Strategists and Academics

Essays on Interaction in R&D

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Abstract

This doctoral thesis consists of five self-contained essays on interaction in R&D between university researchers and private firms. Together, these essays explore the conditions under which private firms benefit from spillovers from publicly funded and organised research. From the first essay, which sets out to empirically validate the theoretical arguments about the benefits of university-industry interaction for private firms, the thesis follows a line of pursuit that goes back and forth between exploration of the different benefits that firms enjoy from university interaction and the relationships between these benefits and the conditions of interaction. In essay II, a typology of rationales for establishing cooperative relations is presented. A considerable breadth of interaction rationales is documented. On closer examination, however, a “core” set of rationales related to innovation, in terms of invented or improved products or processes, are found to be the main drivers of interaction. Developing this view, three critical issues previously studied within innovation economics are re-considered from the point of view of firm rationales for interaction; public co-funding of university-firm interaction (essay II), the role of geographic proximity for interaction on R&D (essay III) and the organisation of public sector research (public research institutes and universities) in relation to firm level competences (essay IV). In a fifth essay, four ideal types of strategy for localised interaction between R&D subsidiaries and universities are proposed. Through the framework developed in this essay, the rationales for interaction are related to the overall R&D strategy of multinational firms. Concluding the thesis, it is discussed how the research presented herein opens up for improved theorizing around the roles of academic research for industrial innovation.

Key words: public research, spillovers, university-industry, innovation, R&D interaction, rationales for interaction, geographic proximity, R&D strategy

JEL-codes: A12, C24, C31, I23, I28, I29, O31, O32, O38,


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List of appended essays

This thesis is based on the work presented in the following essays:


II: Broström A., “Firms’ rationales for interaction with research universities and the principles for public co-funding,” re-submitted to *Journal of Technology Transfer*.

III: Broström A., ”Working with distant researchers - distance and content in university-industry interaction,” in review for *Research Policy*.

IV: Broström A. and M. McKelvey, “How do organisational and cognitive distances shape firms’ interaction with universities and public research institutes?”


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1 Essay I is co-authored with Hans Lööf. Hans Lööf has had a leading role in evaluating econometric methodologies and implementing the matching estimator of this paper. Anders Broström has been actively involved in all stages of the research. As regards essays IV and V, Anders Broström has had a leading role in the research efforts and in writing the essays.
Preface

This publication represents my struggles with the complexities of the public-private interface in research. I sincerely hope that the studies presented herein are able to provide the reader with some insights and interesting ideas for how our understanding of this interface can be further refined. The last few years’ engagement with this study has namely left me convinced that the tensions and opportunities that arise when academic research meets the needs of society (and, as in the concrete case studied in this thesis, of private firms) are in greater need than ever of careful, insightful management.

A number of people have provided invaluable support during the writing of this thesis. My supervisors at KTH – Associate Professor Hans Lööf and Professor Björn Hårsmann – have over the last six years taught me a great deal about the art of research. I very much appreciate that I have been allowed to engage with the studies of economic theory from the perspective of curious scepticism, and that I have been allowed to be wrong about many things, many times. I have been privileged to have further mentors guiding me through the doctoral studies. As director of the Swedish Institute for Studies in Education and Research (SISTER), where this thesis was initiated, Enrico Deiaco gave me the opportunity to engage with several fascinating issues that define the complex of interfaces between public research and the economy. From Professor Maureen McKelvey, now at the University of Gothenburg, I have learnt many things about the process of research and about academic writing. My introduction to economic thinking was facilitated and inspired by Professor Gunnar Eliasson, then at KTH. His theorizing about the micro dynamics of economic growth, driven by solid knowledge of managerial practise, has provided a stimulating background to my further studies. These five persons have that in common that they have believed in me and stimulated me towards pursuing the writing of this thesis. For this, I am extremely grateful.

I also owe my sincere gratitude to Professor Almas Heshmati and Professor Pontus Braunerhjelm for reviewing the manuscript in its entirety and providing valuable comments. Valuable comments on particular studies have also been generously provided by a number of persons. Beyond those whose support was already acknowledged in the five essays, I am also grateful to Dr Peter Schilling at SISTER, Gustav Martinsson at KTH, Tobias Fridholm at CIND, Professor Göran Reitberger and Dr Anna Westberg Broström.

The conclusions of this thesis are quite explicit about the benefits that can be drawn from interaction over research with university researchers, but have less to say about how the university researchers may benefit from interaction with stakeholders. There are other studies reporting that such benefits may indeed exist, and my experiences while writing this thesis support these findings. Discussions with and assistance from Mats Ershammar and Carin Peters at the Stockholm County Board, Dr Emma Källblad and Professor Eric Giertz at KTH, Lennart
Elg and Dr Susanne Andersson at Vinnova and with Peter Johansson, Lena Heldén Filipson, Gunnbritt Morhed and Johan Ancker at the Association of Swedish Engineering Industries (Teknikföretagen) have been particularly helpful in designing the empirical studies. Some of these people have also been instrumental in helping me gain access to key respondents among the more than 100 industry managers that have been interviewed for the studies in this thesis. I am also very grateful to these interviewed persons and to the almost 300 respondents to the survey that is utilized in this thesis for their time and efforts.

The progress in my professional life that is reflected in the completion of the thesis has been made possible by the positive energy that has been created in my private life by my family and friends. In particular, my marriage to Anna and the arrival of our son Arvid has made the period when I struggled to finish this thesis a very bright and happy one. I love you both very much!

Stockholm, April 2009

Anders Broström
Introduction and summary of the thesis

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1. BACKGROUND AND PURPOSE

The study of firms’ interaction with publicly employed researchers is a branch springing from the economics of innovation – the literature dedicated to the study of how economically valuable improvements in terms of new products, processes or new ways to organise economic activities are introduced into an economy. Such studies are typically seen as drawing their basic motivation from the growth theory arguments of Romer (1990) and Grossman & Helpman (1994), where knowledge spillovers between agents in the economy and the introduction of innovations, respectively, are seen as driving aggregate economic growth. The particular study of direct interaction between firms and public research organisations (PROs) is related to two main themes of the innovation economics literature; (1) the role of public investments in research for private sector innovation and (2) the study of the distribution of and different mechanisms for knowledge spillovers. In the remainder of this section, these two issues are briefly discussed.

