treatment status. The participation effect is calculated as the difference in the development in performance between the treatment group and control group. For both groups, the difference in performance is calculated as the performance at time \( t \) subtracted performance at time \( t-1 \), where time \( t-1 \) corresponds to the year leading up to participation while time \( t \) corresponds to the year after participation. The performance of the participating companies is compared to the matched control companies at the same time period to take account of external factors influencing companies’ performance.

The difference-in-difference estimator is employed for each year after participation in order to calculate the participation effect over time. Whether or not there is a statistically significant participation effect is tested using a standard regression technique with robust standard errors.

4.2.5 Handling extreme observation

The presence of extreme observations may distort the participation effect and reduce the estimation precision. For example, data can contain extreme values due to the occurrence of measurement errors or due to mergers and spin-offs of businesses. Such extreme observations can have a disproportionately large impact on the analysis without actually bringing knowledge to the study concerning the impact.

To avoid the distorting impact of outliers, this paper implements certain performance criteria, which serve as thresholds for which outliers are corrected. In the research literature it is common to remove companies that experience a doubling or a halving in performance between two successive years. Due to the relatively low number of participants this approach cannot be implemented. Initially, companies experiencing negative value added are excluded. In addition companies from mining and quarrying are excluded. Where performance in a single year doubles or drops by more than 50 per cent compared to the two neighbouring years, the two neighbouring observations are used to correct the outlier by taking the average performance of these two years.

In addition to the mentioned performance criteria the 5 per cent best and worst performances for each year for both participants and non-participants are removed from the sample. This correction is implemented to further minimise the impact of outliers in order to secure a high degree of robustness and reliability of the estimated participation effect.

4.2.6 Two key indicators in the analysis: value added and productivity

In the analysis, the return of knowledge collaboration is measured between companies and the University of Copenhagen as a difference in the com-

18 See as an example Mairesse and Hall (1995)
panies’ value added and productivity per employee in relation to a control group of statistically identical companies.

Value added is calculated as the difference between turnover and costs of materials and other services used for production such as rent, energy, consumption of stock goods, salaries etc. Value added is based on Statistics Denmark’s calculations and is defined as the company’s turnover plus other operation annual turnover minus the use of goods and services.

Productivity per employee is a measure for how efficiently the work force is used to generate value added. An increase in productivity per employee means that the value added has increased for a fixed number of FTEs. By using this measure it is possible to apply a transverse objective which has the same expression across different industries, sectors and company sizes over time.

Productivity per employee or work productivity is defined as the value added in companies divided by the number of employee FTE.
4.3 Modelling the spill-over from public to private R&D

One of the main arguments for public funded R&D activities in companies and supporting public-private R&D collaborations is that the market will under-invest in R&D. This is due to risk and uncertain return on investment (often requiring a fixed start-up cost) related to especially basic and fundamental research. Having the public sector fund a share of the fixed cost reduces the marginal cost facing the companies, thus making it more likely for companies themselves to engage in R&D funding. Furthermore, the market cannot support an adequate level of professional competency in order to conduct cutting edge research.

On the other hand, critics of public financed R&D and research conducted at universities state that they conduct research that otherwise would have taken place in private companies. As such, the public funded research is substituting the private R&D. The result will be a crowding out of the overall R&D investments at a national level.

The objective is thus to state whether research conducted at the university is complementing or substituting private R&D. Two recently published Danish studies show a rather significant return on investment from investments in private R&D.19 If public research in fact substitutes private investments in R&D it would lessen the socio-economic gain from private R&D.

4.3.1 Estimation strategies

There is no solid history of modelling spill-over from public funded R&D to private R&D.20 As such, it is central to consider which methodology should be implemented. A number of different econometric methods can be applied to shed light on whether public funded R&D collaboration between companies and the University of Copenhagen complements or substitutes private R&D activities.

At the outset, a very basic approach would be to estimate the marginal effect of an additional public granted EURO on private funded R&D based on a cross-section of companies with and without university collaboration. This can be formulated by the following model specification:

$$P_{Fund_{it}} = \beta G_{Fund_{it}} + \varphi'X_{it} + a_{it} + \epsilon_{it}$$

The response variable $P_{Fund_{it}}$ indicates the amount of privately funded R&D in company $i$, at time $t$. $G_{Fund_{it}}$ is the variable of interest representing the amount of public funds granted for R&D collaboration with the university. $X_{it}$ is a set of control variables that may include company size and a set of industry and year dummies. $a_{it}$ is a latent variable which captures the likelihood of a company profiting from R&D activities. This latent variable, which may or may not be accounted for, affects the decision mechanisms of both private and public R&D funding.

A very simple and straightforward strategy would be to estimate the model above by OLS. This strategy however is likely to suffer from a number of issues. First of all, the static cross-sectional approach offers no insight into the dynamic relationship between public and private funded R&D (at least if no lagged funding variables are included in the set of control variables). The effect of public funded R&D collaboration is identified by variation between companies with different amounts of public funding. This could potentially lead to selection bias if public funds are not granted at random (i.e.

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20 See Graversen & Bloch (2008) for a review
public funded companies deviate from other companies in terms of private funded R&D activities. This is the case when the latent variable \( a_{it} \) has not been accounted for. Selection bias is likely to be an issue in the present analysis as various public programmes are often designed in favour of certain types of companies.

It is possible to overcome the issue of selection bias without dealing directly with the omitted latent variable provided the latent variable is constant across time within the companies, formulated by \( a_{it} = a_i \). If this assumption is met, one could overcome the issue of selection bias by utilising a first-difference estimation strategy of the following form:

\[
\Delta P_{Fund_{it}} = \beta \Delta G_{Fund_{it}} + \varphi' \Delta X_{it} + \Delta a_{it} + \Delta \varepsilon_{it}
\]

which is identical to

\[
\Delta P_{Fund_{it}} = \beta \Delta G_{Fund_{it}} + \varphi' \Delta X_{it} + \Delta \varepsilon_{it}
\]

since \( \Delta a_{it} = \Delta a_i = a_i - a_i = 0 \).

By utilising the first-difference approach, one tries to link changes in private funded R&D to changes in public funded R&D while simultaneously checking for changes in other determinants. In this, setting the effect from public funds is identified from variation within the company as opposed to between-variation as in cross-sectional setting. Therefore, selectivity bias will not occur as a result of unaccounted heterogeneity between companies due to the omitted latent variable. However, if the assumption of a time-constant company-specific latent variable is not met, the estimated effect from public funding will be biased due to unaccounted changes in the company’s likelihood of profiting from R&D activities.

In a recent analysis by Graversen and Bloch (2008) the issue of selection bias is dealt with directly by explicitly modelling the decision mechanism of public funding. Furthermore, they also address bias caused by simultaneity in the equation of private R&D funding.

Simultaneity occurs when the amount of public funding cannot be treated as an exogenous determinant of private funding, but instead is an endogenous determined from private funding itself. Simultaneity is likely to occur when public R&D agencies favour companies according to the company’s amount of private funded R&D. This mechanism can be at play if public R&D agencies treat the amount of private funded R&D as an indicator for either the company’s commitment to R&D projects or the projects likelihood of producing results ready for commercialisation.

Graversen and Bloch model the public funding mechanism by two related models. The first model describes a company’s expected amount of public funding. The second model is a binary choice model describing a company’s expected probability of receiving public funding, which handles the selection aspect that the amount of public funding only is observed when a latent public funding variable is greater than zero.

To solve the equations system they employ the Heckman two-step selection model. They manage to describe the probability of receiving public funding based on information on patent applications, participation in private or public R&D collaborations and company size in the previous period. Likewise, they identify the expected amount of public funding based on information on the previous period’s amount of private and public funding plus current year’s total amount of public funding within an industry.
After having described the mechanisms of the public funding process, they insert the predicted amount of public funding and/or the inverse mills ratio (both obtained from the two-step Heckman model) into the main model, thereby addressing the issues of selection and simultaneity.

Application of the econometric approach used by Graversen and Block would have been preferred in the present analysis. However, due to a rather limited number of collaborating companies remaining when matched to the R&D-statistics, it has not been possible to identify the public funding mechanism for collaboration. As a consequence, the first-difference estimation strategy has been chosen as the best among the set of possible alternatives.

4.3.2 Available data for spill-over analysis

To conduct the analysis of how public funding for companies’ collaboration with the University of Copenhagen affects their private R&D funding, data have been gathered from the various sources on collaboration.

Data are required to contain information on the amount of public funding. Because of this, collaboration in the form of patent applications and publications are excluded, as these sources contain no information on public funding. The remaining sources of collaboration thus comprise DAMVAD’s Cooperation Database and the University of Copenhagen’s own registered transactions with private companies.

DAMVAD’s Cooperation Database does contain information on public granted funds. Unfortunately, the grants are only recorded as total granted funds for the entire project. As the project often consists of a consortium of multiple companies and public research institutions, it cannot be determined how the granted funds are distributed within the consortium. Even more so, it cannot be determined to which degree a participating company and the university have cooperated. As a result, the present analysis is restricted only to those companies which figure in the University of Copenhagen’s own registered transactions.

