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How do Organisational and Cognitive Distances Shape Firms' Interactions with Universities and Public Research Institutes?

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Abstract

This paper examines how the institutional set-up of public research organisations (PROs) affects how firms are able to utilise direct interaction with publicly employed researchers. We argue that the role that PRO interaction has to play in the firm's innovation processes depend on the organisational and cognitive distances between the firm and the PRO. In particular, this paper empirically explores how Swedish engineering firms assess the value of R&D partnerships with universities and research institutes. Our theoretical discussion of organizational distance suggests that managers should perceive institute contacts to be more strongly associated with short-term R&D projects than university contacts. This hypothesis cannot be verified. Following from our discussion of cognitive distance, we find that firms with advanced R&D capabilities obtain differential benefits. Their interaction with universities provides impulses for innovation and offers opportunities to learn to a greater extent than contacts with public research institutes. However, firms with less advanced R&D capabilities perceive no significant differences between university and institute interaction. Thus, both organizational and cognitive distance affect firms' interactions with PROs, and our results have implications for the current push in Europe to reform universities and institutes.

Keywords: public research organisations, organisation of public research, universities, institutes, R&D interaction

JEL-codes: O32, M21, O31

1. INTRODUCTION

In recent years a rich variety of literature has focused on the role of universities in innovation (Feldman and Breznitz, 2009). This interest has been motivated by a recognition of public research organisations (PROs) as important complements to private firms in innovation processes. This paper adds to a growing stream of research that seeks to improve our understanding of the role of public sector research and development (R&D) in modern economies by examining the role of a number of interrelated institutional factors such as organisation, research management, incentives and (local) culture (Bonaccorsi, 2007; Carayol and Matt, 2004). Many recent studies have focused on how institutional differences shape differences in academic collaboration patterns (Heinze and Kuhlmann, 2008; Boardman and Corley, 2008). This paper contributes to the literature through an analysis of how firms assess the value of R&D partnerships with two different types of PROs: an academic type of PRO and an industrially oriented PRO. We postulate that these two types of PRO have different organisational and cognitive distances to firms, as a consequence of the differences in the sets of rules, norms and incentives that dominate the respective type of organisation. A key novelty of this paper is that we analyse the role of organisational and cognitive differences between these two types of organisation by relating formal interaction with PROs to firms' objectives and the perceived benefits.

Throughout this paper, we refer to any PRO that is characterised by academic rules, norms and incentives as a *university*. Note that the defining characteristic of this type of PRO is not that it undertakes higher education. In fact, in some national settings, important academically oriented PROs are not higher education institutions (e.g. the CNRS in France and the Max Planck society in Germany). We refer to a PRO that is industrially oriented as a public research *institute*. Widely known examples of such organisations include the German Fraunhofer society and the ITRI in Taiwan, which together with other institutes "emerged as the central and defining institutions of the East-Asian catch-up experience" (Mathews and Hu, 2007, p. 97).

Based on classic arguments from Nelson (1959) and Arrow (1962) through to modern debates, economists argue that basic research funded by the government plays a particular role in stimulating economic growth. Usually, publicly funded research is seen as that carried out by universities. For example, the Triple Helix model discusses the interactions among firms, universities and public policy agents (Etzkowitz and Leydesdorff, 2000). Mansfield (1998) has shown that government-funded science plays an important role not only for the economy per se, but also as a source of impulses and development support for individual firms. Similar results showing how universities can be stimulating sources of ideas for firms are found in broad surveys such as the Community Innovation Survey (CIS). Yet, most of this literature discusses public research organisations as a broad category that includes both universities and public research institutes. In our view, universities and public research institutes are two distinct organisations,

with different organisational routines, incentives for employees and cognitive frameworks. Therefore, universities and public research institutes can be expected to play different roles within the knowledge economy. Surprisingly, these core differences among the two are debated in public policy and visible in detailed accounts in the sociology of science and technology but are rarely examined in detail in the innovation literature.

Universities and public research institutes can be expected to have different characteristics in terms of mission, culture and research scope (Bozeman, 2000). Universities have at least traditionally had a broad mission to develop knowledge, train students and interact with society. Public research institutes and laboratories generally have a more narrow focus, their primary objective being to solve specific problems and issues of relevance to the private sector. Institutes are often set up to assist a particular industry, such as paper and pulp, or along technology lines, such as the joint research venture on integrated circuits. This study argues that the different institutional set-up of universities and institutes leaves them differently positioned to provide specific types of benefits to industrial firms.