Mainstream theoretical understanding of the role of public science starts in the seminal contributions of Nelson (1959) and Arrow (1962). Since (disembodied) knowledge by its nature is nonrival and nonexcludable, and therefore classified as a public good, private actors will not be able to appropriate the full return to investments in knowledge creation. Investments in knowledge creation will therefore be considerably lower than what is socially optimal (Bernstein & Nadiri, 1989; Alvarez-Pelaez & Groth, 2005). This market failure argument makes a case for the state to engage with R&D policy. In particular, it has been used as a rationale for the state to take responsibility for the production of scientific research – a kind of knowledge production in which uncertainty and appropriation limitations are considered particularly severe problems from the point of view of private firms, and the potential for widely useful breakthroughs is particularly high.

The study on direct interaction between those researchers that perform publicly funded research and private firms is of more recent origin. The notion that direct interaction between private firms and publicly employed scientists has a particular role to play for distributing spillovers from academic research has no base in mainstream neoclassical economic theory; it is rather based on considerations of the characteristics of knowledge. The recognition of the ‘tacit’ nature of certain types of knowledge (Polanyi, 1966; Dosi, 1988) suggests that direct contacts between firms and academic researchers are needed to facilitate relevant knowledge flows.1

A complementary argument for the importance of collaborative interaction between firms and universities is that it may counteract tendencies to underinvestment in early stage R&D by allowing firms to reduce the costs and risks they face (Link & Scott, 2001). As noted by Veugelers & Cassiman (2005), such problems can for example be caused by imperfections in the financial

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1 Note that these characteristics of knowledge are in direct conflict with the neo-classical view of Arrow (1962) that has been used to motivate public spending on research for decades (Mowery, 1983).
markets. Arguments supporting this view have been provided by management scholars, who argue that increasing international competition, increasing complexity of technology and continued shortening of development lead times and product cycles push firms away from extensive in-house-only research – in particular from early stage R&D (Gerybadze & Reger, 1999; Tidd et al, 2001).

Starting from the perspective of the processes of innovation rather than from the perspective of public welfare analysis, the literature on innovation systems has also strongly emphasised direct linkages between PROs and firms (Edquist, 2005). In this literature, it is emphasized that innovations are processes of interactive learning, implicating that links between organisations with different competencies and resources are important for system-level (nation, region or sector) performance.

Direct interaction between organisational entities is, however, far from the only channel through which public investments in research are assumed to spill over to the economy at large. Several other types of direct linkages between university research and firms are also identifiable, including the knowledge flows embedded in people that come with the recruitment of students and graduates, and the introduction of new research-based spin-off companies. While direct interaction in joint venture settings, where both sides signal commitment to the collaborative effort, is probably the type of linkage through which the main direct influence of science is realised (Kaufmann & Tödtling, 2001; Adams et al., 2001), these other linkages have been suggested to play a more important role than direct interaction, both from the point of view of single firms and the wider economy (Zucker et al., 1998a; Eliasson & Braunerhjelm, 1998; Salter & Martin, 2001). Furthermore, research results and accumulated knowledge from academe are seen as having spillover effects on the economy through unfacilitated dissemination of knowledge.

Studying these different mechanisms, a central question in the literature is under what conditions publicly funded and organised research has economic spillover effects on private firms. Such understanding is needed to ensure that the public sector engagement has an optimal impact on the aggregate economy. The general purpose of this thesis is to contribute to the understanding of this question. In particular, this thesis links factors such as firm size, sectoral differences and geographical distances to strategic behaviour on behalf of the firm to understand which firms are best positioned to draw benefits from academic research through direct interaction with university researchers. It is explored how the influence of these factors shift with the different purposes that formalised relationships to university researchers can fulfil within each firm.
In the study of technology transfer, the neophyte and the veteran researcher are easily distinguished. The neophyte is the one who is not confused. – Bozeman (2000, p. 627)

In this section, key findings from previous studies on university-industry interaction are discussed. In particular, factors identified as determining the patterns of direct interaction with public research organisations are highlighted, as findings of this nature are relevant not only for the individual essays, but for discussing the aim and contributions of the thesis as a whole. Two categories of empirical studies are described. First, studies that document the incidence of direct university-industry interaction and the determinants thereof are reviewed. Together, these studies provide a convincing, coherent overview of which firms that are likely to engage in direct interaction. Following this literature, the propensity to interact with public researchers can be modelled as a function of firm-level heterogeneity and idiosyncrasy, along with sector-level and linkage-level heterogeneities. A second type of study seeks to establish systematic explanations for firm-level benefits of interaction. Here, evidence is more scattered.

2.1 Determinants of interaction

Considerable interest has been dedicated to the geographical dimension of knowledge flows, as visible in for example the paper trails of patent citations. However, the special case of the geography of direct interaction between university researchers and industry has gone largely un-studied. Summarising available evidence gives a somewhat ambiguous picture (see essay III for a review), but at least in the European setting, it appears to have been easier to set up successful interaction within than across national borders. Note that beyond geographical distance per se, these barriers to interaction are to a considerable extent cultural, language-related and institutional differences. The national limitation of many co-funding schemes for university-industry interaction may also have blocked cross-country interaction. A first firm-level factor that shapes patterns of direct interaction with public research is thus the location of the firm, in relation to various potential interaction partners.

A second firm-level dimension that is commonly associated with differing abilities to appropriate the returns to public science is that of the sector/industry of the firm. Clearly, there are reasons to expect that universities are unequally important as direct sources of knowledge for different industries. In particular, it has been argued that one must distinguish between science-based sectors, where fundamental scientific knowledge has direct relevance for innovation, and other sectors, where the linkages between scientific knowledge and innovations are more indirect (Pavitt, 1984). Pavitt identifies electronics/electrical and pharmaceuticals as science-based sectors. More recently, the biotechnology and financial sectors have been widely discussed as “science-based”. Indeed, academically developed knowledge and methodologies have perhaps never been
more directly relevant for the development of an industry than in the case of the emergence of modern biotechnology in the 1980s and 1990s (McKelvey, 1996; Eliasson, 2000). Also beyond these special cases, the speed of technological progress can be argued to differ between sectors, and thus to create heterogeneous needs for contacts with the science base. Confirming sectorally based arguments, survey studies have confirmed that there is a considerable inter-industry variation in the propensity of firms to draw on university research (Klevorick et al., 1995; Meyer-Krahmer & Schmoch, 1998; Laursen & Salter, 2004).