The statistics on companies’ R&D activities, which the university’s recorded transactions on collaborations have to be matched against, covers the period from 1997-2009. Recorded transactions of collaborations prior to and after this period are therefore excluded. Table 4.2 illustrates how the remaining transactions from 1997 to 2009 are distributed during the period.

The University of Copenhagen have recorded 522 accounts of transactions from 1997 to 2009, cf. column 1. Of these, only a subset of 167 transactions contains information on the actual amount of public grants which are required for the analysis. Note that no observations contain funding amounts after 2007 (se column 2). It should also be noted that these all cover companies’ collaborations with the faculty now known as Life Science.

For the remaining observations, the analysis requires that these can be matched to the statistics on companies’ R&D activities, where information on private funding of R&D is recorded. The statistics on companies’ R&D activities have been restricted to those records with strictly positive amounts of R&D. This decision relates to the fact that the companies receiving the questionnaire on R&D from 1997 to 2006 were not obliged to reply, causing many records to have missing values on R&D.
When restricting the data to observations with strictly positive private funded R&D, the number of collaborations is reduced to 52 observations distributed across 20 unique companies, cf. table 4.2, column 3. The number of observations available in years 2000, 2002, 2004, 2006 and 2008 are denoted by *. This is done to signal that information on a company’s share of respectively private and public funding has been based on imputed values (calculated from share from the previous and following year). This is done as the questionnaire did not include questions with respect to funding sources in these years.

As the first-difference estimator has been chosen as the preferred among the set of feasible estimation strategies, each observation on granted company-university collaboration has to be accompanied by information on private funding in two consecutive years (required for calculating the change in private funding). When this condition is met, the observation will contribute to the identification of the effect of public funding. The right side of table 4.2 shows how many observations contribute to identification.

Column 4 indicates that 75 observations (distributed across 20 unique companies) contribute to the identification of the effect of public funds granted to collaboration with the university.

### TABLE 4.2

<table>
<thead>
<tr>
<th>Year</th>
<th># companies in transaction data</th>
<th>...&amp; with information on public granted funds</th>
<th>...&amp; with positive recorded private funding</th>
<th># companies contributing to identification of the effect from public funds granted to collaboration with the university</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1-year difference structure</td>
</tr>
<tr>
<td>1997</td>
<td>11</td>
<td>5</td>
<td>1</td>
<td>---</td>
</tr>
<tr>
<td>1998</td>
<td>16</td>
<td>9</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1999</td>
<td>19</td>
<td>12</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2000*</td>
<td>21</td>
<td>17</td>
<td>4*</td>
<td>4</td>
</tr>
<tr>
<td>2001</td>
<td>21</td>
<td>20</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2002*</td>
<td>18</td>
<td>12</td>
<td>4*</td>
<td>5</td>
</tr>
<tr>
<td>2003</td>
<td>22</td>
<td>17</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>2004*</td>
<td>48</td>
<td>17</td>
<td>6*</td>
<td>8</td>
</tr>
<tr>
<td>2005</td>
<td>59</td>
<td>20</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>2006*</td>
<td>67</td>
<td>22</td>
<td>9*</td>
<td>11</td>
</tr>
<tr>
<td>2007</td>
<td>81</td>
<td>16</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>2008*</td>
<td>78</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>2009</td>
<td>61</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>522</td>
<td>167</td>
<td>52</td>
<td>75</td>
</tr>
<tr>
<td>Unique companies</td>
<td>291</td>
<td>101</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

*Source: Statistics on business’s R&D and registered transactions by the University of Copenhagen

Note: * indicates years when shares of private funding have been based on imputed values (calculated on share from the previous and following year)
uted across 20 unique companies) contribute to identification when estimating the first-difference across a 1-year period. Note that this number is larger than the number reported in column 3. This is possible as companies take part in identification when they go from zero to a positive amount of granted funds and when they go back from a positive amount to zero.

The last column of table 4.2 lists the number of identifications when estimating the first-difference across a 2-year period. This sample will constitute a preferred population as none of the records of funding have been based on imputed values. When employing this sample, identification of a potential spill-over effect will be based on 37 observations (distributed across 13 unique companies).

Whether the 1-year or 2-year difference structure is employed, it is clear that the analysis will be based on a relatively small amount of data. Table 4.2 also indicates why the analysis has been limited to a first-difference strategy as opposed to an econometric approach that directly addresses selection and simultaneity bias.
4.4 Case studies

As a supplement to the econometric analysis, ten case studies of recent or ongoing collaborations between company and researchers at the University of Copenhagen have been undertaken. An overview of these cases can be seen in table 4.3.

The purpose of the case studies was twofold: first, to illustrate key characteristics of the university’s collaborations with companies (e.g. types of interaction, focus of the collaboration, outcomes and effects etc.) and, second, to provide insight into factors that are important in understanding when and how positive effects are achieved from university/company collaboration.

The collaborations that were investigated in the case studies were selected by the University of Copenhagen, based on their insight into completed and ongoing company-collaborations at the university. Criteria used in the selection of cases were:

- **Success stories.** Insofar as possible, cases with demonstrated outcomes were selected.
- **Scientific disciplines.** The cases were selected to represent a variety of scientific disciplines and departments at the university.
- **Degree of completion.** Projects that were completed or near to completion were preferred, as these were more likely to have achieved measurable effects.
- **Sector and size of collaborating company.** The cases were also selected so as to represent companies from a variety of industries as well as both large international corporations and small research-intensive companies.

The case studies were based on data collected through interviews and desk research. Two interviews were conducted in each case: one with the

<table>
<thead>
<tr>
<th>Company</th>
<th>Principal university researcher</th>
<th>Focus area</th>
<th>Area of science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novozymes</td>
<td>William Willats</td>
<td>Enzymes for biofuels</td>
<td>Natural and technical sciences</td>
</tr>
<tr>
<td>Arla Foods</td>
<td>Arne Astrup</td>
<td>Human nutrition</td>
<td>Natural and technical sciences</td>
</tr>
<tr>
<td>Novo Nordisk</td>
<td>Jens Juul Holst</td>
<td>Drug for treatment of type 2 diabetes</td>
<td>Natural and technical sciences</td>
</tr>
<tr>
<td>IBM Research-Zürich</td>
<td>Mogens Brøndsted Nielsen</td>
<td>Basic research on nanoelectronics</td>
<td>Natural and technical sciences</td>
</tr>
<tr>
<td>Mærsk Oil</td>
<td>Susan Stipp</td>
<td>Nanotechnological applications in the oil industry</td>
<td>Natural and technical sciences</td>
</tr>
<tr>
<td>Schultz</td>
<td>Claus Povlsen</td>
<td>Anonymisation of confidential information</td>
<td>Social sciences and humanities</td>
</tr>
<tr>
<td>Logica</td>
<td>Finn Kensing,</td>
<td>Telemedicine</td>
<td>Social sciences and humanities</td>
</tr>
<tr>
<td>Watagame</td>
<td>Rasmus Helles</td>
<td>Analysis of online gamesite</td>
<td>Social sciences and humanities</td>
</tr>
<tr>
<td>Epitherapeutics</td>
<td>Kristian Helin</td>
<td>Drug for treatment of cancer</td>
<td>Natural and technical sciences</td>
</tr>
<tr>
<td>Sophion</td>
<td>Søren-Peter Olesen</td>
<td>Drugs influence on cardiac arrhythmia</td>
<td>Natural and technical sciences</td>
</tr>
</tbody>
</table>

Source: DAMVAD 2012
principal researcher at the University of Copenhagen, and one with a representative in the collaborating company, identified by the university researcher. In one case, only one interview was conducted, since the case was based on a university start-up, where the principal researcher was also the primary contact in the company.

*Desk research* was conducted online and, in some cases, supplemented by written documentation (e.g. project descriptions and scientific publications) provided by interview respondents.

Moreover, a review of the academic literature on university/company collaboration was conducted in connection with the development of the analytical framework for the cases, including the design of interview guides for academic researchers and industry representatives.

Drafts of all case studies were submitted by e-mail to respondents, who were requested to check the accuracy of facts and quotations in the case descriptions. Their comments were incorporated in a revised and final draft of each case.

Chapter 7 of this report presents results drawn from an overall analysis of outcomes, effects and key enablers in the ten case studies.
5 Effects of collaborating with the University of Copenhagen

This central part of the analysis focuses on the quantitative effects the companies experienced from their collaboration with the University of Copenhagen. The results are:

- We find strong evidence of a positive causal link between companies entering into R&D collaboration with the University of Copenhagen and the development in companies’ productivity per employee. More specifically, companies entering collaboration increased their productivity per employee by an annual average of 6.5 per cent.
- The positive causal link to increasing productivity corresponds to a net gain of € 7,000 per employee on the bottom line for each company year on year as an effect of collaborating with the university.
- The net gain of € 7,000 per employee improves the bottom line of each collaborating company by € 2.43 million, as the average company size is 350 employees. With 550 unique companies in the analysis this adds up to a total economic impact on companies located in Denmark of € 1.33bn.
- On the other hand, we have not been able to find valid results from the analysis on spill-over effects. The lack validity is due to a lack of proper data and information about investments in R&D.

