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**What do we know about Firms' Research Collaboration
with Universities?**

New Quantitative and Qualitative Evidence

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Anders Broström¹, Hans Lööf²

The Royal Institute of technology
Centre of Excellence for Science and Innovation Studies
http://www.infra.kth.se/cesis/research/publications/working_papers
Corresponding author: andersb@sister.nu

¹ Swedish Institute for Studies of Education and Research, Drottning Kristinas väg 33D, SE-114 28 Stockholm, e-mail: andersb@sister.nu

² Royal Institute of Technology, Centre of Excellence for Studies in Innovation and Science, Department of Infrastructure, Drottning Kristinas väg 30B, SE-10044 Stockholm, Sweden, e-mail: hans.loof@infra.kth.se

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Abstract

This chapter provides an integrated view of knowledge transfer between university and industry by combining two different approaches. First, we report results from an econometric analysis, where recent matching techniques are used on a dataset of 2,071 Swedish firms. Our findings from this analysis strongly suggest that university collaboration has a positive influence on the innovative activity of large manufacturing firms. In contrast, there appears to be an insignificant association between university collaboration and the average service firm's innovation output. Second, in the pursuit of credible explanations for these findings, we apply a semi-structured interview methodology on 39 randomly selected firms collaborating with two research universities in Stockholm, Sweden. We identify three ideas for how collaboration may help firms become more innovative in the literature of innovation studies. In analysis of the interviews, we find very weak support for the first idea; that firms are able to exploit and market innovations originating in the university. The second idea – that firms improve their internal innovative capability by collaboration – is found to apply to about half of the investigated firms. Innovation efficiency gains in the form of reduced cost and risk for innovation projects, which is a third idea suggested by the literature, are also suggested to be a major factor behind firms' benefits. Finally, we offer tentative explanations for the lack of measurable effects of collaboration for service firms.

Keywords: University-Industry Link, Innovation, Technology transfer, R&D, Research collaboration

JEL-Codes: C01, I23, O31, O33

1. Introduction

A large body of empirical studies confirms that the use of academic knowledge is beneficial to technological change, innovation and growth in the private sector through new theoretical insights, new techniques, and new skills of a kind that industrial firms find difficult to provide themselves. See Griliches (1979, 1986), Nelson (1986), Jaffe (1989), Mansfield (1997, 1998), Hendersson et al. (1998), Zucker et al. (1998), Adams (2002), Zucker & Darby (2005). It has also been suggested that regions with strong research universities have better opportunities to attract and support innovative industries than other regions. Extending this idea, Luger & Goldstein (1991) argue that regionally based university research-parks can institutionally integrate university and firm resources. Varga (2005) suggests that personal networks of academic and industrial researchers, university spin-off firms and fresh graduates are examples of possible channels for disseminating knowledge between university and industry.

Common empirical indicators of the growing commercial role of universities are industrial funding of university research and partnering projects, patenting and licence income by universities, start-up companies from universities and joint authorship of articles from university and industry research. Counts of patents or innovations, innovation sales, market to book value and stock return are examples of variables used for measuring the impact of academic knowledge on firm performance.

Despite extensive evidence on the importance of partnering between university and industry, however, many researchers emphasize that our knowledge on the interaction between universities and industry is still limited and ambiguous. See, for example Hall, Link and Scott (2003), Jacobsson (2002) and Fontana, Genua and Matt (2003).

The objective of this chapter is to contribute to the understanding of knowledge transfer between university and industry by combining different approaches. We rigorously explore the impact of firms' collaboration with universities on innovation in two steps. First, using a representative dataset of manufacturing and service firms we have applied recent matching techniques to examine the hypotheses that academic knowledge has a positive impact on innovative sales and the propensity to apply for patents. Econometrically, the paper illustrates the differences that emerge from different matching estimators and samples. On balance, we find robust evidence that university collaboration positively influences innovative performance for large manufacturing firms. In contrast, whatever estimator is chosen, the data

show no significant association between university collaboration and the average service firm's innovation sales or propensity to apply for patents.

Second, we are trying to take a step further and conduct a deepening analyse of the collaboration between university and industry through interviews by 39 firms. Econometric analysis of the rich survey data set can take us a long way towards new understanding of the linkages between universities and industry. There are, however, limits to the depth of an analysis made purely from survey data. For example, we find that cooperation with universities has a positive impact on large manufacturing firms' ability to innovate successfully, as measured by its innovation sales and propensity to apply for patents, but the data material cannot help us answer any questions about how such effects are realized. Furthermore, our analysis of the survey material shows mixed results for small manufacturing firms and no effects at all in terms of an increased ability to innovate for the for the typical firm in service-related sectors. Still the firms for which we find only weak or no effect from cooperation constitute about half of the cooperating firm population. Should we understand their decision to cooperate as misinformed, or are these firms cooperating for purposes that we cannot effectively study through the framework of the community innovation surveys? In order to explore these questions, we need complementary methodologies. We employ a semi-qualitative study based on interviews with corporate R&D managers. The respondents' firms were randomly selected for interview among all firms engaged in formal R&D collaboration with two Swedish research universities in 2003-2005.

The rest of the paper is organised as follows. Section 2 briefly reviews some important theoretical and empirical paper on knowledge diffusion and the university-industry linkage. In Section 3, we present the results of an econometric analysis, use this as a starting point for a brief discussion of quantitative versus qualitative research methodology and proceed to present a complementary semi-qualitative interview study. Section 4 presents results from both the econometric analysis and the interview approach. Section 5 concludes the paper.

2. Three Kinds of University-Industry Linkages

In this section, we briefly review the existing literature on the university-industry link. The review is limited to empirical studies that describe firms' main motives to collaborate and the strongly associated issue of firms' gains from collaboration with universities.

Networking and collaboration is a strong theme in modern studies of firms and their innovation activities (Chesborough, 2003). A number of quantitative studies confirm a positive association between the university-industry link and innovativeness at the firm level (Mansfield, 1998; Cassiman & Veugelers 2006). In particular, firms who collaborate with universities are generally those who introduce the most original innovations, whereas no general association between collaboration and a firm's ability to introduce incremental types of innovation can be found (Hanel & St-Pierre, 2006; Monjon & Waelbroeck 2003).