In parallel to geographical proximity and sectoral patterns, the size of a firm has been presented as a third factor of importance in explaining university-industry linkages. Firm size has been found positively related to the propensity to consider public research an important source of knowledge for innovation (Mohnen & Hoareau, 2003) and, more concretely, to the propensity to interact directly with public research organisations (Fontana et al., 2006).

In the short run / partial equilibrium perspective, the size and sector of activity are exogenous to the firm. These variables can therefore be considered to represent a structural perspective on the distribution of knowledge spillovers across firms. It has been argued that the structural perspective is “incomplete and partial” and thus insufficient for studying the complex problem of who (i.e. which firm) is able to appropriate the short and medium term returns to publicly funded and organised science (Laursen & Salter, 2004). Complementing the structural perspective, studies in what Adams et al. (2003) call “the endogenous spillover literature” challenge the view of firms as passive receivers of spillover. By modelling knowledge spillovers at the firm level as at least partially subject to firm activities and strategies, this literature is able to explain a greater fraction of variability in incoming spillovers across firms. An important factor that has been analysed as interrelated with strategic activities in R&D is concepts of firm capabilities, such as absorptive capacity (Arora & Gambardella, 1994; Eliasson, 1990). Possible proxies for such capabilities are measures of R&D inputs such as human capital or R&D investments, or R&D outputs such as measures of publishing or patenting activity. Even when taking the possible simultaneity between these measures and R&D cooperation into account, capability is typically found to drive firms to interact with public research organisations (cf. Veugelers, 1997). Beyond differences in capability, it has also been suggested that differences in how firms organize their innovation processes, including the use of external interaction with customers and suppliers, affect a firm’s propensity to interact with public research organisations (Laursen & Salter, 2004).

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2 Notably, the firm-level factors that are discussed as associated with interaction with public research organisations are also associated with inter-firm interaction on innovation. In fact, since interaction with different kinds of actors can fulfill different roles for the innovation activities of a firm (Cohen et al., 2002), maintaining various types of external linkages in innovation can be considered as complementary activities, at least for the type of advanced firm that is typically found to collaborate with public research institutions (Arora & Gambardella, 1990; Belderbos et al., 2004a).

3 In the literature on the economics of innovation, the more narrowly defined concept of absorptive capacity (Cohen & Levinthal, 1990) has often been used in reference to firms’ abilities to innovate. For the analysis of such problems, however, absorptive capacity and dynamic capability can be considered as interchangeable concepts.
Veugelers & Cassiman, 2005). A typical approach in this literature is to study firm level strategic activities such as cooperation on R&D alongside with structural variables such as size, sector, R&D capabilities etc. as determinants of spillover impact (Cassiman & Veugelers, 2002).

There is thus considerable evidence that an analysis of which firms that interact directly with public research (i.e. establishes some form of direct contacts to PROs) should seek to take structural factors (size, sector), the issue of geographic proximity and two types of strategically determined variables (R&D capability, strategy for R&D) into account. Adding further complexity to the analysis, there is evidence that these factors interact with each other in determining the propensity for interaction. For example, Feldman (1994) and Acs et al. (1994) report that geographic proximity is particularly important for enabling small firms to interact with universities. Pavitt (1984) reports that firms in the industries he identifies as science-based are typically large. On the other hand, biotech firms, which also have been found more likely to interact with universities than other firms, are typically of modest size. Moreover, the choice of R&D strategy may be related to the size and sector of the firm, as these factors may determine the importance of incoming spillovers to the firm (Cassiman & Veugelers, 2002). I conclude that it is important to take all of the identified factors into consideration when designing research and analysing data on university-industry interaction. Failure to do so will typically bias the analysis.

2.2 Determinants of firm-level effects from interaction

One should expect that, at least for firms reporting persistent interaction with public research organisations, firms’ investments in such interaction in terms of direct funding and the labour of firm R&D staff are associated with appropriate long-run returns by firm management.\(^4\) However, when analysing the firm-level benefits of direct interaction with public research organisations, we must be aware that not only the magnitude of these benefits, but also the nature of the benefits may differ significantly between firms. Interestingly, the same set of factors that have been identified as determinants of interaction have been used to disentangle the different effects that firms gain from such interactions.

Santoro & Chakrabati (2002) report that larger firms mainly interact with public research organizations to build competencies in non-core technological areas, while small firms focus more on problem-solving in core technological areas. Shane (2002) claims that large firms and what he calls entrepreneurial firms make different use of academic consultants. While large firms seek to obtain assistance related to advanced technology developed by the firm, entrepreneurial firms establish consulting arrangements with a scientist when seeking to commercialise technology developed by that scientist. Perkmann & Walsh (2008) argue that the type of

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\(^4\) Nonetheless, we must expect that the returns differ between firms. Such differences may be related to the same factors that are listed in this section as determinants of interaction. For example, Laursen & Salter (2006) find that firms may apply interaction strategies that are too aggressive for optimal innovation performance.
academic consultancy that is mainly driven by research-related ambitions, and which therefore potentially reinforces rather than deteriorates the academic output of the engaged scholars, is mostly paid for by large firms with advanced R&D capabilities. No empirical test of this plausible hypothesis is, however, provided by Perkmann and Walsh. Audretsch & Stephan (1996) argue that in the biotech sector, linkages to distant scientists (who e.g. sit on the advisory board of the firm) can be used to signal the quality of the company and guide the R&D direction of the company. In contrast, direct knowledge transfer from universities is primarily associated with localised university-industry linkages. Cohen et al. (2002) report differences in how public research is used in 34 different sectors. In one sector (aerospace), public research is identified as an important source of information that both suggests new projects and contributes to project completion. In the pharmaceutical, petroleum, steel, machine tool and semi-conductor industries, public research is an important information source suggesting new projects (but less important for project completion). On the other hand, in the food, paper, drugs, glass, search/navigation equipment and car/truck industries, public research is primarily an important source contributing to project completion.

As demonstrated in this section, the same type of factors that determine a particular firm’s propensity to interact with a particular public research organisation (geographic proximity, size, sector, R&D capability, R&D strategy) are also suitable determinants of the benefits that the firm derives from interaction. The identification of relevant factors represent a first step towards the construction of a framework that is capable of explaining the impact of public sector research on the individual interacting firm. Notably, however, the literature on this subject is not yet well developed. In particular, there is very limited systematic understanding of how these factors interact, e.g. how a small, non-advanced firm is able to benefit from local and non-local linkages to universities, respectively. Throughout this thesis, I explore how our understanding of university-science linkages and their economic impact can be advanced by integration of the managerial dimension (i.e. heterogeneity in the rationale for establishing linkages) into the framework that is provided by the literature discussed in this section.