The following provides a more in-depth description of the results.

5.1 Companies gain from collaborating with the University of Copenhagen

The econometric analyses point to a positive causal link between companies entering into R&D collaboration with the University of Copenhagen and the development in companies’ productivity per employee. Figure 5.1 presents the collaboration effect over time and shows by percentages how much more growth in productivity companies experience as a result of collaborating with the University of Copenhagen.

FIGURE 5.1
Causal effect on increase in productivity of collaboration with the University of Copenhagen

Source: Calculations by DAMVAD based on micro data from Statistics Denmark
The analysis in figure 5.1 is based on 170 companies collaborating with the university. The control group consists of 1,402 companies.

There is a significant positive effect on productivity per employee of participating in R&D collaboration two years after the establishment of collaboration where the effect remains statistically significant and increases over the time.

The participation effect is measured as the difference between the two curves. Two years after establishing knowledge interaction, the companies experience a productivity return of 6 per cent increasing to 11 per cent four years after establishing the collaboration. The first year after participation does not show any significant differences in performance between the control group and the treatment group. This implies that it is not possible on a reasonable basis to disprove that the two groups perform similarly the first year after participation.

Furthermore, the figure shows productivity development prior to establishing collaboration for the control group and the treatment group. The two groups have an almost identical productivity growth in the year preceding the engagement of collaboration. This indicates that the PSM method has successfully managed to identify a credible control group. This implies that the result can be interpreted as the causal relationship between entering into R&D collaboration with the University of Copenhagen and an effect in productivity per employee.

There are different ways of collaborating with the university. The results in figure 6.1 rely solely on three levels of collaboration, i.e.: Co-financed R&D-projects, acquisition of R&D and R&D collaboration based on public schemes. The first two levels are based on the university's own registers whereas the latter stems from DAMVAD's collaboration database.

This study has investigated the effect of joint publication and patenting and has been unable to find a clear effect on companies that publish together with the university of Copenhagen. One reason could be that these companies do not reach the same level of competence development which is the case with the other types of collaboration. At the same time, it is possible that the economic effects of co-publishing with the University of Copenhagen occur later and therefore are not detected in this analysis.

Furthermore, there is a methodological issue concerning the fact that it is difficult to assess the intervention or initialisation in joint patents and publications of the collaboration and hence the knowledge transfer. Thus, it is difficult to make sound conclusions based on this material.

As mentioned in the methodological section, the conclusions should take the question of unobservable factors into consideration. There is a fundamental difficulty assessing factors with relevance for the identified effects that are unobservable.

However, this is the best possible basis for assessing the impact. Furthermore, the analysis includes many different observable factors such as company size, industry, R&D, educational background, company performance, import/export relations etc. in the years prior to the initial collaboration. In total, this gives broad knowledge regarding the individual companies. The potential unobservable factors do not apparently influence the observable factors regarding company industry, performance, R&D.
strategy, human resource strategy etc. prior to the collaboration.

5.1.1 Ruling out the effect from collaboration with other universities

This analysis centres on companies with R&D collaboration with the University of Copenhagen. Meanwhile, companies might have knowledge interaction with other Danish or foreign universities which is not handled in this analysis.

The impact from collaboration might distort the estimated participation effect. The estimation could suffer from a downward bias due to the fact that the identified control might have experienced an unobserved gain from collaboration with other universities thus lowering the estimated treatment effect.

On the other hand, the impact assessment could suffer from an upward bias since companies collaborating with the University of Copenhagen might in addition collaborate with other universities. This would imply that the participation effect from collaboration with other universities would potentially be ascribed to the interaction with the University of Copenhagen.

Figure 5.2 presents the results from restricting data on the control group to include only collaboration with the University of Copenhagen. Thus potential effects from collaboration with other universities are ruled out in the control group.

The results indicate immediate effects after year one, whereas figure 5.1 shows an effect after two years. Here there is an immediate effect of a 7.4 per cent increase in productivity. There is a more immediate short term effect whereas the levels of effect are somewhat alike in the following periods of time. Finally, it seems in figure 5.2 that the effect

FIGURE 5.2
Causal effect on increase in productivity of collaboration with the University of Copenhagen, restrictions on the control group

Source: Calculations by DAMVAD based on micro data from Statistics Denmark
is diminishing in year 6 after initiating the collaboration. This is somewhat unexpected comparing to the results in figure 5.1 where we see an effect in year 6 after the initial collaboration.

It is rather difficult to explain the differences in growth pattern. One reason though might be that restricting data also means a reduction in the number of observations. The control group is different and that also implies that the treatment group is different due to the common support approach presented in chapter 4.

5.1.2 Economic impact from collaboration measured in euro

The first part of the analysis has identified a causal positive connection between entering into R&D collaboration with the University of Copenhagen and companies’ development in productivity per employee.

This subsection follows the same approach as mentioned above, but converts the productivity impact to economic return measured in euro.

The analysis shows that companies participating in R&D collaboration with the University of Copenhagen experience an average annual productivity gain of € 7,000 per employee. The result is measured over a six-year period, which the effect analysis covers, and indicates that companies experience a gain corresponding to € 7,000 in productivity each year due to their collaboration with the University of Copenhagen.

Table 5.1 shows the development of the productivity effect after the time of participation. The effect is approximately € 5,800 two years after establishing collaboration and increases over the years to € 11,000 six years after collaboration.

With an average increase in productivity of € 7,000 a year the collaboration companies are 6.5 per cent more productive than companies in the control group. Generally, the average productivity per employee is € 108,000 among companies with similar characteristics as companies collaborating with the University of Copenhagen. This corresponds to the fact that the average employee in these companies is 6.5 per cent more productive in comparison to similar companies that do not collaborate with the University of Copenhagen.

Comparing the additional effect per employee with the average company size of 350 employees, which characterises companies collaborating with the University of Copenhagen, shows that the average company achieves an annual gain in value added of approximately € 2.43 million. In other words, the companies’ bottom line increases on average by € 2.43 million year on year after engaging in collaboration.

It is possible to make a rough estimate of the total productivity effect considering all companies that have collaborated with the University of Copenhagen. The estimate amounts to € 1.5 billion by mul-

<table>
<thead>
<tr>
<th>TABLE 5.1</th>
<th>Average impact on productivity per employee by participation in R&amp;D collaboration with the University of Copenhagen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years after participation</td>
<td>1</td>
</tr>
<tr>
<td>Impact of at least one collaboration</td>
<td>Insignificant</td>
</tr>
</tbody>
</table>

Source: Calculations by DAMVAD based on micro data from Statistics Denmark.
tiplying the company specific gain of € 2.43 million with the 625 different companies with collaboration with the University of Copenhagen. Collaboration centred on publishing is omitted from the impact assessment where this calculation is adjusted accordingly.

5.1.3 Socio-economic impact
Can companies located in Denmark overcome the challenges arising from establishing collaboration with the University of Copenhagen, which this analysis has pointed to as a significantly associated boost to their productivity? This part of the analysis presents a simple estimate of the socio-economic impact related to the situation where all companies’ potential to engage in collaboration with the university do so.

DAMVAD (2011) has estimated that there are 2,447 companies in total in the Danish business sector with R&D activities which have not formed part of R&D collaboration during the time period in focus. Under the assumption that all of these 2,447 companies have the potential to participate in R&D collaboration with the University of Copenhagen the associated change in companies’ behaviour has a potential annual socio-economic impact of € 3.05 bn. This amounts to 1.3 per cent of the Danish GDP.

A great amount of caution should be considered when interpreting the socio-economic impact. The estimate was made under a high degree of uncertainty and makes use of the restrictive assumption that all additional collaboration yields the same impact from collaboration as documented in this analysis. There is no sound evidence of the participation effect considering the companies’ potential to establish collaboration which means that the estimation serves as an illustration of the potential socio-economic impact. At the same time, companies might have chosen not to engage in collaboration with the university due to the fact that the associated costs are expected to surpass the expected gains from the collaboration. Consequently, it is generally difficult to delimit the group of companies that are potential to engage in R&D collaboration with the University of Copenhagen.

5.1.4 Impact for companies with a single collaboration
The analysis makes use of an evaluation method which considers participation as a binary choice of either collaborating with the university or not. The participation choice is observed annually. If we look at companies participating only once, there are no issues, however, if several collaborations takes place over a number of years there is a risk that the effect of the individual collaborations are blurred.

The analysis’ mappings of collaborations with the business sector as well as the case studies show that several companies are engaged in a complex pattern of collaboration. Thus, where the same company may engage in various collaborations with the University of Copenhagen in one year, others may have recurring collaborations several years in a row and finally can participate in different collaboration types with the University of Copenhagen during the same year. This creates a challenge from separating short and long-term effects, as the effects of different collaborations are likely to blend together.

By solely considering companies with a single collaboration, a more straightforward and intuitively understandable estimate of the collaboration effect is obtained, albeit at the expense of leaving out companies with multiple collaborations. Therefore,
both analytical approaches are applied since each of these contributes with relevant knowledge to the collaboration effect.