However, the issue of through what main mechanisms R&D collaboration affects a firm is far from unambiguously resolved by previous research. We proceed by reviewing three basic types of explanations for how university collaboration helps firms become more innovative than non-collaborating firms.

2.1 Does collaboration allow firms to exploit university innovations?

The most basic of all conceptual models for firms' utilization of university research is the one nowadays frequently referred to as 'the linear model'. According to this view, technological development in firms draws from the pool of research results produced at universities. Although this model has been declared invalid and 'dead' numerous times (Stokes, 1997; Rosenberg, 1994) it is still influential in both academic and policy-related debates. Recent papers devoted to the resurrection (or re-formulation) of the linear model include Colyvas et al., (2002) and Etzkowitz & Goektepe (2005). An unusually precise model of how firms benefit from organised relations in a strongly linear fashion is presented by Siegel et al. (2003). The authors depict the transfer of a technology from a university to a firm as a one-way chain from Scientific Discovery via Patenting to License to Firm. Colyvas et al. (2002) also assume that some research results have a value for industry in a way clearly influenced by the linear model. They describe two types of university inventions: those that are "ready to use" for a firm and those that need further development to be commercially useable.

Although the view that universities have a major economic role to play as disseminators of research results to firms and to potential (academic) entrepreneurs has faced extensive criticism (Cohen et al., 2002; Agrawal & Henderson, 2002) the alleged death of such models is, it seems, slightly exaggerated. Could it be that a significant portion of firms' benefits of collaboration with universities arises from successful identification and exploitation of research results and, in particular, of university IPR?

2.2 Does collaboration improve firms' internal innovation capability ?

Complementing the above view, a number of studies have furthered our appreciation of more indirect kinds of effects and motives for collaboration.³ Although it must be recognized that inter-industry differences in the relationship between university and industrial innovation in most studies dealing with this dimension across industries has been found to be very high (Mowery & Sampat, 2002), several survey studies show that the primary sources of innovation in most sectors can be found among customers, suppliers and, to some extent, competitors (Fontana et al., 2003; Klevorick et al. 1995). Collaboration could thus be thought to have a main function as that of increasing a firm's internal capability to innovate, i.e. to exploit innovation opportunities arising from all sources.

A few studies on research joint venture (RVJs) report firm motives for participation of a more indirect nature than the direct exploitation of university IPR. Hall et al. (2000) document two broad industry motivations, the first being access to complementary research activity and research results, the second access to key university personnel. Caloghirou et al. (2001) report from a large set of RJVs established in the context of the European Framework Programmes over a period of fourteen years, that the main motivation for firms is to achieve a "positive impact on their knowledge base". Hall et al. (2001) take a departing point in data from the Advanced Technology Program (ATP) funded by the US government. They find that "industrial research participants perceive that the university could provide research insight that is anticipatory of future research problems and could be an ombudsman anticipating and translating to all the complex nature of the research being undertaken."⁴

The ability of a firm to exploit external knowledge was successfully conceptualised by Cohen & Levinthal (1989, 1990). Their concept of "absorptive capacity" was presented as an intangible asset created by research investments, in that research activities facilitate creation of internal competence and of useful network that allows the firm to identify, assimilate and

³ It seems to the authors that the new appreciation of indirect effects stands in intellectual debt to the earlier academic discussion about the role of R&D in firms; see for example Rosenberg (1990).

⁴ While the latter studies cover a broader set of collaborative projects and can be expected to be more representative than the single case, the type of publicly sponsored programmes which they document are not fully representative of firm's R&D collaboration with universities. Hall et al. (2001) note that ATP projects are supposed to be characterized by "high social value and high risk, involve largely generic rather than largely proprietary technology, and be at such an early stage in development that the technology is not easily appropriable".

exploit external information. As argued by Lim (2000), cooperation with both academic and commercial actors can be a way for the firm to build such absorptive capacities.

One possible conclusion to draw from this literature' is that the firms' cooperation with universities should primarily be seen as a way to increase the firm's absorptive capacity and, indirectly, its ability to technological, market driven development.

2.3 Does collaboration allow more efficient innovation investments?

A growing strand of research literature recognises that outsourcing rationales impact firms' decisions also in the area of R&D (Gerybadze & Reger, 1999; Harryson, 2006; Lambert, 2003; OECD, 2001). This development is driven by a tendency towards greater and broader knowledge needs to ensure competitiveness and by a simultaneous pressure for effectiveness and focus (Bowonder et al., 2005). Barnes et al. (2002) find that "part of the attraction for companies entering into collaborations is that research can be conducted that could not otherwise be justified in-house, since it provides a means of sharing the cost and risk of the work".

The decision whether to perform a certain task inside or outside of the own organisation (outsourcing) is traditionally driven by a simultaneous analysis of costs and risks for the firm. In our case, the choice to work with a university may allow a firm to share research costs with the university, other companies and/or public sources. As regards the risk factor, the decision to outsource R&D can be understood as a mean to avoid the risk inherited in building internal competence in a certain field that is potentially important, but that may later prove less lucrative, i.e. to avoid technological lock-in (Nelson, 1982; Dosi, 1988).

As a tool for cost and risk management, outsourcing behaviour may lead to greater efficiency. It is worth noting that since collaborating firms are generally found to invest more in innovation than other firms (Laursen & Salter, 2004; Fontana et al., 2006), we should avoid interpreting efficiency gains from collaboration as mainly a way to reduce long-term costs for innovation, but rather as a way to afford continued investments.

Albeit there are few – if any – contributions in the literature attempting to connect innovation efficiency benefits to effects on firms' innovativeness, there are thus reasons to believe that efficiency effects explain at least a portion of firm's innovation gains from collaboration with universities.

2.4 Three questions for empirical study

Summarizing this review, we find well-documented accounts for the firms' need to collaborate with universities as well as a well-documented positive association between firms' innovativeness and the industry-university link. However, the literature does not offer a robust explanation for how collaborative efforts are realised into innovation benefits for the firms. However, the literature does not offer a robust explanation for how collaborative efforts are realised into firms' innovative capacity.