3. THEORETICAL FRAMEWORK AND METHODOLOGY

This doctoral thesis consists of five self-contained essays. They all take departure from a joint set of questions derived from economic theory, but different sets of theory derived from outside the mainstream neo-classical paradigm have been brought in to bear on the respective questions. The motivation for this theoretical triangulation is the underlying ambition to incorporate the strategic
perspective of the firm into the analysis of the economy-level phenomena of knowledge spillovers and, implicitly, economic growth.5

3.1 Endogenising the impacts of public research

An important ambition of this thesis is to bring elements of strategy into the study of university-industry interactions in a novel way. While there is a partial overlap between the strategy and management literatures on the one hand, and the field of economics on the other, there is also a basic difference concerning the perspective. As stated by Langlois (2003, p. 283), “strategy is concerned descriptively with firms and normatively with the tasks of managers, whereas economics is concerned descriptively with the economic system and normatively with the effective functioning of that system”. This thesis takes the position that not only can valuable ideas flow between the different disciplines that touch upon the problem of the public-private interface in R&D and innovation, but by borrowing the perspective of the management scholar, novel approaches to studying some of the problems of economics can emerge. This is the approach that is developed through essays II-IV, where observations of heterogeneity in the use of interactive linkages to universities are used as a starting point from which to re-assess a series of problems from the innovation economics literature.

The economics of science and technology is a field with a tradition of eclecticism (Audretsch et al., 2002). From that stream of research, the study of the interfaces between public and private R&D has inherited a tradition of synthesizing empirical observations and insights from other disciplines with problems generated from the framework of economics. Examples include the influence of sociological concepts on the so called new economics of science (Dasgupta & David, 1987, 1994), the conceptualisation of innovation processes from the point of view of economic history (Klein & Rosenberg, 1986) and capability-related concepts such as absorptive capacity (Cohen & Levinthal, 1990) or dynamic capabilities (Teece et al., 1997) from management studies.

The latter influence is the one that is most clearly reflected in this thesis, and as such deserves further comment. While often attributed to the works of the management scholar Jay Barney (1991), the ‘capabilities theory’ of the firm has been clearly influenced by Nelson & Winter’s (1982) evolutionary approach and by the theory of firm growth developed by the economist Edith Penrose (1959). Developed in response to the traditional focus of economists on explaining firms’ behaviour as a function of macro-environmental forces in a representative agent

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5 The neo-classical micro-economic framework is primarily a tool for analysing how firm behaviour and performance are affected by market interaction and macro-environmental forces, as mediated by the price mechanisms. Heterogeneity in terms of performance among firms is viewed as a temporal state of disequilibrium. In that sense, neo-classical microeconomic modelling is not the most natural place to start to investigate how differences in firm performance and capabilities are shaped by discretionary choices on behalf of firms (Nelson, 1991). Neither is neo-classical microeconomics, albeit investigations to this end are beyond the direct scope of this thesis, likely to be the most proper framework to study how firm-level decisions and activities aggregate to economic growth (Eliasson, 1984).
framework, capabilities theory sets out to describe organisational and performance heterogeneity. In doing so, it can be criticised for its inability to explain firm heterogeneity. This thesis makes reference to such ‘heterodox’ concepts of firm strategy and firm capabilities, suggesting that they can be usefully adapted for addressing some of the traditional problems of economics – in the case of this thesis to understand how public investments in academic science spills over to private firms (cf. Langlois, 2003).

3.2 Methodological considerations

In parallel to the shifting use of theoretical perspectives over the five essays in this thesis, the methodology used also varies between the essays. The shifting use of supporting theoretical perspectives and empirical methodologies reflects the shifting nature of the distinctly different but inter-linked research questions that represent the line of argument of this thesis.

Interviews with R&D managers, guided by reviews of existing literature and supported by discussions with various experts at supporting organisations, have been used to systematise patterns of behaviour (essays II and V) or to explore an issue, paving the way for hypothesis testing (essay III). Survey data has been used to test hypotheses generated from theoretical propositions and empirical observations in essays I, III and IV. The shifting methodological approaches of the thesis thus represent an iterative process of systematization, abductive exploration and inductive reasoning through hypothesis testing.

A general problem facing research on interaction between public and private research organisations is that of generalisation beyond the observed. The researcher must consider to what extent the observed characteristics of a certain selection of interactions are specific for the observed firms, e.g. whether the outcomes and modes of interaction are related to the specific R&D capabilities and innovation strategies of the observed firms. This problem is discussed in each of the five essays in its particular context, but a few general remarks can be made.

In the context of case- and interview studies, generalisation by statistical inference is not possible. Still, the design of the procedure through which cases are selected and careful account for this procedure in the research output are key to allow the reader to judge the analytical generalisability of the presented findings (Yin, 2003). In the essays II and V, interview-based case studies are used to systematise R&D managers’ views on the role of university relationship to their respective firms. In terms of generalisability, emphasis is here on including sufficiently many cases and a sufficiently broad set of interacting firms within the frames of carefully designed selection criteria. In parallel to a statistical analysis, the demand on what can be considered a “sufficient” number of cases is inversely related to the scope of selection, and what scope that can be considered “sufficient” is directly related to the research question motivating the study. In essay II, the scope is rather broad (“firms who interact with universities in R&D”) and hence the number of cases investigated unusually high for an interview study. The contribution of this essay
is made possible by the use of an interviews-with-random-sampling methodology which is
designed to provide in-depth information on the complex issues of university-industry exchange
from each case, while allowing for a higher degree of generalisability than that of case-study
research with only a few selected cases. In essay V, on the other hand, the scope is more narrow
(“foreign-owned R&D subsidiaries which interact with universities in R&D”), and the number of
studied cases correspondingly lower.