In this section, an effect model is set up which focuses on companies with just a single collaboration, whereas the next section will add an effect model which looks at companies with one or more collaborations.

Companies with just a single collaboration also experience effects. The participation effect is measured as the difference between the two curves. Three years after initiating the knowledge interaction, companies experience a productivity return of 11.8 per cent increasing to 21.6 per cent five years after initiating the collaboration. The first two years after participation do not show any significant differences in performance between the control group and the treatment group. This implies that it is not possible on a reasonable basis to disprove that the two groups perform similarly the first year after participation.

Again, the figure shows productivity development prior to establishing collaboration for the control group and the treatment group. The two groups have an almost identical productivity growth in the year preceding the engagement of collaboration. This indicates that the PSM method has successfully managed to identify a credible control group.

Compared to the analysis without restrictions to the number of collaborations, the effects cut in a year later. Furthermore, the effects vanish at year 6 after the initial collaboration. It is difficult to explain the differences in the growth patterns. The cases state that long term relationship, mutual trust and in-depth understanding of the different settings for the university and companies are crucial for the success. A “one-off” single collaboration does not imply deep understanding and long term relation-

**FIGURE 5.3**
Causal effect on increase in productivity of a single collaboration with the University of Copenhagen

Source: Calculations by DAMVAD based on micro data from Statistics Denmark
ship. This can explain why the effects cut in later.

On the other hand, the effects five years after the collaboration are notably higher compared to the analysis without restrictions to the number of collaborations. And after six years the effect vanishes. Again it is difficult to explain this pattern. It can be due to the companies maximising their profits five years after the collaboration. At this point, rival companies can see the success of the collaboration and they start to imitate and then obtain a success evening out the competitive advantage. Another explanation is the lack of solid data. The restriction of only a single collaboration diminishes data. As such, the population might be too small to trust the results.

5.2 Research spill-over

Another part of the analysis concerns the spill-over effects of research collaboration. More specifically, the analysis has looked at whether public funding for research through research collaboration has a positive effect on private R&D funding or whether public funding results in crowding out.

Private R&D investments seem to increase in the successive years after initiating collaboration with the University of Copenhagen. Figure 5.4 shows how private R&D investments have developed before and after the initial collaboration with the University.

Figure 5.4 shows that whereas the average investment in R&D the year before collaboration was €29,000, the average the year after collaboration is €48,000. That is a significant increase. This analysis aims at uncovering whether the increase is just additional public funding, e.g. from the university, or if there are additional investments. In other words, whether collaboration with the university is crowding out or complementing private R&D?

Generally, there are some mixed results from quantitative analyses dealing with the effects of private R&D. A recent Danish study concludes a positive impact from public R&D to private R&D and thus public R&D in fact complements and en-

---

**FIGURE 5.4**

Trend in private R&D investments before and after collaboration with the university

![R&D investments before and after initial collaboration](image)

Source: Calculations by DAMVAD based on micro data from Statistics Denmark
On the other hand, there are some mixed results from international studies\textsuperscript{23}. The main part of the literature shows that public investments in R&D do in fact complement private R&D. But the picture is not unambiguous. As such, other studies also identify the opposite result. Furthermore, there are only a few studies focusing solely on public research conducted by the university and its effect on private R&D.

Public co-funding of R&D activities can lead to an increase in private funded R&D investments, if the public funds reduce the company’s marginal costs to such a degree that the company finds it profitable to take on additional R&D investments on its own.

In chapter 4, several estimation strategies for measuring a potential spill-over effect were presented. The need for addressing selection and simultaneity bias was stressed. This can be done by using the approach applied by Graversen and Bloch (2008). However, due to a rather limited amount of data the first-difference strategy has been chosen as the most suited in the present analysis. Results from two first-difference OLS regressions are presented in table 5.2\textsuperscript{24}.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|}
\hline
Explanatory variables & Dependent variable: ln(private funded R&D) & \\
\hline
ln(Public funding for collaboration with the University of Copenhagen) & 0.004 & 0.020*** & \\
& (0.006) & (0.008) & \\
\hline
ln(Other public funding) & 0.025*** & 0.028** & \\
& (0.009) & (0.011) & \\
\hline
ln(employment) & 0.249** & 0.118 & \\
& (0.118) & (0.088) & \\
\hline
Year dummies & Yes & Yes & \\
Industry dummies (DB07-std. deg. 19) & Yes & Yes & \\
Observations & 1182 & 634 & \\
Observation identifying university funding & 37 & 20 & \\
$R^2$ & 0.05 & 0.10 & \\
\hline
\end{tabular}
\caption{Spill-over analysis. Estimated impact from first-difference OLS regression.}
\end{table}

\textit{Source: Own calculations based on statistics on business’s R&D and registered transactions by the University of Copenhagen.}

\textit{Note:***, ** and * respectively indicate significance at the 1, 5 and 10 percent level, cluster robust standard errors in parenthesis.}

\begin{equation}
\Delta P_{\text{Fund}_{it}} = \beta \Delta G_{\text{Fund}_{it}} + \varphi l \Delta X_{it} + \Delta \varepsilon_{it}
\end{equation}

\textit{where }$P_{\text{Fund}_{it}}$\textit{ represents a company’s amount of private funded R&D, }$G_{\text{Fund}_{it}}$\textit{ represents public granted funds for col-}

\begin{footnotesize}
\textsuperscript{22} See Graversen & Bloch (2008) Additionality of public R&D funding in Business R&D.
\textsuperscript{24} The econometric model is given by:
\end{footnotesize}
The first column of table 5.2 gives the estimated effects when the model is performed on data from 1997-2009. This coefficient on public funds granted to collaboration with the University of Copenhagen is highly insignificant. Other public funding and company size, on the other hand, have both a positive and significant impact on the amount of private funded R&D.

The second column gives the estimated parameters based on a model only specified for the period 1997-2005. This has been done to avoid the break in data in 2007, where the statistics on companies’ R&D where handed to Statistics Denmark and respondents were made obligated to reply. Noteworthy the effect from public funded university collaboration becomes positive and highly significant when restricting the sample period. The effect indicates that a 10 per cent increase in public funded collaboration with the university on average increases the company’s private funded R&D investment by an additional 2 per cent. The impact from other public funding remains positive and significant, while the effect from company size has turned insignificant.

It goes without saying that the estimated effect from the variable of interest should be interpreted with extreme caution. Firstly, the positive and significant effect produced by model 2 is identified by merely 20 observations, making it more likely for the positive correlation to be spurious. Secondly, table 5.2 shows that the effect is in no way robust for alternative specification of the sampled period (this is likely also a consequence of the low level of identifying observations). Thirdly the econometric model has not directly addressed the hazards of selection and simultaneity bias. As described in chapter 4, it is likely that companies granted public funds are not selected at random. Furthermore, it is likely that public R&D agencies might favour certain companies based on their amount of private R&D funding. The estimated results offer no conclusion as to whether public granted funds for R&D collaboration with the University of Copenhagen should simulate the company’s private funding. Under certain circumstances, private funding seems to increase when public granted funds increase. However this could merely be a product of spurious correlation or unattended endogeneity.

In conclusion, we would not rely on the results of this part of the analysis. The robustness of the results is weak and the data are too vague. Thus it is not possible to implement the proper econometric models that take into account the different challenges of this type of modelling and analysis.
6 University/company collaboration; who, when and why

6.1 Introduction

This chapter extends the results of the econometric analysis presented in chapter 6 using insights gained through case studies of ten collaborative relationships between scientists from the University of Copenhagen and private companies.

The case studies complement the econometric analysis by providing qualitative insight into the positive effects of university/company collaboration identified in the quantitative analysis. Moreover, the case studies also point to possible explanations of why and under which circumstances these effects arise.

Main conclusions from the case studies are:

- The collaborations have several benefits for academia and industry in the short run; key benefits for academia include the practical application and utilisation of research, valuable input to research and publications, and access to funding, while key benefits for industry include access to highly specialised expertise, technology and research results.

- The case studies also point to a number of additional, long-term effects that are not captured in the econometric analysis. Across the cases we see changed R&D behaviour as a result of collaboration, both in academia and in industry. The cases also reveal innovation effects in the form of development and commercialisation of new products, as well as economic effects through generation of annual turnover from innovations. On a societal level, there are several examples of collaborations that have led to significant and important effects for society by addressing important societal issues and by creating jobs.

However, the case studies also show that successful university/company collaboration builds on a number of key enablers. These include a mutual understanding of the different goals of the research and business world. While companies ultimately keep their eyes on the bottom line, academic researchers are focused on generating scientific publications; successful collaborations are collaborations where both parties respect and support the goals of the other party.

- Finally, the study also points to a number of barriers to university/company relationships. Among these are high transaction costs spent on working out the legal framework for collaboration, and differences between an academic culture focused on long-term goals and a business culture with shorter-term focus. On the whole, the study shows that successful collaborations often require long-term relationships, where the parties build trust, develop insight into each other's competences and goals, and find ways of mitigating barriers to fruitful collaboration.