We believe that the lack of systematic study of these important effects is caused by a rather natural methodological problem: the problem of connecting an effect found on the general level through statistical analysis to its causes is clearly related to the strengths and weaknesses of the respective research methods used. Econometric analysis of innovation is a tool for generalization and average effects but is difficult to use for the study of complex processes. In contrast, organisationally based studies of innovating firms are primarily meant to allow the researcher to deal with complexity but find it hard to establish out effects, and in particular to generalize to a larger population of firms.

Nonetheless, in this section we have identified three possible explanations from the literature, which we formulated as questions. In the following section, we will discuss how attempts can be made to add the missing links in the chain between development at the organisational level and macro-level effects by addressing these questions.

3. Two methods to analyse R&D collaboration

This section first reports the main results from an econometric analysis which explores the effects of university-industry collaboration, and then describes a complementary semi-structured interview approach to tackle the same issue. Since the main focus of the paper is to examine how this combination of quantitative and qualitative methods allows us to tackle the complexity innovation process, we refer to Lööf & Broström (2006) for a more detailed presentation of the empirical model and the estimation procedure.

3.1 An econometric approach

Does collaboration on innovation with universities boost firms' innovation sales and propensity to patent? While Mansfield (1998) and others find support for the idea that the relationship with universities positively influence the firm's innovation output, in general their results do not imply a causal link between university collaboration and innovation output. The root of the problem is that we can only observe the innovation output for either the collaborating firms or the non-collaborating firms, while our main interest is to determine the innovation output the collaborators would have experienced, had they not collaborated. Since the university collaborators is a selective group with larger R&D intensity, more patents, more demand pull oriented innovations, more innovation sales as a share of total sales, larger propensity to apply for patents, more human capital, larger export intensity and larger firm size, the challenge is to find a proper control group.

Lööf and Broström (2006) apply recent matching techniques in order to evaluate the importance of innovation collaboration between university and industry. Using alternative estimators on a representative sample of 2,071 firm-level observations from the Swedish Community Innovation Survey, including four subsamples of manufacturing and service firms, and two alternative performance measures, the main conclusions are the following. First, the particular matching estimators used (the so called nearest neighbour) sensible for pure technical factors such as sample weights, exact matching, bias correction and number of firms in control groups. Second, there are differences between manufacturing and service firms and between small firms and larger firms. Third and most important, on balance, robust evidence is found that university collaboration positively influences innovation sales as well as the propensity to apply for patent for manufacturing firms with 100 or employees. In contrast, whatever specification of the empirical model, the data show no significant association between university collaboration and the average service firm's innovation sales or propensity to apply for patents. The estimation results are presented in the appendix.

3.2 What do we learn from the econometric approach – and what remains to explain?

The econometric analysis allows us to examine the effects of collaboration with universities on observable performance variables. The Swedish CIS-data suggests that cooperation with universities has a positive impact on large manufacturing firms' ability to innovative, as measured by its innovation sales and propensity to apply for patents, but the data material can not help us answer any questions about how such effects are realized. Nor can the data supply credible answers to the question why collaborating service firms and smaller manufacturing

firms do not seem to enjoy similar benefits from collaboration as do large manufacturing firms. Since only half of the total cohort of firms indicating influence from university research to their innovation activities belong to the group of large manufacturing firms, we must ask whether their decision to collaborate is a misinformed one, or whether these firms enjoy other types of benefits that cannot be effectively studied through the framework of the community innovation surveys?

The lack of reliable survey information about the processes of collaboration on innovation is rather natural; in fact, it is well accepted that survey methodology becomes less suitable the more abstract and complex the object of study is. Much of our current understanding of university-industry linkages are based on innovation surveys and on quantitative output data (patents, bibliometrics, etc). While studies of such indicators have advanced the field considerably, one must ask to what extent the full scope of university-industry relations in research and innovation is adequately covered?

To be able to address the questions posed above - why positive impact can be observed for some categories of firms, and why other categories of firms collaborates despite visible positive effects - we need to undertake complementary research.

3.3 A semi-qualitative approach

Case studies of a particular firm, a group of firms or an innovation process have contributed to deepening the discussion on innovation and collaboration, but the common choice of cases to study is the 'typical' sectors or innovation process (biotechnology, semiconductors, etc) and again one must ask whether the full scope of relations are covered. This problem is related to one of the inherited problems of case study methodology: to determine whether findings from one or a handful of cases can be meaningfully generalized to other cases. The problem is unavoidable, since the number of cases that one can study in parallel is limited by the fact that in-depth case studies are quite time consuming.

In an attempt to provide more in-depth understanding of each case than what is allowed through a survey approach while reducing the problems of studies on a very limited number of cases, we have performed interviews with 39 firms. To avoid biased results, we need to control the selection of firms. We therefore apply a random sampling method. For availability reasons, we use the full lists of firm collaborating with two leading Swedish research

universities; the Royal Institute of Technology (KTH) and the Karolinska Institute (KI) as starting point for this selection.⁵

From data supplied by the two universities, we identified firms who paid a total sum of at least 100.000 SEK in connection to research collaboration with either one of these universities during the period 2003-2005. A small number of firms with less than 50 employees were removed from the sample, as it was believed that the rationale for cooperation among these firms may be too heavily related to the characteristics of key firm personnel to be meaningfully compared with the cooperation rationales at larger firms. 138 firms were identified in this manner. 34 firms collaborating with KTH and 29 firms collaborating with KI were randomly selected, giving us a stratified group of 66 firms.⁶ The relative sizes of the two strata correspond to the relative size of each group in our total sample.

For twelve firms collaborating with KI, we were not able to conduct interviews (either the KI researcher or the identified person at the firm denied us to interview her/him, or the information about a proper contact at the firm could not be retrieved). For two of the interviewed firms, interviews showed that the collaboration is not even loosely coupled to innovation activities in these firms. For three further firms, collaboration is limited to clinical trials only. Since we believe that these firms would not indicate university influence in innovation in a CIS-survey, these five were removed, giving us a final stratum of eleven firms. Most of the contacts that did not lead further were identified as clinical trial collaborations, so we do not think that the inclusion of these respondents would have given us reason to question the results of the analysis. Negative results were also given from attempts to contact six firms who worked with KTH, lending us a final stratum of 28 firms. The data presented here thus represents 39 firms, which is almost a third of the total group of collaborating firms meeting our requirements. The group contains 22 firms corresponding to the group “large manufacturing firms” in the econometric analysis, which was found to benefit from R&D collaboration with universities, and 17 firms corresponding to the other three groups, for which no collaboration effects were found. The sizes of the two groups corresponds relatively well to the findings of the econometric part of the study, where half of the firms collaborating with universities belong to the group large manufacturing firms.