As is further developed below, we expect that firms should have different rationales for interacting with the two types of organisation. These expectations are derived from an analysis of two dimensions: *organisational* and *cognitive* distances. The first of these dimensions concerns the differing degrees of control that firms are expected to be able to exert over their interactions with university researchers compared to that which they can exert over institute researchers. The second dimension concerns the extent to which firms, and here we differentiate between firms with advanced R&D capabilities and firms with less advanced capabilities, share a set of knowledge-related characteristics with the two kinds of PROs. We analyse both these dimensions to derive predictions of how the institutional set-up of a PRO and the level of innovation capability of the firm determines what firm-level effect a certain firm-PRO linkage is likely to have. In discussing the effects of linkages, we build on the findings of Klevorick et al. (1995) and Cohen et al. (2002), who report that academic research contributes to two sets of objectives for the firm: the generation of new ideas and innovation completion.[1] The first objective is related to impulses to innovation, or what can be called "learning what you need to learn", while the other objective is to be able to pursue an innovation project already defined by the firm, usually meaning direct problem-solving or goal-oriented technology development. We define a linkage to a PRO as *open-ended* if this linkage is perceived to be more important to provide the firm with impulses to innovation and facilitate learning (open-ended search) than to help the firm complete projects initiated by the firm. In a second step, we differentiate between two types of innovation projects in which firms can acquire assistance: short-term and long-term. The first type is expected to reach a marketable stage within one year, and is typically thought of as highly applied

[1] Collaboration with PROs also serves a wider set of purposes, more indirectly related to innovation outcomes. Examples of such purposes, which are outside the scope of this paper, are related to recruitment, access to international networks and access to public co-funding (Broström, 2008).

R&D. The second type is long-term development of technology or other exploratory R&D that is not expected to result in new or significantly improved products or processes within a timeframe of one year. We define a linkage to a PRO as *focused on short-term effects* if the former type of rationale dominates the latter for this particular linkage.

In discussing, first, the difference between new ideas (open-ended rationales for interaction) and project assistance (ex-ante well-defined rationales for interaction); and, second, the difference between long-term and short-term projects, we develop a more nuanced view of the discussion of PRO-industry linkages as oriented towards either "basic" or "applied" R&D. Following Aghion et al. (2008), we consider the "basicness" of R&D to be related to the distance between the innovation phase and a marketable product. In the classic definition of basicness, it is related to the degree of appropriability (Nelson, 1959; Arrow, 1962). In works that take this classic approach, the basicness of research is conceptualised as related to the knowledge involved per se. In contrast, by adopting the usage of Aghion et al., the concept of "basicness" can be used to discuss and empirically investigate interaction outcomes from the market-oriented perspective of the firm.

Our analysis allows us to make three predictions about the interaction experiences of engineering firms. First, interaction with universities should be more likely to be focused on learning. Second, contacts with institutes should be more likely to be focused on short-term effects. Third, these effects should be more clearly pronounced for firms with advanced R&D capabilities than for firms with less advanced capabilities. These predictions are tested using novel data from a survey of 425 Swedish engineering firms, which were assessed in a sample selection probit framework.

This study is a contribution to the literature on external relationships for innovation, given that our knowledge of the role of institutes in collaboration networks is very limited. Even if institutes are included as a distinguishable group in e.g. the Yale and Community Innovation Survey (CIS) surveys, many studies refrain from analysing collaboration with this particular group (cf. Klevorick et al., 1995). Instead, these two groups are often merged in order to focus on the broader issue of collaborative linkages between public and private R&D. Thus, for many studies reporting from, for example, the PACE, KNOW and CIS surveys, the focus is on PROs as a single group (cf. Faulkner and Senker, 1993; Beise and Stahl, 1999; Cohen et al. 2002; Arundel and Geuna, 2004; Fontana et al. 2006; Cassiman and Veugelers, 2002; Tether and Tajar, 2008). In light of the current push in Europe to reform universities and institutes, new examinations of the possibly *different* roles of universities and institutes in innovation networks should have important messages to send to public policymakers and PRO leaders.

This paper is organised as follows: Section 2 discusses the division of labour in the knowledge economy, and more specifically how universities and public research institutes may be expected to play different roles in innovation collaboration with firms. This discussion is linked to the

notion of organisational distance. Section 3 discusses how these organisational differences may be mediated by firm innovation capability. This discussion is linked to the notion of cognitive distance. Section 4 presents the survey and details of the data collected to test the three hypotheses derived from the literature reviews in sections 2 and 3. Section 5 presents the modelling framework within which the data are tested, and the results of these tests. Section 6 concludes the paper, providing insights into the broader implications of the study.