Overall, the case studies show that the formal R&D collaborations represent but the tip of the iceberg; beneath the surface lies a myriad of more or less formalised interactions between companies and academia. These interactions range from informal personal ties to academic scientists serving as consultants to companies or members of scientific advisory boards.

Although these interactions are less visible than formal R&D collaborations, the case studies suggest that they play an absolutely vital role in building and maintaining robust, long-term relationships between universities and companies. It is from
such relationships that successful instances of formal R&D collaboration emerge.
Thus, while the econometric analysis showed that formal R&D collaboration generates higher productivity and employment in companies, the qualitative case studies indicate that such formal collaboration often rests on a much broader and often informal set of interactions between companies and academia.

These findings hold important policy implications, namely that in order to generate the positive effects of R&D collaboration between universities and industry, it is not enough to simply stimulate formal R&D collaborations; policymakers must also stimulate and facilitate other forms of interaction between public and private science, notably the establishment of long-term relationships between scientists in companies and in universities.

In the following, we present the results of the case studies. First, we outline the different types of interaction between university and industry that took place in the collaborations investigated in the case studies. We then describe the immediate outcomes of these collaborative relationships and their broader, more long-term effects. Finally, we discuss enablers and barriers of successful university/industry collaboration, that is, factors that respectively promote or hinder the types of outcomes and effects that can be attained through such collaboration.

6.2 Many channels for university/company interaction

Academic research has shown that university researchers interact with companies using a broad range of channels, the most important of which are joint research, consultancy and contract research, and training of new talent (D’Este and Patel 2007).

This is illustrated by the case studies, which exhibit a broad range of types of interaction, including:

- **Industry funding for academic research.**
- **Joint research projects,** that is, formal collaboration on clearly defined research tasks. These projects may be co-financed by public funds, for example through participation in public research or innovation programs.
- **Joint development and commercialisation projects,** where focus is on applying, developing and commercialising university inventions or jointly developed technologies.
- **Contract research,** where academics perform clearly defined research tasks on behalf of industry, e.g. based on specialised expertise, experimental techniques, or equipment.
- **Consulting,** where academics make use of insights from their own research or from the academic community at large to provide counsel or perform specific tasks for companies.
- **Collaboration on education and training of researchers,** e.g. through industrial PhDs.
- **Technology transfer,** i.e. transfer of university-developed technology through licensing or other forms of technology transfer agreements.
- **Other forms of formal collaboration,** e.g. participation in scientific advisory boards in companies or in industry organisations.
- **Provision of research materials and/or access to research facilities and equipment.**
Informal knowledge exchange and sparring, e.g. based on related but distinct research activities in academia and industry

Establishment of university spin-offs.

Most of the collaborations investigated in the case studies involved several of these different types of interaction.

6.3 Immediate outcomes of collaboration

This section presents findings from the case studies regarding the immediate benefits that industry and academic partners derived from their collaboration.

6.3.1 Benefits to academia

The academic researchers interviewed in connection with the case studies pointed to several benefits of collaborating with industry, which are described in the following. It is, however, important to note that not all of these benefits are present in all cases.

Practical application and utilisation of research. Many of the researchers interviewed for the report stress the wish to see their research put to practical use as a motivating factor behind their involvement in university/industry collaborations. Researchers in the case studies stated that they through collaborations want to demonstrate that they don’t live in an ivory tower. That they want to take part in the development of products, services and practice and make a practical difference for citizens, the economy and Danish society as such. As one university professor commented, “The old wisdom that you’re either doing basic research or applied research isn’t valid longer. Today many good researchers do both.”

Case study: Epitherapeutics

Spin-off company that develops drug to fight cancer keeps researchers at Copenhagen University on their toes

Epigenetics is the study of heritable change in gene expression or cellular phenotype that is not caused by changes in the underlying DNA sequence and is currently one of the most dynamic fields in bioscience. Epigenetic drugs are regarded as holding great future promise for the treatment of cancer. Kristian Helin, a world-renowned researcher in epigenetics, and Director of the Biotech and Research Innovation Centre (BRIC), founded Epitherapeutics in 2006. At Epitherapeutics researchers are trying to develop drugs for the treatment of cancer, building on insight from basic research in epigenetics carried out at BRIC. Although the research carried out at BRIC is basic research, Helin also puts emphasis on the benefits of Epitherapeutics for the research carried out at BRIC. The development of drugs at Epitherapeutics keeps researchers on their toes, because it challenges them that their research is being put to practical use in the development of drugs.

Valuable input to research and publications

Academic researchers have to continually develop new research ideas, find data, undertake research, and disseminate the results of this research through publications in scientific journals. Collaboration with industry can be an important driver by providing new insights and ideas.

Moreover, in several of the cases, the university/company collaboration has generated data that will be the starting point for later research or can be used by researchers in the future project. In one of the cases, e.g. industry collaboration resulted in the company turning the researchers’ prototype into a commercially viable product. The later phase of the research project involved a study of the workings and impacts of this product.
Case study: Collaboration with watAgame

Helping watAgame measure the activity of its users gives researchers at Centre for Communication and Computing (CCC) an interesting dataset for further research in online behaviour.

watAgame produces a free community website for girls called goSupermodel. Researchers at CCC helped watAgame collect and analyse data about their users, with the purpose of describing differences in use between different types of users and users in different countries. Results show that there are important differences between users and can be used by watAgame to tailor their product to needs of different user groups. The greatest benefit for researchers is the data about the actual behaviour of users on community websites, which holds great potential for further research in their field, since research build on this kind of data, is currently the focus internationally of research on online media.

Case study: Collaboration with Logica

Collaboration with industry gives opportunity for real-life test of telemedicinal solution

Co-Constructing IT and Healthcare (CITH) headed by professor Finn Kensing at the University of Copenhagen and the global business and technology service company Logica are collaborating on a project that aims to create IT applications and services to support communication and collaboration across organisational and professional boundaries, and among health staff and patients.

In the first phases of the project, researchers studied how existing solutions in the area work and on the basis of this, they developed a prototype of a new telemedicine solution. Subsequently, Logica turned the prototype into an actual application. In the coming phase of the project, the application is to be thoroughly tested on hospitals and in patients’ homes and health-related and other results documented. The collaboration gives researchers access to data about the application and how it works in real life, thereby furthering the scientific study of heterogeneous and distributed networks.

Insight into industry knowledge and R&D priorities

Several of the academic researchers interviewed highlighted the value of gaining access into industry’s knowledge as a key benefit of collaboration. Academic respondents stressed that companies’ insight into private sector research (including their own in-house R&D) and into developments in the market can be very valuable in setting directions for university research.

Access to specialised research know-how, facilities and equipment. Many companies invest large financial resources in developing research facilities, acquiring highly specialised research equipment, and hiring and training staff to make effective use of these facilities. Through collaboration with companies, academics can gain direct or indirect access to these research assets.

Network in industry and beyond. Several university researchers also emphasised the role of collaboration with companies in expanding their networks, and especially in building ties to people in industry.

Access to funding for research and for training of young researchers (PhDs and post-docs.). Industry is an important source of research funding for university researchers, particularly in view of increasing constraints on base funding for universities and the associated growing need for external funding. Collaboration with industry increases the likelihood for academics of acquiring external funding, partly because it provides access to people in companies, who make or influence funding decisions, and partly because the collaboration may open the door to follow-on projects. Moreover, as described above, the cooperative relationship with companies provides the academic researchers with insight into companies’ research needs and priori-
ties, which also increases the relevance of new research ideas and therefore the likelihood of attaining funding.

In the cases studied, funding from industry primarily took the form of direct research from funding or co-funding of joint projects. Collaboration with industry also in some cases made academic researchers more eligible for funding from e.g. the Council for Strategic Research, which often values or even requires collaboration with private companies.

6.3.2 Benefits of collaboration for companies.

Business partners in the case studies also identified a series of benefits from collaborating with academics. These are described in the following.

**Access to highly specialised expertise.** Academic researchers are experts in their field; moreover, they are often specialised in narrow fields of research into which they therefore develop rare and extensive insight. This quality makes them attractive to companies that wish to undertake research in these fields.

**Access to state of the art technology and/or research results.** In addition to providing access to specialised expertise, collaboration with academics also provides companies with access to the latest research results, including unpublished results that can help shape or direct corporate research. In addition, academics often develop new research techniques or equipment. Although these new research technologies are usually in prototype form, they can open new R&D opportunities for industry. Companies can also help to apply and develop these technologies further, and to contribute to their commercialisation.

For example, one of the cases studied revolved around a technology for high-throughput screening of enzymes, enabling faster and better identification of enzymes that could be used in further research and in industrial applications. A key aim of the university/company collaboration in question is to explore and develop this technology, with a view to its potential commercialisation.

**Better insight into own products.** In some of the cases, the primary benefit for companies has been a better insight into their own product and the value customers get from it. The collaboration with researchers has provided the company with insights and data that it cannot gather through its day-to-day activities. For example, in one of the cases, academic researchers invented a way of measuring and analysing how the company’s customers interact.