⁵ Universities are often unwilling to provide full lists of their industrial collaboration partners and details on how much money that has been paid by these firms to the University. However, in Sweden Universities are obliged to provide such information by law.

⁶ The stratification was motivated by a need to balance the study between the needs of firms collaborating with a typical engineering University (KTH) and a typical medical University (KI) respectively.

For each of the selected firms, a university researcher collaborating with the firm was identified. The researcher was asked to identify the proper contact person at the firm; a person who was both personally involved in the collaboration and who had significant influence over the decision to enter into this particular university collaboration. The firm contact persons were asked to participate in semi-structured research interviews, lasting between 45 and 120 minutes. Most questions were phrased in an open-ended fashion, but in some questions the respondents were asked to assess a statement or an effect using a four-point Likert-scale.

To keep an overview of the cases, responses from both open and closed (Likert-scale) questions were assessed, and each respondent classified in a number dimensions. We refer to this approach as semi-qualitative, since it inherits strengths and weaknesses from both qualitative and quantitative methodologies.

4. Results

4.1 In search for causes for effects

In this section, we report results from the semi-qualitative analysis. Starting with an analysis of how firm benefits are realised into innovative products, we explore three questions:

Q1: Does collaboration allow firms to exploit university innovations?

Q2: Does collaboration improve firms' internal innovation capability?

Q3: Does collaboration allow more efficient innovation investments?

The case studies undertaken for this study have been designed with these questions in mind. To illustrate the three questions and possible answers, we present six cases from our sample of 39 firms.

Case 1: A large manufacturing firm in the transport equipments business

The firm, which belonged to a multinational corporation, preferred to collaborate with universities in consortia with other firms with similar interests. In particular, collaboration was made attractive by government co-funding. For the firm's management, the opportunity to leverage R&D money was a very important instrument in the constant struggle for R&D funds within the multinational corporate structure. The firm sought "concrete" results in collaboration projects, but did not expect to be given results directly applicable in its product

development. Results that gave ideas for further R&D and results that helped the firm overcome identified problems were considered equally important.

Case 2: A large manufacturing firm in the pulp & paper business

The firm collaborated with the Royal Institute of Technology to access complementary knowledge. The firm had a narrow, 'traditional' set of R&D competencies associated with its main products. In a recent strategic remodelling of its R&D processes, the firm seeks to concentrate its internal R&D expertise even further. However, management experienced a need to scan new developments in broad scientific areas such as surface chemistry, nanotechnology and biotechnology, as it was felt that advances in these areas could likely impact their business. A concentration strategy therefore had to be complemented with a strategy for increased and more organised collaboration with universities. In the cases where such passive cooperation leads to the identification of a specific opportunity, a joint-venture collaboration project with university researchers was often initiated. These projects generally were of an explorative nature. It did, however, also occur that the firm collaborated with universities in well defined projects of a more short-term nature.

Case 3: The large telecommunications firm

Following rapid structural as well as technology-based market changes, the firm has re-oriented its entire R&D strategy and, as a consequence, its collaborative relations to universities. The firm no longer sees itself capable of running any research, and technical development has been drastically downscaled. Cost/risk reasons are therefore main drivers for the firm's collaboration with universities, but the content of collaborative efforts has changed from technical R&D to projects helping the firm to design new services. The nature of these projects are seldom such that they result in new innovative services. Collaborative projects are rather seen as inputs to the firm's continuous development processes.

Case 4: A large manufacturing firm in the business of electronic equipment

Due to military connections and therewith associated needs for secrecy and due to the very special types of facilities needed for product development in the firm's line of business, the firm is not a very frequent collaborator. However, the firm has identified an innovation opportunity that can only be explored through further development of a generic technology. This task demands knowledge of theoretical physics, in which the firm has no expertise of its own. By collaborating with researchers at the Royal Institute of Technology, the firm is able to pursue the development of the technology, which has possible applications in a number of the firm's product lines.

Case 5: A large computer systems firm

The collaboration rationale of this firm is similar to many others, in that it seeks impulses to product development from collaborative products. But for this firm, these impulses are not related to R&D processes in a direct way. Instead, the firm wishes to investigate new areas in which its technological base may allow it to respond to emerging market needs by collaborating with universities. While the firm's R&D organisation also collaborates with universities around more technical R&D issues, the kind of market-oriented collaboration described here is run through local sales and marketing organisations.

Case 6: A medium sized firm in the biotechnology sector

Biotechnology is normally considered to be the sector where the link between academic research and product innovation is as strongest. The firm, however, claims that indirect effects of collaboration are more important and more common than concrete results, even if it does run some well-defined projects with university researchers where concrete research results are expected. More importantly, the firm sees collaboration with leading researchers as critical to its ability to generate new ideas and to assess and develop the ideas that evolve internally. The use of such contacts applies both to early phase R&D and the clinical phases. As the networks and the academic experience are important factors, this kind of collaboration cannot be understood as a result of cost/risk considerations.

To summarize, none of the six cases presented above support the idea of universities as sources of product ideas in the sense that innovations in universities are commercialised as novel products or processes in firms (Q1). In the two cases where the linkages between university research and (potential) firm innovation are most concrete (cases one and four), there are still strong element of adoption and indirect benefits present. Furthermore, the concrete results that were sought were pre-defined by the firms, rather than ready to use "off the academic shelf". The remaining four cases illustrate even more indirect linkages between university research and firm innovation.

In cases one, five and six, we find examples of how collaboration allows the firm to increase its internal capability to innovate (Q2). We find dominating elements of rationales to increase innovation investment efficiency through reduction of costs and risks (Q3) in the collaborative behaviour of firms in cases one, two and three.