In the remaining three essays, the research questions are linked to model based evaluations of
causal relationships. Here, the issue of generalisation is closely linked to the issue of selectivity,
possibly also simultaneity, bias. In the context of essays I, III and IV, bias arises if the decision to
interact with public research organisations is correlated with traits that affect the outcomes of
such interaction. Particular estimators have been designed to handle this problem. In essay I, a set
of non-parametric matching estimators based on Abadie and Imbens (2002) are used to compare
the outcome in terms of innovation outputs between firms who do, respectively do not, interact
with universities on innovation. The contribution of this essay is closely linked to the novel
application of this estimation technique, which has been developed in labour economics, to a
familiar problem of innovation economics: the issue of the direct effects of firms’ interaction
with university researchers. In essays III and IV, this estimation technique is not directly
applicable, as the analytical focus is on how a specific variable (geography and public research
organisation, respectively) affect a reported outcome from interaction. For these studies, I fall
back on the well-known sample selection estimation methods developed by Heckman (1979).

Beyond the generalisation issues discussed so far, it may be useful to reflect on two broad
questions related to the research design: to what extent are the findings presented in this thesis
specific to the Swedish context in which the thesis is empirically founded and to what extent are
the findings specific for certain sectors? As seen from the summary in Table I, three of the
studies draw exclusively on observations from Swedish firms, and the remaining two partly do so.
Two of the studies draw exclusively on the engineering sector, which together with the
pharmaceutical and biotechnology sectors is the standard setting where university-industry
interaction has been observed and analysed. In the three remaining studies, no sectoral selection
criterion has been applied.

Table I: Criteria for selection of firms in empirical analyses

<table>
<thead>
<tr>
<th>Essay</th>
<th>Geographic selection criterion</th>
<th>Sectoral selection criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Swedish firms</td>
<td>All sectors</td>
</tr>
<tr>
<td>II</td>
<td>None⁶</td>
<td>All sectors</td>
</tr>
<tr>
<td>III</td>
<td>Swedish firms</td>
<td>Engineering firms</td>
</tr>
<tr>
<td>IV</td>
<td>Swedish firms</td>
<td>Engineering firms</td>
</tr>
<tr>
<td>V</td>
<td>Stockholm, Cambridge, Zurich</td>
<td>All sectors</td>
</tr>
</tbody>
</table>

⁶ Firms were selected on the basis of formal interaction with two universities in Stockholm. 37 out of 50 respondents worked for Swedish firms.
To what extent, then, do these methodological choices about selection criteria limit the possibilities of generalising the results? Let us first consider to what extent the mechanisms of university-industry interaction are country-specific. While empirical firm-level studies of innovation activities with data across countries still are scarce, existing evidence tends to indicate that country similarities are more significant than country particularities. This view is supported by studies of the innovation-productivity relationship across countries; at least when comparing traditional western countries, allowing for differences caused by differing market sizes and when pooling data across countries (Janz et al., 2003; Mohnen & Therrien, 2005; Griffith et al., 2006; Raffo et al., 2008). I interpret these findings so that there is no reason to be overly cautious about generalisability of the results of this thesis on the basis of country differences. Nonetheless, certain details of the empirical findings should not be generalised without caution. In particular, discussions of the difference between the regional and the national level (essay III) or the heterogeneity of universities (essay IV) refer directly to the Swedish context.

In reference to the main results of the essays, however, I would argue that the Swedish experiences are particularly relevant to study. Figure I displays, for each European country with more than 5 million inhabitants, the percentage of all innovative firms that report co-operation with public research organisations in the CIS 4 survey. It shows that Swedish firms’ interaction with public research institutes is on the EU-average, but interaction with universities is more common among Swedish firms than among average European firms. This relatively high frequency of interaction suggests that firm strategies for interaction and different modes of interaction are well developed among Swedish firms, making the Swedish setting suitable for the analysis of different rationales for interaction and their consequences.

![Figure I: Co-operation with public research in Europe's larger countries. Source: Eurostat, CIS 4.](image-url)
A particularity of the Swedish university system is that faculty members at universities (but not at public research institutes) retain the rights to immaterial property that originates from publicly funded research. The consequence for direct university-industry interaction is that firms that interact formally with university researchers make contractual agreements about immaterial property rights with the researchers personally, rather than with the university at which the researchers are employed. As emphasised by Mowery and Sampat (2004), there is however no robust evidence that the allocation of immaterial property rights to universities has substantial effects on the mechanisms or intensity of university-industry interaction. Note also that the trade with immaterial property rights in the form of patent acquisitions and licensing are rated as a relatively unimportant channel for knowledge flows between public and private research even in the US economy (Cohen et al., 2002), which is considered to rely more on formal immaterial property rights than other OECD economies. There seems to be little reason to believe that the findings in this thesis would be an artefact of the Swedish professors’ privilege legislation.

Turning next to the issue of generalisability beyond specific sectors, I note that this is mainly a question of importance for essays III and IV. In essay I, two broad sectors are considered in parallel (manufacturing and “services”). In essays II and V, firm-level observations from a wide set of sectors are included and systematised beyond sectoral divisions.

The hypotheses that are developed in essays III and IV are related to theory on interaction in innovation activities that in itself is not limited to a specific sector (or, for that matter, to the specific case of university-industry linkages). In essay III, however, there is no previous research to fall back on that deals with sub-firm level factors, and the hypotheses formulated are based on interviews with managers in engineering firms. Furthermore, when collecting data to test the respective hypotheses, the questionnaire that was used was formulated on the basis of interviews with managers and industry experts. As indicated in Table I, the survey was conducted among engineering firms only. Hence, the hypotheses of these essays have only been carefully studied in the context of engineering firms. The hypotheses per se are not, however, specific to any one type of sector, and they might as well be tested in other contexts. I hope to be able to return to this task in future work.

4. OUTLINE OF THE THESIS

The five essays of this thesis are self-contained studies, but they also follow a systematic logic. The first step seeks to empirically validate the theoretical arguments about the role of university-industry interaction for private firms (essay I). From this point, the thesis goes back and forth between exploration of the mechanisms through which firms strategically seek to benefit from university interaction and the relationships between these mechanisms and the conditions of
interaction. In particular, five conditions are being examined: public funding of collaborative research (essay II), the geography of interactions (essay III), the organisation of public research (essay IV), the capabilities of the firm (essays II, IV and V), and the organisation of the firm (essay V).