2. ORGANISATIONAL DISTANCE: A CONTROL-BASED ARGUMENT

This study examines direct, formalised interactions between engineering firms and public research organisations – a form of firm-PRO linkage that has been found to be the more strongly associated with firm-level benefits than other, more informal types of interactions. This finding has been confirmed both for universities (Kaufmann and Tödtling, 2001) and institutes (Adams et al., 2003). This section develops the idea that even when formalised, interaction with universities is associated with different degrees of control by the firm than interaction with public research institutes. This difference is related to the division of labour in the knowledge society, in that different organisations may populate different parts of the public system for knowledge creation and diffusion. To capture this difference, we use the notion of organisational distance. This theoretical construct refers to the rate of autonomy and the degree of control that can be exerted in inter-organisational arrangements (Boschma, 2005), once a temporary contractual relationship has been established. In other words, we define organisational distance as an inverse measure of principal-agent-style control; from close control and surveillance opportunities (short organisational distance) to limited possibilities to control or steer the contracted partner (long organisational distance).

Existing literature suggests that the institutional factors which determine the organisational distance to firms should have an impact on the usefulness of interaction with PROs to industry. Bozeman and Crow (1991) sampled 134 government laboratories and 139 university laboratories in the United States. They found that laboratories which have "commercial efficiency criteria" are more likely to report involvement in technology transfer to industry. Baldini et al. (2006) conclude that differences in patenting activity by Italian universities are to a large degree explained by differences in internal regulations for the management of immaterial property. Lach and Schankerman (2008) show that universities in the United States that provide stronger royalty incentives to faculty scientists generate greater license income, controlling for university characteristics. When comparing two types of organisational forms for universites (public and private), the authors find that the impact of incentives is larger in private universities.

This study focuses on systematic institutional differences between universities and institutes, which we see as directly related to their different organisational missions and to the types of research and development in which we would expect them to engage. On the one hand, we view a university as an institution governed by academic rules, norms and incentives (Dasgupta and David, 1995). Researchers are exclusively rewarded on the basis of peer review and of the impact of their academic publications. Importantly, individual scientists retain the right to decide what projects to take on. On the other hand, we view an institute as a hybrid form of organisation, where a mission to perform R&D relevant to innovation and to interact with private businesses is a clear objective and, moreover, is carried out through managerial control and coordination mechanisms. Control mechanisms and a reward system only partly based on the impact of academic publications also reduces the conflict between academic objectives and firms' objectives – sometimes described as a conflict of "publishing or patenting" – that is reported to constitute a significant barrier to collaboration between firms and university researchers (Lee, 1996).

Because of these differences, we expect that the organisational distance between firms and public research institutes will be lower than that between firms and universities. We therefore expect institutes to be better positioned than universities to interact with firms on the basis of agreed contracts that give the firm the ability to control the focus of the interaction and maintain that focus on a problem or task specified by the firm. These aspects are related to the fact that the two types of PRO are expected to have differing views on project objectives and timely deliverance, as well as different views on what constitutes an "interesting problem".

We are now ready to develop formal hypotheses. Our first hypothesis focuses on the difference between open-ended rationales for interaction, and rationales related to an objective defined by the firm. From our discussion, it follows that interaction is more likely to successfully contribute to project objectives already defined by the firm when the firm and the PRO are at short organisational distance from each other. On the other hand, interactions at short organisational distance may not be flexible enough to stimulate the emergence of new ideas and interactive learning (Liebeskind et al., 1996; Blanc and Sierra, 1999). Based on our view of institutional differences between universities and institutes, we have the following hypothesis:

H1: Linkages to universities are more likely to be *open-ended* than linkages to public research institutes

Our second hypothesis focuses the analysis on project completion, that is, firm-PRO linkages that help the firm to complete projects initiated by the firm. We expect researchers in universities to have lower incentives than their colleagues in institutes to engage in interaction with firms where the objective of the firm is short-term development. This expectation builds on a stylised view of such short-term projects as typically not generating academic research results, and of universities as governed by academic rules, norms and incentives. Even though contacts with

firms' applied problems can inspire further research and help university researchers to fund their departments (Lee, 2000), the total incentive of a typical university researcher should still be lower than that of a typical institute-employed researcher. In consequence, we expect the following:

H2: Linkages to institutes are more likely than linkages to universities to be *focused on short-term effects*

To summarise our first two hypotheses, we predict that firms are more likely to use universities as "listening posts" and to use institutes as suppliers of applied services. These hypotheses, if confirmed, would confirm a view of a "division of labour" between universities and institutes in a national innovation system (Nelson, 1993; Arnold et al., 1998).