Analysis of the total set of 39 cases shows that the points made from the above six cases also are valid for the whole set of randomly selected firms. In fact, only three of the studied cases provide examples of collaboration leading to the transfer of university innovations to firms

(Q1), and in all these cases, the firm had other motives that were considered more important by the respondents.^{7,8} The sparse occurrence of concrete “technology transfer” in a randomly selected sample of firms collaborating with a university is a finding that contradicts that of e.g. Colyvas et al. (2002) and challenges the basic assumptions about the commercial use of university knowledge in existing firms found in parts of the literature of innovation studies.⁹

Regarding collaborations increasing the firm’s own ability to innovate (Q2), the full set of cases provides a list of benefits fitting this description. The most obvious effects of this sort are those related to learning in the firm and to the inflow of fresh ideas and impulses into the firms R&D processes. Many respondents stated that collaboration served the purpose of introducing a new field of knowledge to the firm, or allowed the firm to continuously follow the scientific front. But we also find that collaboration increases the innovation ability of firms from the perspective of human capital management. Collaboration allows the identification of competent people to recruit and increases many firms’ attractiveness as an employer for valuable experts. A final important type of effect is illustrated by case five. Just as in case five, a number of respondents motivate the collaboration with universities in a fashion that is more related to the goal of maximising the revenue from the firm’s technological know-how and existing innovative products than to the introduction of new ones. Several others, especially in the broadly defined life-science sector, see branding of the firm and of certain products as an important effect of collaboration with academic scientists.¹⁰

Analysing the full sample, we find that effects fitting the Q2-question are identified by three out of four respondents. Cooperation with universities thus indeed seems to be a way to both build the firm competence often referred to in the innovation literature as absorptive capacity and to increase the economic revenue from innovations. We conclude that Q2 seem to provide

⁷ These cases consist of 1) a consultancy which marketed the methodology / product of an academic researcher in collaboration with the researcher, 2) a medical service company whose contacts with academics allowed it to once in a while develop research projects with commercially interesting results together with the academic discoverers and 3) the insurance company which recently invested in a spin-off company based on research which it had originally co-funded.

⁸ It should be noted that our selection method may make the investigation slightly biased, in that firms which are not engaged in formal collaboration (involving monetary flows between the partners) not are included. Under Swedish law, the researcher owns his or her IPR, so no financial flows through the university would be necessary for collaborations limited to IPR-transfer only. Although the legal situation does not allow too rigour analysis of the situation, the dominating view is the main adaptors of university IPR are large firms that mainly also collaborate in other ways and, to some degree, university spin-off firms (VINNOVA 2004).

⁹ It should, however, be pointed out that a broad stream of research following Nelson (1986) and Klevorick et al. (1995) points out that the direct effects of academic research on industrial R&D are very limited with the exception of a few technologies. While often not being too specific, papers following these contributions generally argue that university research has significant indirect influence on firms.

¹⁰ This finding reminds us to avoid the misperception that the two outcome variables of our econometric analysis (innovation sales and propensity to patent – see section 3) have to be strongly interconnected.

an important piece in the puzzle of how collaboration positively affects the innovativeness of a firm.

As regards the third question, a broad range of rationales related to efficiency gains through cost- and risk reduction are identified in our interview study. For each studied firm, we use information from a number of interview questions to assess whether the respondent sees collaboration with universities as an attractive alternative to in-house research for cost/risk reasons or as a unique complement to own R&D that the firm cannot supply for itself within reasonable time and/or at reasonable cost. We find that cost/risk reasoning strongly influences the decision to collaborate of one out of two respondents. The decision to work with universities for efficiency reasons seems strongly connected to highly specialised areas of expertise, for which specialised competence and equipment is needed.

Concluding this subsection, we note that while two of our three questions seem to find positive answers in the interview study, they do not seem to adequately describe the full set of benefits enjoyed by firms. To delve deeper into the large complexity of firms' innovation processes and their need for cooperation, further theoretical guidance and further empirical efforts seem necessary.

4.2 Why don't service sector firms seem to become more innovative through collaboration?

In this section, we have analysed how collaboration with universities may help firms become more innovative in two dimensions. We claim that the two types of effects delineated here are likely to explain a significant part of the effects observed on large manufacturing firms in the econometric analysis. However, we note that our interview material of 39 firms does not signal that large manufacturing firms differ in any significant way in respect to the two main questions Q2 and Q3. The proportion of large manufacturing firms for whom cost- and risk reduction rationales (Q3) are important equals the share of all other firms for whom such effects are a major component of collaboration. Similar results are found regarding the indirect nature of collaboration effects (Q2), we have already noted that the strong dominance of 'indirect' types of effects is a common feature across all firms studied. Naturally, there are considerable differences in the content of collaboration – large manufacturing firms do for example stand out as particularly susceptible for effects related to human capital – but on a

more abstract level, needs for networking, learning, orientation and exploration characterize the broad set of firms over sectoral borders.¹¹

Seeing that both Q2 and Q3 can be answered equally positively for service firms as for large manufacturing firm, one must ask why collaboration does not seem to have any positive effect on the latter category in our econometric analysis? Since we have established that direct commercialisation of the type formulated in Q1 has a limited influence even on large manufacturing firms, we find it unlikely that this effects explains the difference between manufacturing and service firms. A first interpretation of the lack of effects, which also finds some support in the studied cases, is that non-manufacturers may quite simply face greater problems in the realisations of benefits from collaboration with universities. Even though cost/risk effects and indirect benefits characterise manufacturing and service sector firms alike, we find indications that the distance between collaborative content and product/process introduction is greatest for non-manufacturing firms. A weaker tradition of collaboration around services may contribute to such problems. Our analysis of the 39 interviews does, however, suggest that we perhaps should rethink how we study non-manufacturing firm in two ways before we dismiss their use of university collaboration as misguided.

First, we find (in accordance with Boer et al., 2001), that some firms outside the manufacturing sector obviously collaborate with universities without intentions to support innovation, as the concept is defined in the CIS survey. While this phenomenon is also found among manufacturing firms, it seems to be more frequent among non-manufacturing firms. We may therefore be measuring the wrong output variables in the econometric study. Rather than increased ratio of sales derived from recently introduced products and increased propensity of patenting, we should perhaps study productivity or other profit measures to capture the effects of collaboration on the average service sector firm. In particular, the patenting behaviour of non-manufacturing firms is clearly different from that of manufacturers. In the Swedish CIS 3 data 19 % of non-manufacturers with R&D positive investments have applied for a patent, compared to 38 % of R&D-performing manufacturers.