In essay I (co-authored with Hans Lööf), the impact of a firm’s collaboration with universities on innovation is examined using data from the Swedish version of the community innovation survey (CIS). This essay tests the theoretically based notion that interaction with universities can be instrumental in successfully developing innovative products and processes, and thus constitutes a starting point for the thesis. With some notable exceptions, previous empirical investigations have confirmed the theoretical predictions. We use a novel matching technique to deal with the problems of selection bias that are typical for attempts to establish treatment effects. The essay illustrates the differences that emerge from different matching estimators and samples. Considering this evidence, we find robust evidence that university collaboration positively influences the sales based on innovation and the propensity to patent of large manufacturing firms. In contrast, no significant association between university collaboration and performance in innovation can be found for small manufacturing firms, or for non-manufacturing firms of either size-class.7

Essay II takes the results of essay I as a point of departure, and goes on to investigate the mechanisms through which interaction with a university may help a firm to succeed as an innovator. Empirically, this essay draws on interviews with R&D managers at 50 firms who have formal relations with two research universities in Stockholm. A distinctive typology of rationales for establishing cooperative relations is presented, demonstrating a considerable breadth of interaction rationales. On closer examination, however, a “core” set of rationales related to innovation in terms of invented or improved products or processes are found to be the main drivers for interaction by the R&D managers. Based on this framework, the implications for public co-funding are analysed. In particular, the compliance between different rationales for interaction with public rationales for supporting university-industry relationships is discussed. In this exercise, public co-funding that allows the firms to influence (part of) the academic agenda is identified as a particularly interesting case that requires further theoretical attention.

Essays III and IV build directly on two key findings from essay II. From a methodological point of view, a central contribution of essay II is that it demonstrates how certain aspects of university-industry interaction can be analysed from the point of view of firm rationales. And since a “core” set of rationales was identified in that essay, analysis can now be meaningfully

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7 Note that these results do not automatically suggest that small firms and non-manufacturing firms “fail” to benefit from interactions with universities; it may be that the measures used in this study (and in most of the innovation economics literature) are too strongly oriented after a view of R&D based on the experiences from large manufacturing firms to properly capture the outcomes of other firms’ interaction. For a further discussion, see Broström & Lööf (2007).
limited to the different ways in which interaction can be related to the innovation processes of the firm. In essay III, this approach is used to analyse the role of geographic proximity for interaction on R&D. Narrowing the cross-sectoral perspective from essay II to engineering firms, a further set of interviews with Swedish R&D managers is used to explore the relationship between geographical distance and the different phases of the innovation processes. These interviews suggest that linkages in geographical proximity are more likely to generate impulses to innovation and create significant learning effects at the firm. Similarly, geographic proximate interaction is more likely to successfully contribute to R&D projects that are close to the market (i.e. expected to have market impact within one year). For interaction in long-term R&D projects, geographic proximity is generally seen as a less critical factor. A survey to 425 R&D managers in Swedish engineering firms provides evidence that supports these hypotheses.

In essay IV (co-authored with Maureen McKelvey), a parallel investigation of the role of the organisation of public research for R&D interaction is reported. This factor has largely been neglected in previous studies on university-industry linkages, and our essay is a first attempt to incorporate organisation as a new variable in the general framework describing the workings on university-industry linkages. We examine how R&D managers at Swedish engineering firms assess the value of R&D partnerships with two types of public research organisations: public research institutes (PRIs) and universities. Our results suggest that contact with university researchers are more likely than contacts with public research institutes to be open-ended, i.e. to provide firms with impulses to innovation and offer opportunities to learn rather than used to solve problems defined by the firm. However, a comparison between firms applying for patents and other firms shows that these differences are only valid for the former group – for non-applicants, which can be assumed to have less advanced R&D capabilities, there are no significant differences between universities and institutes. Assuming institutes to be more oriented towards applied R&D than universities, we also test the hypothesis that institute contacts are more likely than university contacts to be motivated by short-term rather than long-term problem solving. This hypothesis can not, however, be verified. All in all, our results suggest that in terms of perceived effects of R&D managers, public research institutes and universities are more similar as collaboration partners than what could be expected, given the differing institutional setups.

Taken together, the results presented in essays III and IV indicate that firms with advanced R&D capabilities have potential advantages to gain from locally based interaction with research universities, in order to facilitate learning effects that help the firm identify and formulate new innovation projects. If such benefits are significant, firms would have an incentive to locate their advanced R&D activities close to universities, in order to facilitate interaction-based learning. In essay V (co-authored with Maureen McKelvey and Christian Sandström), these predictions are tested on the case of R&D subsidiaries of multinational enterprises found in three European regions with reputable universities. Similar to essay II, this essay investigates the details of how
firms benefit from interaction with universities, albeit in this essay the context is a specialised one. By concentrating on the particular case of R&D subsidiaries, this essay connects the benefits of interaction to the overall R&D strategy of multinational firms. Four ideal types of strategy for localised interaction between R&D subsidiaries and universities are proposed. The empirical results allow an investigation of the alternative strategies for policymakers and university leaders interested in stimulating such linkages.

5. DISCUSSION

Each of the five papers of this thesis contributes to the literature on university-industry interaction, albeit attacking the issue from different angles. In this section, I elaborate on the contributions of the thesis as a whole. In particular, I show that the present thesis opens up for improved theorizing around the roles of academic research for industrial innovation. This contribution stems from the development of a novel conceptualisation of academic research, based on the point of view of industrial firms — a view that also can be meaningfully related to the economy-wide impact of academic science.

5.1 Beyond the discussion of basic vs. applied research

In countless academic studies as well as in the rhetoric of public debate and official documents governing the funding of public research, research has been conceptualised as existing on a one-dimensional scale between ‘basic’ and ‘applied’ activities. From this view, a stylised analysis of some central issues (all of which are touched upon elsewhere in this thesis) as typically used in the literature is summarised in Table II.

<table>
<thead>
<tr>
<th></th>
<th>Basic research</th>
<th>Applied research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge produced</td>
<td>Codified</td>
<td>Tacit</td>
</tr>
<tr>
<td>Spatial characteristic</td>
<td>Global</td>
<td>Local</td>
</tr>
<tr>
<td>Opportunities for private appropriation of results</td>
<td>Limited</td>
<td>High</td>
</tr>
<tr>
<td>Public funding</td>
<td>Yes</td>
<td>Only under special circumstances</td>
</tr>
<tr>
<td>Organisation of public research</td>
<td>University</td>
<td>Public research institute</td>
</tr>
</tbody>
</table>

The characterisation of research as either basic or applied has been criticized. Discussing the case of the natural sciences, Reagan (1967) claims that basic research is an almost mythical concept that is very difficult to observe in the everyday activities of scientific laboratories. In an attempt to explain the persistent popularity of the concept, he argues that the advocates of the concept
are mainly motivated by its usefulness in political debates on research funding: “we can question whether the insistence upon the uniqueness and separability of basic research is not at least as much a political as a scientific concept, in origin and in significance.” Obviously, the distinction between basic and applied research is not more clear-cut in social or engineering sciences. Critiques of the use of this distinction in studies on the economics of innovation and research are possibly on three associated accounts.