**Access to critical and constructive feedback on research and product development.** Several of the companies interviewed highlighted the great value from using academic researchers as sparring partners on their ongoing activities. Such interaction may be organised either through formal collaboration (e.g. by hiring an academic researcher as a part-time consultant or member of an advisory board) or informally (e.g. based on strong personal ties developed through formal collaboration). Several of the case studies provide examples of such collaboration; these cases indicated that the academic researchers often provide value not only through their specialised expertise but also through their general insight into their discipline and into R&D methods.

**Access to talent.** Several company respondents highlighted the importance of collaboration with universities in providing access to new talent, i.e. Master’s level students and Ph.D. candidates. Collaboration opens the door to close interaction with
these students, many of whom eventually go on to pursue jobs in the business sector.

**Network in academia.** Just as academic researchers can extend their professional networks through collaboration with industry, companies can also build network ties through their interaction with public researchers. Companies can establish or strengthen ties to the university researchers that they collaborate with, but they also gain access to these researchers’ international, academic networks.

This is important because, as one industry representative explained, people working in industry often have little time to build networks, which also restricts the flow of new ideas and insights to their work. According to him, collaboration with academia therefore offers a valuable opportunity to effectively build new networks in relevant research fields.

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**Case study: Collaboration with Mærsk Oil**

*Finding solutions to society’s problems by uncovering nature’s secrets*

A research collaboration between scientists at the Nano-Science Center and the Danish oil company Mærsk Oil is aimed at using basic nanotechnological research to increase the amount of oil recovered from chalk reservoirs in the ocean.

The research project has already generated new fundamental insight that can, in time, be used to develop techniques for more effective utilisation of global oil resources. In addition, the collaboration has generated funding for basic research and supported training of young researchers and acquisition of key research equipment by the collaborating academics. The joint research has also generated several spin-off projects that are currently being developed by the university scientists. For Mærsk Oil, in addition to producing basic research with important industry perspectives that are now being explored further, the project has also contributed to more effective recruitment by bringing the company into contact with university students.
6.4 Effects of collaboration

The benefits described in the previous section generate a number of broader, long-term effects for academics, for industry, and for society in general. The effects that have been identified in the case studies include effects on academics’ or companies’ R&D behaviour as well as innovation, economic and societal effects. These effects are summarised in table 6.1 and described in the following.

As stated in chapter 3, this report distinguishes between four different levels of effects:

- **Behavioural additionality**, e.g. strategic changes in management, the organisation changes in R&D collaboration with universities.
- **Innovation effects**, e.g. more innovation, increased R&D activity or patents.
- **Economic effects**, e.g. increased productivity or increased employment.
- **Social effects**, e.g. socio-economic growth, new solutions to challenges in society related to health, environment or energy.

6.4.1 Behavioural effects

The benefits derived from university/company collaboration can have a significant impact on the parties’ R&D behaviour. For example, academics interviewed in connection with the case studies stated that the insight into industry research needs and priorities that they gain through collaboration contributed to greater relevance in their academic research, as it allows them to design research projects that are valuable from both an academic and an industrial perspective.

Meanwhile, industry representatives explained that the critical and constructive feedback that they receive from their academic partners makes for more effective maturation and development of research ideas and projects in the long-term.

On a related note, several respondents from both academia and the private sector noted that the insight gained over time from university/industry collaboration enables more effective prioritisation and management of research activities. As one university professor explained, there are many po-

---

**FIGURE 6.1**
Effects of university/company collaboration identified in the case studies

<table>
<thead>
<tr>
<th>For academia</th>
<th>For industry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Behavioural effects</strong></td>
<td></td>
</tr>
<tr>
<td>Greater relevance in research (from better insight into industry needs and priorities)</td>
<td>More effective maturation and development of research projects</td>
</tr>
<tr>
<td>More effective prioritisation and management of research activities</td>
<td></td>
</tr>
<tr>
<td>Enhanced capability from university/industry collaboration</td>
<td></td>
</tr>
<tr>
<td><strong>Innovation effects</strong></td>
<td></td>
</tr>
<tr>
<td>Application, development and commercialisation of university inventions</td>
<td>Development and commercialisation of new products through R&amp;D</td>
</tr>
<tr>
<td>Joint patenting and commercialisation activities (typically led by industry)</td>
<td></td>
</tr>
<tr>
<td><strong>Economic effects</strong></td>
<td></td>
</tr>
<tr>
<td>Annual turnover from commercialisation of university inventions and/or joint patenting activities</td>
<td>Annual turnover from development and commercialisation of new products</td>
</tr>
<tr>
<td><strong>Societal effects</strong></td>
<td></td>
</tr>
<tr>
<td>More effective combinations and synergies between public and private research</td>
<td></td>
</tr>
<tr>
<td>Increased and more effective utilisation of university research and inventions</td>
<td></td>
</tr>
<tr>
<td>New innovations that create value for society (e.g. in relation to healthcare and the environment)</td>
<td></td>
</tr>
</tbody>
</table>

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tential research paths to choose from, and choosing the right path is as important for academics as it is for industry. Companies often invest large resources in research, which is not disseminated outside of the company, but which academic researchers can gain access to through collaboration. Such insight can for example help distinguish the more promising research paths from the less promising ones. Armed with such knowledge, academics can make more effective use of their limited resources by focusing their attention on research directions with greater scientific potential and/or market relevance.

Similarly, several industry representatives explained that state of the art research insights that academics derive from their own research and from their interaction with other academic researchers through collaboration, conference participation, reviewing work in progress and the like, can provide timely access to important knowledge that can affect which research paths a company chooses to pursue. This is especially valuable in research areas where there is a high degree of uncertainty and many possible research directions.

In one case study from the pharmaceutical industry, the support and arguments provided by researchers at the University of Copenhagen lent support to a project that was met by considerable scepticism in the company, but which eventually resulted in the development of a new and lucrative drug.

In summary, the knowledge gained through university/industry collaboration enables faster and more informed decisions about which R&D strategies and projects to pursue, in both academia and industry. Finally, both academic and industry representatives reported that ongoing collaboration enhanced their capacity and capability for university/industry collaboration. For example, academic researchers mentioned developing greater insight into industry needs and priorities, allowing them to suggest more relevant and valuable joint research projects, while industry researchers mentioned getting better at choosing the right academic partners for a given project. Moreover, both academic and industry respondents acknowledged the role of university/industry collaboration in building greater absorptive capacity.

6.4.2 Innovation effects

The collaborations investigated in the case studies have also contributed to the development and commercialisation of concrete innovations, that is, new or significantly improved products, technologies, processes etc.

For example, a decades-long collaboration between researchers at the university and in a large Danish pharmaceutical company lead to the development and launch of a new, effective treatment for type 2 diabetes.

25 “Absorptive capacity” refers to an organisation’s ability to recognize the value of new information, to assimilate it, and to apply that knowledge to useful ends (Cohen and Levinthal 1990). Absorptive capacity is crucial in ensuring positive outcomes from R&D collaboration.
Case study: Collaboration with Novozymes

Breaking down walls to produce tomorrow’s biofuels

Scientists at the Department of Plant and Environmental Sciences undertake research in how to break down plant cell walls to enable better and more efficient production of biofuels, for example by using enzyme technology. In their search for the right enzymes, the academic scientists have also invented a technology that enables the high-throughput screening of large quantities of enzymes.

To develop this technology further, the university scientists have entered into a collaboration with Novozymes, the global leader in enzyme technology. A key aim of this collaboration is to adapt the technology for use in ‘real life’ commercial settings. In addition, the project will also further research on sustainable methods of producing biofuel.

6.4.3 Economic effects

By stimulating and supporting the development of concrete innovations, the collaborations described in the case studies also have (or are expected to have) very tangible immediate economic effects, generated from the commercialisation of university inventions or new products developed by industry.

In one of the cases studied, researchers from the University of Copenhagen helped develop a new and automated way of working, which reduced the manpower used to solve a given task by 60 to 65 per cent. This optimisation has already covered its own costs, and the participating researchers and the company are looking into the possibilities of applying the method invented to other areas.

In several of the cases, scientific discoveries by researchers at University of Copenhagen led to the creation of new high-tech companies after having attracted considerable amounts of capital from investors.

Case study: Collaboration with Schultz Information

Researchers at Centre for Language Technology (CST) helped Schultz increase efficiency in publishing decisions by the National Tax Board and the Danish National Tax Tribunal by 60 - 65%

Schultz Information is a publisher specialised in publishing information for the public and private sector. One of Schultz’s existing products is a database, where decisions by the National Tax Board and the Danish National Tax Tribunal are made public on the internet. Before the decisions can be made public on the internet, it’s imperative that they are anonymised in order to protect the persons and companies involved in the decisions. Traditionally, this task has been performed manually, but based on research in computational linguistics CST developed a programme that does the same task automatically – and more accurately than the traditional manual work process. A main benefit for Schultz was higher productivity – the money saved due increased efficiency has already covered the development costs.

Case study: Collaboration with Novo Nordisk

Groundbreaking basic research that led to innovative treatments for diabetes and obesity

A collaboration between scientists at the Department of Biomedical Sciences and the Danish pharmaceutical company Novo Nordisk has lead to the development of an innovative new drug for the treatment of type 2 diabetes and possibly also for obesity, both of which pose major and growing challenges to society.