¹¹ Our interview material, which is based on random selection of firms (see section two) does, unfortunately, only include two smaller manufacturing firms. We are therefore not able to obtain even a tentative conclusion as regards differences between smaller manufacturing firms and large ones from the interview material. It can be mentioned that previous research indicates that small firms generally engage in collaborative R&D to seek economies of scale and to solve problems in core technological areas, whereas larger firms primarily seek economies of scope, e.g. to exploit their competencies and capabilities in new product areas and non-core technological areas (Nioisi, 1996; Santoro & Chakrabarti, 2002).

Second, it may be hypothesised that methodological issues contribute to this result. Not many of our highly qualified respondents felt comfortable to reduce their complex R&D needs and its effects to the level of abstraction presented in our three questions Q1, Q2 and Q3. We have attempted to deal with this problem through the adoption of a semi-structured interview methodology, which has allowed us to discuss these matters from a few different angles, leaving it up to the researchers to abstract the compiled information. While this method has its obvious inherited problems, it allows us to capture some of the great complexity of the matter. In view of the obvious complexity and fuzziness, questions about the general reliability of previous survey research are raised. To what extent have for example the respondents of the Carnegie Mellon Survey been able to deliver accurate and reliable information about information sources for project initialization and project completion respectively in the interesting and influential article by Cohen et al. (2002)?

While the above described potential problems apply to the full set of firms, the definition and measurement of innovation seems to be particularly problematic outside the manufacturing sector. The CIS3 survey was focused on “innovation based on the results of new technological developments, new combinations of existing technology or utilisation of other knowledge held or acquired by your enterprise”.¹² The CIS3 question used as output variable is phrased in the following manner: “... did your enterprise introduce any new or significantly improved products (goods or services) which were also new to your enterprise’s market?” While the concept of ‘innovation’ is strongly integrated into engineering and manufacturing sectors, many parts of the concepts and its terminology have ‘fuzzy’ meanings in the context of a service-oriented business (Toivonen & Tuominen, 2006). To respondents from the business service sector, service innovations may not be recognizable as innovations. This hypothesis may explain the lack of econometric evidence for innovation effects from collaboration for non-manufacturing firms reported in the previous section of this article. In either case, this line of argument suggests that the field of innovation studies is up for a real challenge, as new survey techniques may have to be developed to increase understanding of the ever increasingly important field of service innovation.

On a final note, we would like to point out that respondents of the CIS III survey were asked to “indicate the sources of knowledge or information used in your technological innovation”, where innovation is defined as the introduction of new or significantly improved products and

¹² The CIS4 takes a broader stance, defining as innovation “major changes aimed at enhancing your competitive position, your performance, your know-how or your capabilities for future enhancements”.

services. Given the two issues formulated above (service firms may do other things than innovation / service firms may have difficulties defining innovation) it may be hypothesised that respondents fail to recognize universities as a ‘source’. Firms who formally collaborate with universities may thus actually appear in the group of non-collaborators in the quantitative analysis of this paper, reducing the precision of the econometric study.

5. Summary and conclusions

This chapter set out to contribute to the literature on university-industry linkages, and to our understanding of research collaboration between firms and universities in particular. Recognising a gap in the literature between studies of effects enjoyed by collaborating firms and the study of rationales and concrete outcomes from collaboration projects, we have presented an attempt to discuss how the two ends of this chain of evidence can be connected.

Econometric analysis has allowed us to investigate the influence exerted by university research on firm’s innovativeness. A positive influence, in terms of increased propensity to apply for patents and an increased share of sales related to innovative products, was found for large manufacturing firms. For the full set of manufacturing firms (including small firms) the indications on positive effects are clearly less robust, and for firms in non-manufacturing sectors, no evidence on a positive influence from collaboration could be found. To pursue the study of how the positive effects for large manufacturing firms are achieved and why similar effects cannot be as easily found for other firms, we used semi-structured interview methodology to study 39 randomly selected firms collaborating with two universities in Stockholm, Sweden. This study revealed that indirect effects seem to be very important. In the literature, two types of university inventions are often depicted: those that are “ready to use” for a firm and those that are “embryonic” in nature, needing further development to be useable by industry. We find *no* strong examples of valuable product innovation being picked “off the shelf” of university research through research collaboration, and thus reject the idea that such effects explain the positive effects from collaboration found in the empirical part of the study.

Previous research has found that ideas for innovations come from customers, clients and (to some degree) from competitors. Our results point to the importance of learning and orientation from university cooperation, which enables the firm to translate these market opportunities into technical or organizational problems. Furthermore, firms are able to strengthen their networks and manage their human capital through innovation. We conclude

that through these mechanisms, collaboration indeed seems to improve firms' internal innovation capability.

Furthermore, benefits from collaboration with universities are for some firms achieved through leverage of research investments. Cooperation seems to allow some firms to reduce costs and risks associated with research. Thereby, firms are becoming more efficient innovators. This type of argument is found to provide a second credible explanation for how collaboration helps firm become more innovative.

The analysis of this paper also allows some enquiry into methodological issues. In particular, the research throws some new light on the limitations of the innovation literature in both breadth (a prevailing focus on 'manufacturing' sectors) and methodological scope (gap between survey-based findings and case study research insights).

Starting with the latter issue, our study highlights some of the 'blind spots' associated with survey-based research approaches. The survey-base methodology is generally better suited for evaluating effects and describing associations between clearly defined variables than for identifying the mechanisms through which these associations are brought about. Our interviews reflect the obvious fact that there are effects from collaboration that go beyond what is measurable in the CIS3-survey. Furthermore, the large degree of complexity and fuzziness calls for great caution in the design of research surveys and in interpretation of survey results. The differences in collaborative patterns and effects observed in the econometric analysis also calls for great caution in any theoretical contribution of more general nature that may be deduced from in-depth case studies.