First, the dichotomy has been challenged on conceptual basis. Stokes (1997) argued that the one-dimensional concept cannot account for substantial parts of the fundamental research that underlies modern technologies. Stokes argues that only by adding the dimension of ‘consideration of use’ and by recognising the existence of use-inspired, fundamental research, which Stokes exemplify with the work of French chemist Lois Pasteur, can we avoid serious misinterpretations of the role of research in technological progress. It also remains at best questionable whether the basic-vs.-applied dichotomy represents a relevant dimension in which to analyse the tradeoff between industrial and ‘purely academic’ interests in academic research (Ranga et al., 1999; Van Looy et al., 2004; Azoulay et al., forthcoming).

A second line of critique is that even if the basic-vs.-applied dichotomy can be motivated in discussing the role of public science in economic systems, following Nelson (1959) and Arrow (1962), it should not be used as a general characterisation of research. For example, it has little to say about the strategic motivation for and organisation of industrial research. When nonetheless used in such contexts (e.g. Cockburn et al., 1999), the concepts have to be redefined (or, to use Marxian terminology, reified) in a way that may cause conceptual confusion. For example, Cockburn et al. associate basic research with activities that build absorptive capacity in the firm, but do not present any arguments about the extent to which such activities have similar characteristics as ‘basic’ curiosity-driven university research.

Last but not least, a third intrinsic problem with the basic-vs.-applied distinction is that it can not be operationally well-defined. Basic research is for example often defined from the perspective of the motivation for research, but how can one ever For example, the position of a particular research endeavour on the basic-vs.-applied scale depends crucially on the time perspective: how fast does research have to lead to a ‘solution to a particular problem’ for it to be considered applied? As a consequence of such ambiguities, ‘basic research’ is used with interchangeable definitions, producing results that cannot be compared.

In his critical discussion of the basic-applied dichotomy, Reagan (1967) concludes: “Definitions being arbitrary in any case, perhaps we need different types of definitions for different purposes, or to illuminate particular aspects being emphasized in a given context. It would be useful in this connection to explore the views of sponsoring agencies; directors of programs that use science; and research administrators in universities, industrial firms, and government laboratories.” In line
with these 40 year old suggestions, the studies presented in this thesis adopt the perspective of
the user of science – in this case defined as firms interacting with universities – and develop a
different characterisation of research that can be used to analyse specific research questions.

In three of its chapters, this thesis approaches the previously examined questions listed in Table I
from a new perspective. Essays II, III and IV use firm managers’ perceptions of how far away a
certain innovation is from the market to analyse the roles of geographic distance, organisational forms
and public co-funding of interaction. This approach breaks away from the basic-vs.-applied
dichotomy. It is also not a matter of simple re-naming. In a previous examination of this
problem, Rogers & Bozeman (1997) report that collaborative projects between public and private
research labs which were perceived as oriented mainly towards “basic” research were as likely to
facilitate short- and medium-term industrial product development as were “applied” research
projects.

5.2 Towards a theoretical framework?

With university-industry linkages having received significant attention from scholars for quite
some time, we should be in a position to move towards the construction of a theoretical
framework that links observable characteristics of university-industry interaction to their impact
on the firm and the wider economy. The long-term objective of such modelling would be to
improve the microeconomic foundations of growth theory (cf. Acs et al., 2009) in a manner that
makes not only key decisions of economic agents, but also the long-term growth levels, truly
endogenous (Jones, 1995). Can the present thesis, which is empirically oriented, contribute to
such a development? Before addressing this question, let us consider what requirements we
would have on a theoretical framework for university-industry interaction. Two criteria seem
reasonable. First, it is attractive to build such a theoretical framework on economically motivated
rational or semi-rational behaviour of economic agents. That is, we should endorse the principle
of methodological individualism (Blaug, 1992). Secondly, we should construct theory that is
empirically testable based on operational categories, so that the theoretical concepts can be
meaningfully captured by empirically observable characteristics. This is particularly important to
enable comparability between the findings of different research reports.

Research approaches that meet these two requirements include the strand of literature that puts
emphasis on the individual who is engaged in technology transfer (Zucker et al, 1998a,b) and the
wave of firm level modelling that is emerging, enabled by the quickly growing access to advanced
micro-level data (Belderbos et al., 2004b; Laursen & Salter, 2006). Notably, neither of the two
requirements are met by one popular line of analysis that have tried to link firm level
characteristics to the effects of interaction through characterisation of the knowledge involved in
interaction. These characterisations are typically referred to as tacit or codifiable; scientific or
technological; basic or applied. As argued above, these classifications of knowledge – while
theoretically elegant – are asserted with significant ambiguity when deployed in empirical studies. Similarly, attempts to study university-industry interaction through a focus on the form/mode of the interaction (Arvanitis et al., 2008) fail the test of the criteria proposed above, as the linkage to economic incentives is generally underdeveloped. While studies on the modes of interaction are valuable per se, they are therefore not good building blocks for further theorizing.

So how about developing theory around firm rationales for interaction, for example as delineated in this thesis? Clearly, basing theoretical work on firm rationales satisfies both criteria proposed above. Firm rationales for interaction can also be connected to the wider question of the economic impact of public research. Interestingly, it has recently been shown that the characterisation of research in terms of the number of stages remaining until a commercial payoff can be realized can be used to formally model the role of public science for optimal technological development (Aghion et al., 2008). While scientific openness is critical for academia to fulfil its role as creator of economically valuable knowledge also in the framework of Aghion et al. (Murray et al., 2008), it is thus not necessary to base the definition of economically valuable public science on an appropriation rights argument. Together with the essays of this thesis, these findings seem to motivate further research analysing the spillover effects of public science from a distance-to-market perspective, e.g. in connection to the organisation, management and funding systems for publicly funded research.