The drug, which in 2011 alone generated 6 billion Danish krone in revenue for Novo Nordisk, has been developed during the course of a decades-long collaboration, based to a large degree on basic research undertaken at the University of Copenhagen.
6.4.4 Societal effects

Finally, the case studies provide several examples of collaborations that have led to significant and important effects for society by supporting the utilisation of university research and by bringing together skills, insights and resources from the public and private sector to address important societal issues such as diabetes, obesity, renewable energy etc.

Furthermore, several of the cases have led directly to the creation of high-tech jobs, particularly in the Copenhagen area.

Case study: Collaboration with Arla Foods

Improving public health through university/industry collaboration on nutrition research

A long-standing and multifaceted collaboration between the Department of Human Nutrition and the food industry, notably with Arla Foods, generates vital insight into human nutrition. Collaborative ties range from arm’s-length interaction on nutrition research to direct collaboration in the form of joint R&D projects and consulting.

The collaborative relationship helps inform academic research, among other things by pointing university researchers in more promising research paths. In addition, it generates knowledge that helps the general public make informed nutritional decisions and thus supports the long-term development of public health.

6.5 Enablers of successful collaboration

As previous research has shown, the effects described in the previous section do not automatically arise from all university/company collaborations. Instead, they are the result of a complex set of factors that contribute to fruitful collaboration.

Successful collaboration is often the result of a long-term and highly iterative process. Many of the respondents underlined the importance of acknowledging that good collaboration often takes time. It takes time to build mutual understanding, to learn about each other’s competences, to develop personal relationships, to build trust, and to engage in projects that are valuable to both parties and exploit their complementary competences.

In addition, good research comes from seeing scientific and technological opportunities and exploiting them. However, it is impossible to know when such opportunities will emerge, and public and private researchers must therefore be ready to act once they do.

The implication of these findings is that successful university/industry collaboration is more likely when both academia and industry invest in long-term relationships, open-ended interactions and ongoing dialogue.

Some of the factors that have been identified in the case studies and are presented in the following.

Mutual understanding of research needs and goals. Several respondents from universities and from industry stressed that successful collaboration requires that the parties have a considerable understanding of each other’s challenges, priorities and research needs; such a mutual understanding is essential in developing projects that are relevant and valuable to both parties. According to one company respondent, mutual understanding is built up through repeated interaction over a long period of time.

Some respondents also drew attention to the importance of similar or at least compatible cultures. For example, several academic scientists have
better experience collaborating with industry when they collaborate with exclusive R&D departments, i.e. with industry scientists that often have an academic background and similar mindsets to academic researchers, than when they collaborate with employees that are closer to the market. Similarly, several company respondents preferred working with academic scientists who have insight into and substantial experience with companies.

**Personal ties matter.** The case studies indicate that successful collaboration – especially in the long-term – is often based on good relationships between individuals rather than between organisations. Both industry and academic respondents stressed the importance of strong personal ties in building effective university/industry collaborations.

Such ties facilitate the development of the mutual understanding just described. By contributing to greater mutual insight, they also enable the collaborating parties to engage in projects that effectively exploit complementarities in their knowledge and competences.

Strong personal ties also help to build trust, which prompts collaborators to share more information with each other and to engage in ventures with a higher degree of uncertainty (because of the expectation that problems will be handled effectively and with mutual respect).

Finally, several respondents also underlined that personal ties can help reduce barriers normally associated with university/company collaboration.

The implication of these findings are that policy-makers and universities themselves seeking to promote university/company collaboration should focus not only on **inter-organisational** relationships (e.g. designing formal collaborations, developing contracts etc.) but also on securing adequate incentives and conditions for **interpersonal** relationships, for example by stimulating greater mobility between public and private sector research.

**Informal collaboration is at least as important as formal collaboration.** The case studies indicate that in many university/industry collaborations, formal R&D collaboration represents but the tip of the iceberg: beneath the surface we find a broad range of collaborative arrangements, many of which are informal.

The fact that these arrangements are less visible to outsiders does not, however, make them less important. In fact, many respondents emphasise the importance of informal interaction in building effective collaborations, for example by contributing to the development of mutual understanding and strong personal ties.

These findings imply that efforts to stimulate formal university/company collaboration should be complemented by efforts to support and promote informal ties between public and private researchers, for example by recognising that building such ties requires a significant investment of time and resources on behalf of both parties. Again this implies securing adequate incentives and conditions for **interpersonal** relationships.

**Flexibility and degrees of freedom make for more effective collaboration.** As stated earlier, many of the case studies involved several different types of interaction between academic researchers and companies. Several respondents explained that different forms of interaction serve different purposes, particularly over the course of long-term relationships between a company and one or more university researchers. Being able to shift between different types of collaborative arrangements
brings an important flexibility to the relationship, allowing the collaboration to adapt to changes in the parties’ research priorities and resources.

Respondents also stressed that formal collaboration is a relatively small part of the overall university/industry collaboration that they engage in. For example, some companies employ academic researchers in open-ended consulting agreements or as members of their advisory boards. Such arrangements bring greater degrees of freedom into the collaboration, according to both academic and company respondents, for example by making it easier for the parties to share sensitive information or to call each other simply to discuss an idea. This facilitates ongoing dialogue between the parties, which in turn supports the development of new joint project ideas.

These findings are important, because they emphasise the value of consulting and other arrangements whereby individual academic researchers develop close, formal ties to companies. Such arrangements bring a risk of conflict of interest and require a substantial investment of time and resources on behalf of the researchers. However, the cases indicate that such arrangements can also play a significant role in the development of successful, long-term collaborative relationships with industry.

“Marriages of choice” are better than “marriages of convenience”. One respondent stated that collaborations between academics and forms can often be compared to “marriages of convenience” or even forced marriages, e.g. to obtain research funding that requires university researchers to partner with a company. However, “marriages of choice”, where academic researchers collaborate with companies because it adds value to their research, and where they have a genuine interest in the collaboration, are, in his opinion, much more successful in the long run; this is in large part because they increase willingness to collaborate and commitment to the venture on both sides.

“Marriages of choice” between industry and academia require, however, that there is an ongoing interaction between companies and university researchers, whereby they can share knowledge, gain insight into each other’s competences and activities, and develop ideas for joint projects. Such interaction can for example take the form of research talks to industry audiences, short-term consulting or collaboration on PhD training.

Successful collaboration is often the result of a long-term and highly iterative process. Many of the respondents underlined the importance of acknowledging that good collaboration often takes time. It takes time to build mutual understanding, to learn about each other’s competences, to develop personal relationships, to build trust, and to engage in projects that are valuable to both parties and exploit their complementary competences.

In addition, good research comes from seeing scientific and technological opportunities and exploiting them. However, it is impossible to know when such opportunities will emerge, and public and private researchers must therefore be ready to act once they do.

The implication of these findings is that successful university/industry collaboration is more likely when both academia and companies invest in long-term relationships, open-ended interactions and ongoing dialogue.

Good collaboration requires openness, as collaboration outcomes cannot be accurately predicted. Finally, one university respondent ex-
explained that he purposefully tries to maintain a high degree of openness towards companies that are interested in collaboration. As he explains, academics are sometimes not interested in engaging in collaborations that they do not expect to generate groundbreaking research. In his experience, however, some of his department’s most novel research results and most prestigious scientific publications have come out of collaborations that did not at the outset seem extraordinarily promising. As a result, he is generally open to any collaboration, as long as it is relevant for the department’s research profile and as long as it brings some external funding (e.g. for one or two PhD scholarships). He emphasizes openness from academic researchers as an important enabler of fruitful and innovative university/company collaboration.

6.6 Barriers to university/company collaboration

Whereas the previous section looked at the enablers of university/company collaboration, this section presents findings from the case studies regarding key barriers that hinder such collaboration.

Differences in orientation and goals. University-company collaboration is, as one interviewee remarked, about the meeting of two “equally strange worlds”. As mentioned earlier, universities and companies have different goals and motivations for entering into collaborations and different focus-points in the projects, different ideas about dissemination of project results (secrecy vs. publication), different timeframes etc.

A lack of ability on either or both sides to understand the logic and goals of the other partner can be an obstacle to making the adjustments and compromises necessary for the realisation of a successful collaboration. Several company representatives in the case studies underlined that it is very important for researchers to be able to apply a commercial perspective to their research ideas, among other things to facilitate the assessment of the commercial viability of the project. This naturally does not mean that academic researchers have to be as skilled in developing and marketing products as the companies, but an ability to evaluate non-academic aspects of their projects is a good starting-point for collaboration with companies.

One company respondent provides the following example of how different goals and approaches to work can impact collaboration: “Academics generally focus more on scientific results than on how those results can actually be used or on the needs of industry. They are happy to stop at brilliant, esoteric results, e.g. if they have observed two or three instances of a certain case or situation. But for this information to be of value to industry, for us to be able to invest more research money in it, we have to know if the result is reliable. This requires more persistence on the part of university researchers.”