Returning to the issue of a focus to manufacturing firms, the fact that the two identified ways through which collaboration helps a firm become more innovative applies to service firm as well as to manufacturing firm leads us to believe that it may be fruitful to study collaboration mechanisms in a broader setting. At the same time, we suggest that problems of measurement and definitions make it difficult to compare innovation in manufacturing and non-manufacturing sectors with data such as that of the CIS.

In combination, these remarks present some serious challenges for further research. Methods allowing researchers to handle the complexity and analyse results with econometric tools are called for. For example, the addition of 39 further interviews would render us a material which would allow at least a basic quantitative analysis of the relations between firm characteristics (business model/sector, size, etc) and cooperation effects. As tedious and

resource-consuming as such work may seem, it is probably only through such efforts that we can dig deeper into the complex world of R&D relationships and their outcomes.

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Appendix

Effects from collaboration: Quantitative analysis

In the first part of the appendix, the estimated effect of the university-industry link (UIL) on innovation sales is presented (Table 1). Part two show the causal effect of UIL on the firm's propensity to apply for patents (Table 2). The different specifications of the matching estimator are described in Table 3.

Innovation sales

A simple matching with no adjustments and four matches is presented in Table 1, where line 1 (Panel A) reports that collaboration on innovation with universities increases innovation sales with about seven percent for the average innovative firm. The estimate is highly significant (at 1% level) for the overall sample and for manufacturing firms. The estimate is significant at the 5% level for the sample of service firms. The subsample of service firms with 100 or more employees is the only sample for which we find no significant impact of university-innovation collaboration (UIC).

Panel B-E compare the performance of the non-adjusted estimator with the averages of various adjustments. First, line 2 of Panel B shows that sampling weights is an important issue. For the overall sample and for the typical service firm, the average effect of UIC is not significantly different from zero at neither the 5% nor the 1% level when sampling weights are applied in the estimation. In this estimation set-up, UIC has a causal and positive effect on innovation sales significantly different from zero only for the manufacturing firms.

When exact matching (innovation input and the eight discrete variables respectively, see Line 3 and 4) is added to the weight-adjustment the estimates for the total sample shows a positive effect only on exact innovation input. For manufacturing firms, the estimates are significant only for the firms with 100 or more employees. With this set-up, UIC has no positive influence on innovation sales for service firms.

Panel C adds biased adjustment to the sample weights but remove the requirement of exact matching. Moreover, two other distance measures are compared to the four matches. If we increase the number of matches the results only changes marginally over all samples. Comparing line 6 and 7 informs us that that the choice of distance measure is not important

when no matches are exact. The main result reported in Panel C is that UIC is associated with an increase in innovation sales for the average innovative manufacturing firm but not for the typical innovative service firms.

When we match exactly on all the innovation input variables, the estimates for manufacturing firms with 100 or more employees are significant or highly significant (See Panel D, row 10-14). For the total sample of manufacturing firms, the estimate is significantly different from zero when the number of matches is greater than or equal to 16. In the case of the Mahalanobis distance measure between the vectors or matches, we also find a significant association between UIC and innovation sales for all manufacturing firms when only four matches are used. The estimates for the service firms are not significant.

Panel E (row 15-19) presents matching outputs when we use the set of discrete variables (but not R&D and other innovation input) as exact matches. The results show that the average innovative firm in the economy does not benefit from academic knowledge in terms of increased innovation sales. One exception is found for the subgroup of manufacturing firms with 100 or more employees, where the choice of distance measures has no significant impact on the estimated relationships.

Table1: Estimation results, dependent variable is Innovation Sales

Estimator ¹	All firms		Manufacturing		Manufacturing Employment>99		Services		Services Employment>99	
	N= 2, 071		N= 1,242		N=366		N=830		N=233	
	Coeff	Std err	Coeff	Std err	Coeff	Std err	Coeff	Std err	Coeff	Std err
A: 1	0.074***	0.019	0.071***	0.023	0.074***	0.023	0.082**	0.040	0.052	0.051
B: 2	0.089	0.047	0.095**	0.046	0.115***	0.026	0.074	0.074	0.026	0.073
B: 3	0.085**	0.039	0.043	0.046	0.071***	0.026	0.102	0.077	0.011	0.089
B: 4	0.089	0.053	0.038	0.049	0.078***	0.028	0.108	0.070	0.056	0.069
C: 5	0.078	0.045	0.107**	0.045	0.118***	0.025	0.067	0.071	-0.072	0.074
C: 6	0.082	0.048	0.104**	0.047	0.117***	0.027	0.085	0.074	0.005	0.067
C: 7	0.071	0.033	0.098**	0.038	0.123***	0.024	0.094	0.063	-0.003	0.073
C: 8	0.074	0.052	0.098**	0.0443	0.086**	0.026	0.058	0.077	0.031	0.076
C: 9	0.090	0.074	0.084**	0.037	0.099***	0.025	0.072	0.093	- ¹	- ¹
D: 10	0.069	0.043	0.067	0.044	0.076**	0.031	0.050	0.073	-0.087	0.083
D: 11	0.080**	0.039	0.075	0.053	0.069***	0.026	0.074	0.075	0.022	0.086
D: 12	0.064	0.041	0.103**	0.041	0.081***	0.081	0.032	0.065	-0.051	0.078
D: 13	0.061	0.043	0.101**	0.044	0.063**	0.027	0.053	0.081	0.021	0.086
D: 14	0.075	0.048	0.088**	0.040	0.066**	0.027	0.088	0.077	- ¹	- ¹
E: 15	0.079	0.050	0.018	0.046	0.068	0.035	0.109	0.064*	-0.055	0.071
E: 16	0.096	0.054	0.044	0.050	0.092***	0.029	0.112	0.069	0.066	0.064
E: 17	0.051	0.042	0.042	0.048	0.088***	0.029	0.097	0.057	0.056	0.063
E: 18	0.104	0.055	0.039	0.043	0.115***	0.026	0.079	0.078	0.082	0.069
E: 19	0.098	0.063	0.057	0.029	0.101***	0.025	0.073	0.079	- ¹	- ¹

Note: Significant at the 1% (***) and 5% (**) level of significance. (1) Too few observations

(1) For a definition of the estimator, see table 3 below

4.2 The propensity to apply for patents.

Table 2 gives the results obtained from matching the cross-sectional data with respect to a firm's propensity to apply for patents. There are four major points to be made about these estimates. The first is that, using the same framework as for the estimations presented in Table 6, the estimated results, considered together, tells a similar story as the one for innovation sales. Thus, some of the estimates suggest interaction between universities and firms affects innovation performance and some does not. The differences are on the one hand explained by firm size and by sector, on the other hand by the different applications of matching estimators.