The studies presented in this thesis suggest that when relating firm-level factors such as firm size, sector, R&D capabilities and R&D strategy to each other and to interaction-level characteristics such as mode of interaction and geography of interaction, the interaction-level variable of the specific rationale for the interaction can be usefully integrated in the analysis. There may thus be a case for using the interaction rationale variable as a basis for further theorizing about university-firm interaction.8 However, for theoretical progress along this line, the different rationales for interaction must be properly related to the factors driving the investment decisions of the firm. This step, which goes beyond the scope of the present thesis, requires further empirical research on the costs, failure rates and pay-offs as related to the different types of benefits that firms derive from interaction with public research organisations. That is, while the concept of rationales for interaction provides a bridge between the ex-ante expectations of firms and the ex-post effects that firms gain from interaction with PROs, the connection between ex-ante and ex-post must be made explicit to allow formal theorising based on this concept. Only then can we identify the magnitude of potential spillovers from public research to individual firms.

8 While beyond the scope of the present discussion, interaction rationales could equally well be used to analyse the more general case of interaction on innovation between a firm and different kinds of partners.
6. POLICY IMPLICATIONS

In today’s global economy, investment in science and innovation is not an intellectual luxury for a developed country, but an economic and social necessity, and a key part of any strategy for economic success.


The idea of an institution that, independent of political and religious authorities, engages in the pursuit of knowledge for the development of society is an appealing one. It has a long tradition. Three years after his coronation as “holy roman emperor” in 1155, Fredrick Barbarossa signed the Constitutio Habita, in which the University of Bologna was guaranteed independence. However noble and altruistic the act of signing this charter may appear, it is clear that already this first European university was considered not only a centre of knowledge, but also an economic and political asset. Even after a league of Lombard city-states defeated the imperial forces at Legano in 1176, the new rulers of Bologna let the scholars keep their independence – on the condition that they swore to confine their teaching activities to the city itself. The rulers of the city thereby sought to ensure a continued inflow of European students to the already recognised seat of learning.

It seems that universities throughout history have maintained their double role as sources of both economic and philanthropic values. However, the rhetoric motivating their funding through public sources has shifted between each of them from time to time. The quote by Britain’s former minister for science and technology Lord Sainsbury, which opens this concluding section, represents a view of universities as “engines of growth” that has won considerable influence in recent times. This view suggests that the research presented in this thesis may be of interest to the domain of policy. So what messages can be read out of its five essays?

The five stand-alone essays contained in this thesis each reports results that relate to public policy. However, it can be argued that the most interesting contributions of this thesis to the understanding of how public policy should relate to the issue of university-industry interaction are derived when considering the policy-related implications of the results in different combinations.

Combining the findings of essays I and II, we may conclude that interaction with university researchers strengthens the average firm as innovator – at least in the case of large manufacturing firms – and that such effects arise in a rich variety of ways. We thus have the outline of a case for allowing, perhaps even supporting, direct university-industry interaction.

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9 “ Engines of growth” is the title of a report issued in 2003 which describes the regional impact of the activities of the eight research universities in Boston.
Adding the findings from essay III to this story, we find that for an important subset of the mechanisms that drive these effects, geographical proximity is a facilitating factor. At least, there is evidence of a significant difference between domestic and foreign university-industry linkages for Swedish engineering firms. By further comparing these indications with the findings of essay IV, we are able to draw some conclusions about how the organisation of the national public research system affects the opportunities for domestic firms to find suitable interaction partners. In particular, we note that firms are most likely to pick up new perspectives and ideas that enable them to start new innovation projects when interacting with domestic (preferably local) universities. At least for more advanced firms, this role of domestic universities can not be substituted by institutes, creating an important role for domestic universities of high academic standing in advanced economies. On the other hand, domestic institutes are an ideal partner for the short-term, application-oriented project needs of advanced firms.

Hence, a government that wants to position a country as an attractive location for private R&D activities should build domestic public sector research expertise of relevant scale that includes both academic and industry-oriented qualities. In essay V, it is tested whether these suggestions can be drawn so far as to indicate that governments can rely on university research to attract international greenfield R&D establishments in their capacity as interaction partners. The findings show that such a policy is if not misguided, so at least associated with significant challenges. Only for a particular type of small corporate research units that seek to interact very closely with university researchers can public research environments exercise such a decisive attraction for location. And for that type of international investments to take place, the public research organisation must be visible as a “global centre of excellence” in a relevant research area, and an institutional framework that enables public-private interaction as well as opportunities for co-location must be put in place.

In conclusion, I define two broad policy-related themes that flow naturally out of this thesis, but which are not covered explicitly in any of its chapters. First, the essays in this thesis seem to point to a need for certain pluralism in terms of organisation and co-funding within the national system of research, if this system is to function as a valuable partner for industrial firms. This is a serious challenge, that should not be dismissed as a call for “more of everything”. To develop cohesive research and innovation policy that is able to balance the different demands on the public research system, we need to increase our understanding of the different roles that public research has to play for industrial renewal and the trade-offs between these roles.

Second, this thesis analyses firms’ strategic interactions with industry. In the many contacts with firms that I have had in writing this thesis, I have become convinced that firms are becoming, or at the very least are actively trying to become, more deliberately strategic about their external

Note that for a few very advanced and resourceful firms, geographical distance is most likely a less relevant hinder for interaction.
R&D relationships – including those with public research organisations. At the same time, the interest of the state in university-industry relationship has increased strongly. As a consequence, the interface between public and private research is changing. Putting it bluntly, if the interfaces between public and private research were formerly populated by publicly and privately employed academics and sponsored by more or less benevolent firms, they are now the playground of privately employed strategists and publicly employed academics. In response to these changing conditions, the academics, or at least the policy makers that fund them and the university leaders that organise them, probably have to become more strategic themselves.

Many voices have been raised, warning that interaction with industry may destroy the long-term value of the science base. Certainly, these objections are valid in the sense that there are tensions between the interests of the different actors in the public-private research interfaces, for example between the notion of scientific results as open to the world and the appropriation interests of private firms (Campbell et al., 2000) or between the academic long-term research agenda and the short-term needs of private firms (Geuna, 2001). Outright rejection of direct university-industry interaction is, however, not likely to constitute an optimal policy. Rather, the concerns point to the need for careful management of the interfaces between public and private research. More than a decade after its publication, and more than eight centuries after the charter of the University of Bologna was signed, Lee’s (1996) characterisation of universities as in the process of searching for “the boundaries of university-industry collaboration” still captures the present situation quite accurately.

7. REFERENCES


An example of such behaviour visible in the studies is the emergence of a type of highly specialised corporate research units that is identified and described as “Seamless networks” in essay V. The identified units are all rather new establishments, suggesting that this is a new phenomenon.