Company respondents describe that they are often approached by academics with projects that are not sufficiently aligned with companies’ research interests and goals. This does not, however, necessarily imply that joint projects should have short-term relevance for industry; several of the cases studied revolve around basic research, albeit basic research that ultimately has industrial applications.
Successful university/industry interaction is based on projects that carry relevance for both academia and industry. However, this does not necessarily mean that collaborations between universities and companies are focused on applied research.

A collaboration between scientists at the Department of Chemistry and IBM Research in Zürich is an example of a public-private collaboration on fundamental research. The collaboration was part of a larger, EU-funded project to undertake basic research on the possibility of using single molecules as components in electronic devices, for example to store or transmit information. The project was a “high risk, high gain” project, which generated fundamental knowledge that will ultimately help build electronic devices using nanotechnology, which will enable the development of smaller, faster and better electronic equipment.

Similarly, several academic respondents stressed that they do not engage in collaborations with industry unless these collaborations are expected to yield interesting research activities and results, which can be disseminated through publications in scientific journals; companies seeking to collaborate with university researchers must therefore take this into consideration in developing and suggesting ideas for collaborative ventures. Meanwhile, academic researchers also emphasised the importance for companies of understanding that collaborations must be based on activities that are research-relevant; companies cannot commission university researchers to undertake specific studies.

High transaction costs related to handling the legal formalities of the collaboration. Companies as well as researchers describe the legal paper work connected to university/company collaborations as time-consuming and tedious. Many respondents requested more flexible or efficient ways of working and reduced bureaucracy.

Some respondents emphasised that this is especially important in the initial phase of the project, where cumbersome administration or excessive legal details can hinder successful collaboration, and where there is neither prior collaboration experience between the parties nor strong personal relationships that can help mitigate this obstacle.

University/company collaboration and the academic reward structure. The performance of academic researchers in all fields is increasingly assessed based primarily on their publications in peer-reviewed journals. Although most of the university/industry collaborations reviewed in the case studies lead to research that can be published in such journals, respondents explain that some forms of collaborations (e.g. contract research and consulting) are more about the practical application of existing scientific results rather than the development of new, publishable research. As described earlier, such collaboration with companies can play a vital role in the development of long-term cooperative relationships or in getting access to vital company funding. Nonetheless, some researchers warn that there is a danger that such projects come to be viewed as unnecessary distractions from the “real work” of researchers, and that only those researchers with a strong desire to put their research to use in practice will engage in them, while many others will refrain from them, partly because they are also very time-consuming. Thus, many academic researchers face conflicting incentives to, on the one hand, publish and engage only in original research collaboration with industry and, on the other hand, also invest time and resources in contract research and consulting, which may contribute less to publication lists but however help build strong relationships to the business sector.
Lack of mobility between universities and industry. Several respondents commented on the fact that there is very little mobility between companies and universities in Denmark. There are very few incentives and support structures to promote the movement of individuals across the boundaries of the academic or private sectors. Such mobility can be an important enabler of stronger relationships and better mutual understanding between universities and companies.

Case study: The founding of Sophion

*Dual background in industry and academia eases collaboration between industry and academia*

Søren-Peter Olsen had a background in the Danish biopharmaceutical company Neurosearch, before becoming a professor at University of Copenhagen in 1998. In his last years at Neurosearch he helped founding Sophion, a company that specialises in solutions for automated patch clamping aimed at companies performing drug discovery.

Sophion started out as an R&D programme at Neurosearch, before it became an independent company in 2000. During the initial phase, Olesen was able to use his network in both industry and academia, to secure funding and the cooperation of DTU, to ensure that the early phases of development of the company kept low transaction costs and a minimum of legal paper work.
7 Conclusions: Effects of university/company collaboration

The university plays a crucial part in society. It is a social and cultural backbone as well as an economic lighthouse. Historically, universities have played a crucial role as the backbone of societies, a role they still fulfill by educating excellent skilled citizens, but also by conducting basic and cutting edge research. Furthermore, universities are important engines of knowledge production and innovation. Their key contribution to industry and society in general comes from the education and training of graduates (Salter et al. 2000).

Another important means by which universities create value is through direct interaction and collaboration with industry. This is by no means a new phenomenon. The emphasis on university/company interaction has been boosted by the fact that while public funding for universities has decreased, costs associated with scientific research have increased, forcing universities to seek external funding (Geuna 1999, 2001).

Policymakers’ interest in stimulating university/industry research collaboration is however also motivated by recognition of the importance of problem-solving at the technological frontier as an enabler of technological development and as a vital source of inputs to basic science (e.g. Brooks 1994; Rosenberg 1994; Vincenti 1990). This view has been boosted further by the ideas behind ”mode 2” (Gibbons et al. 1994) and the ”triple helix” collaboration (Etzkowitz and Leydesdorff 1997, 2000).

Despite the strong focus on the value that universities create and their importance to society, there is only limited tradition for evidence-based analysis stating the economic impacts of a university. There is no doubt that universities by their size with a large number of employees and students will play a regional economic role. This is also the conclusion in two studies completed on the economic impact of The University of British Colombia and Pennsylvania State University (see Sudmant 2009 and Tripp Umbach 2009).

The same conclusion can be reached if we only look at the size of The University of Copenhagen. Focusing on the sheer size of the university it is without doubt that the university is important to its surroundings. Some basic figures for 2011 are:

- Employed 9,185 full time equivalents.
- Revenue of more than € 1bn.
- 37,869 enrolled students.

Even so the above figures do not say much about the additional effect that The University of Copenhagen creates. One could argue that a hospital with almost 10,000 doctors and nurses would also have a strong economic impact to its region.

The University of Copenhagen has strong focus on creating value to companies and the society surrounding the university. This is stated in the strategy of the university. And it is also in line with the political trends in many European countries in recent years. European governments emphasise the need for transforming the funding of the universities into the knowledge economy in order to strengthen the competitiveness in the global economy. The Danish government platform focuses on creating new partnerships linking companies to universities.

This economic impact analysis measures the effects of R&D collaboration with The University of Copenhagen. The effects are measured at company level in terms of increased value added in companies and behavioural additinality in terms of additional increase in private R&D investments.
Thus the analysis only focuses on a part of the total value the University of Copenhagen creates for the surrounding society.

The report finds strong evidence of a positive causal link between companies entering into R&D collaboration with the University of Copenhagen and the development in companies’ productivity per employee. More specifically, companies entering into collaboration increase their productivity per employee by an annual average of 6.5 per cent. This positive causal link to increasing productivity corresponds to a net gain of €7,000 per employee on the bottom line for each company year on year as an effect of collaborating with the university. The net gain of €7,000 per employee improves the bottom line of each collaborating company by €2.43 million, as the average company size is 350 employees. With 625 unique companies in the analysis this adds up to a total economic impact on companies located in Denmark of €1.5 bn.

Whereas the econometric analysis shows that formal R&D collaboration generates higher productivity, the qualitative case studies indicate that such formal collaboration often rests on a much broader and often informal set of interaction between the collaborating partners. The case studies show that the formal R&D collaborations represent but the tip of the iceberg; beneath the surface lies a myriad of more or less formalised interactions between companies and academia. These interactions range from informal personal ties to academic scientists serving as consultants to companies or members of scientific advisory boards.

Although these interactions are less visible than formal R&D collaborations, the case studies suggest that they play an absolutely vital role in building and maintaining robust, long-term relationships between universities and companies. It is from such relationships that successful instances of formal R&D collaboration emerge.

These findings hold important policy implications, namely that in order to generate the positive effects of R&D collaboration between universities and industry, it is not enough to simply stimulate formal R&D collaborations; policymakers must also stimulate and facilitate other forms of interaction between public and private science, notably the establishment of long-term relationships between scientists in companies and in universities.

The effects only cover part of the activities at the University of Copenhagen. As such, the stated effects are minimum estimates of the total impact of the university.

The analysis implements econometric methods and uses several different sources to access micro level data. This provides us with a unique possibility to follow the recommendations of several economic institutions including the OECD, EUROSTAT and the World Bank Group in measuring impacts. The recommendations among others focus on establishing a counterfactual situation.

Setting up a counterfactual situation is not an easy task. Can the counterfactual situation actually be simulated or are there some unobserved factors that are not possible to encounter? The methodology and data used in this analysis put forward the best case given the data available. And as such, the results are the most solid and robust given the data available.

Thus, the results reported here are the best case for an econometric analysis of the value added and impact of the University of Copenhagen. Despite the substantial effects and knowledge provided through the cases, it is still largely unex-
plained how the effects occur. There are huge differences in how and why effects occur at company level. These differences differ from company to company from collaboration to collaboration.

As such, there are still questions concerning how and why there are the identified effects. What triggers the effects and are the triggers different between different areas of science? What is the time span from the first initial informal contact to a more formal collaboration to an eventually effect? How does the knowledge transferred from the university to the company affect the company as an entity as well as the individual employee engaged in the collaboration? What are the main roles of universities and what are their secondary roles in fostering a successful collaboration? And what lessons can be learned from different areas of research? These questions still remain to be answered in order to get a deeper understanding of cause and effects, how the effects occur and not least at what point and why.
8 References


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