The second is that UIC contributes significantly to the explanation of cross-sectional differences in the propensity to apply for patents among manufacturing firms with 100 or more employees. Given a bias adjusted estimator and a weights sample, the results suggest that UIC increases the propensity to apply for patents in a range of 17-32 percent depending on number of matches, distance between the matched pairs of covariates (determinants) and the requirement of exact matching.

The third major finding of interest is that we cannot reject the null hypothesis for neither the subsample of service firms, nor the subsample of manufacturing firms. All 18 estimators show non-significant results when weighted samples are used.

The fourth finding is that the results for the overall sample including all 2,071 firms and the subsample with 1,242 manufacturing firms are inclusive.

The concluding robust finding for all firms in our sample (Column 1) is that the influence from universities are significant only when the bias adjusted estimator matches exact on R&D and other innovation inputs. In contrast, the most interesting lessons to emerge from the empirical analysis reported in Column two (manufacturing firms) is that whether we choose to match exact on either the indicator variables or the innovation input or choose to not match exact on any variables at all, the data show a significant association when the number of matches is 64. Otherwise no systematic pattern can be established.

Table 2
Estimation results: Dependent variable is Patent application

	All firms		Manufacturing		Manufacturing Employment>99		Services		Services Employment>99	
Estimator ¹	N= 2, 071		N= 1,242		N=366		N=830		N=233	
	Coeff	Std err	Coeff	Std err	Coeff	Std err	Coeff	Std err	Coeff	Std err
A: 1	0.252***	0.040	0.257***	0.050	0.280***	0.052	0.059	0.052	0.148*	0.089
B: 2	0.085	0.075	0.144**	0.089	0.227***	0.061	0.021	0.099	0.040	0.122
B: 3	0.178***	0.064	0.128	0.109	0.172***	0.060	0.061	0.085	0.014	0.122
B: 4	0.013	0.067	0.068	0.086	0.244***	0.061	0.039	0.072	0.045	0.082
C: 5	0.105	0.069	0.174	0.086	0.246***	0.055	0.014	0.088	-0.028	0.110
C: 6	0.090	0.076	0.157	0.094	0.229***	0.058	0.020	0.094	0.019	0.097
C: 7	0.128**	0.065	0.210***	0.079	0.296***	0.052	0.015	0.073	-0.033	0.114
C: 8	0.088	0.084	0.152	0.092	0.252***	0.058	0.004	0.099	0.005	0.110
C: 9	0.075	0.119	0.197**	0.080	0.275***	0.051	-0.017	0.120	- ¹	- ¹
D: 10	0.151**	0.071	0.165	0.095	0.119	0.073	0.051	0.083	-0.161	0.108
D: 11	0.175***	0.062	0.165	0.106	0.172***	0.060	0.050	0.082	0.027	0.128
D: 12	0.238***	0.077	0.299***	0.085	0.198***	0.055	0.044	0.077	-0.047	0.143
D: 13	0.173**	0.075	0.193**	0.086	0.223***	0.065	0.054	0.094	-0.026	0.142
D: 14	0.207**	0.088	0.246***	0.089	0.248***	0.0717	0.195	0.122	- ¹	- ¹
E: 15	0.020	0.064	0.053	0.088	0.324***	0.080	-0.019	0.067	-0.124	0.107
E: 16	0.016	0.067	0.068	0.085	0.243***	0.062	0.038	0.071	0.045	0.077
E: 17	0.066	0.084	0.066	0.084	0.246***	0.061	0.041	0.057	0.047	0.075
E: 18	0.065	0.083	0.108	0.084	0.281***	0.056	0.028	0.089	0.107	0.087
E: 19	0.088	0.092	0.174***	0.060	0.248***	0.053	-0.002	0.108	- ¹	- ¹

Note: Significant at the 1% (***) and 5% (**) level of significance. (1) Too few observations

(1) For a definition of the estimator, see table 3 below

Table 3: Definition of the estimators

Estimator	Sample Weights	Exact	Number of matches	Bias adjustment	Distance measures ¹
A: 1	No	No	4	No	Inverse
B: 2	Yes	No	4	No	Inverse
B: 3	Yes	R&D-input	4	No	Inverse
B: 4	Yes	All discrete indicators	4	No	Inverse
C: 5	Yes	No	1	Yes (Human capital)	Inverse
C: 6	Yes	No	4	Yes (Human capital)	Inverse
C: 7	Yes	No	4	Yes (Human capital)	Mahalanobis
C: 8	Yes	No	16	Yes (Human capital)	Inverse
C: 9	Yes	No	64	Yes (Human capital)	Inverse
D: 10	Yes	R&D-input	1	Yes (Human capital)	Inverse
D: 11	Yes	R&D-input	4	Yes (Human capital)	Inverse
D: 12	Yes	R&D-input	4	Yes (Human capital)	Mahalanobis
D: 13	Yes	R&D-input	16	Yes (Human capital)	Inverse
D: 14	Yes	R&D-input	64	Yes (Human capital)	Inverse
E: 15	Yes	All discrete indicators	1	Yes (Human capital)	Inverse
E: 16	Yes	All discrete indicators	4	Yes (Human capital)	Inverse
E: 17	Yes	All discrete indicators	4	Yes (Human capital)	Mahalanobis
E: 18	Yes	All discrete indicators	16	Yes (Human capital)	Inverse
E: 19	Yes	All discrete indicators	64	Yes (Human capital)	Inverse

(1) The metric for measuring the distance between two vectors of covariances. Letting $\|x\|_V = (x'Vx)^{1/2}$ be the vector norm with positive definite weight matrix V, we define $\|z-x\|_V$ to be the distance between the vectors x and z. We use two alternatives for V. *Inverse*: V is the diagonal matrix constructed by putting the inverses of the variance of the covariates on the diagonal. *Mahalanobis*: $V=S^{-1}$, where S is the sample covariance matrix of the covariates.