3. COGNITIVE DISTANCE: MATCHING INNOVATION CAPABILITIES

Beyond the control-related argument for why we expect different public research institutions to have different functions in innovation networks, such patterns may also arise from differences in knowledge. Previous studies on linkages between firms and PROs have taken an interest in how differences in the knowledge base make public institutions more or less valuable as partners in innovation activities. The reported evidence is, however, ambiguous. Ponomariov (2007) finds that academics active at institutions with relatively low academic prestige, are most likely to report interaction with firms. Mansfield and Lee (1996) find that when representatives of a number of large US companies identify their most important partners among universities, both top-ranked and more average-performing research groups are included. Schartinger et al. (2002) report similarly ambiguous results in an Austrian study – the academic performance of the collaboration partner can be shown to be important in joint ventures, but not for other forms of interaction. We aim to advance this discussion by relating the competences of the two types of PRO to the partner firm's competences and to the benefit of the interaction perceived by the managers of firms.

Only a handful of previous studies have empirically contrasted the role of public laboratories and institutes with that of universities, and almost all the available studies describe the situation in the United States. Crow and Bozeman (1998) discuss how US government laboratories are characterised by more applied research, whereas universities are said to be oriented towards basic research. Somewhat contrasting evidence is presented by Jaffe and Trajtenberg (1996) and Jaffe and Lerner (2001), who find that while the laboratories lagged behind universities both in terms of patenting volume and patent quality in the 1970s and early 1980s, that gap had closed by the 1990s. A corresponding trend in Europe for convergence in the output patterns of each sector of

PROs is reported by Senker (2006). However, none of these previous studies has examined the role of universities and institutes from the perspective of the interacting firms. This section applies a wider characterisation of knowledge than that reflected in patented output in order to develop such a perspective.

From the perspective of the firm, variation and diversity are necessary for exploratory, open-ended activities that may generate impulses for future innovation (March, 1991). Bercowitz and Feldman (2007) argue that such characteristics are less likely to be found in an external partner operating "in the shadow of the same dominant industry technology paradigm". In a similar vein, Noteboom (2000) discusses how the "cognitive distance" between two firms affects the potential for valuable learning between the firms. Cognition in this sense includes an overlap in knowledge bases, values, norms and the heuristics of attribution and decision-making. At overly large cognitive distances, actors will not be capable of meaningful exchange. In congruence with Bercowitz and Feldman and with March, however, Nooteboom argues that too little cognitive distance reduces the value of inter-organisational learning and impulses. In essence, cognitive distance between two firms is likely to have an inverted U-shaped relationship to the outcome of learning between two organisations. This argument has been refined and tested by Noteboom et al. (2007), by adding the notion that for relationships devoted to exploitation rather than learning and exploration, cognitive distance is mainly a problem for interchange. These arguments are summarised in the stylised illustration at Figure 1. Note that the potential value of a linkage is considered in relation to a fixed level of investment in establishing and maintaining the linkage on behalf of the firm.

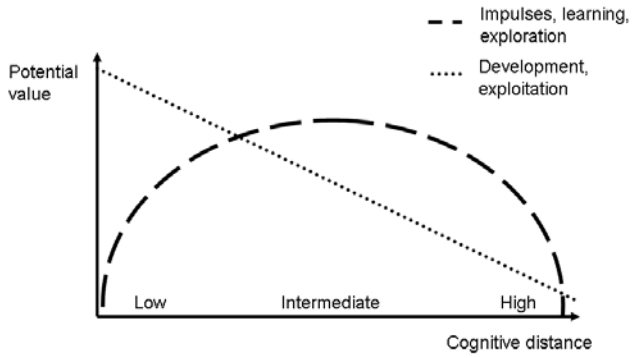

Figure 1: The potential value of inter-organisational contacts, given a fixed level of costs, for exploration and exploitation

From the view of the differing missions, incentives and models of organisation between universities and institutes developed above, we predict that university staff on average are at a greater cognitive distance from R&D personnel in firms than are researchers at institutes. We develop our argument by introducing a second dimension of analysis: firm level capabilities for

innovation. We postulate that for engineering firms with advanced R&D capabilities, institutes are at a short cognitive distance and universities at an intermediate distance. Furthermore, we postulate that for firms that lack advanced R&D capabilities, institutes are at an intermediate cognitive distance and universities at a long distance. [2] Table 1 summarises these predictions.

Table 1: Summary of predictions of the potential value of inter-organisational contacts

	Advanced R&D capabilities	No advanced R&D capabilities
Cognitive distance to universities	Intermediate	Long
Potential for impulses	High	Low
Potential for development	Intermediate	Low
Cognitive distance to institutes	Short	Intermediate
Potential for impulses	Low	High
Potential for development	High	Intermediate

Source: authors' exposition

For advanced firms, the cognitive distance argument in this section and the organisational distance argument in section 2 work in the same direction. For non-advanced firms, the two arguments go in somewhat different directions. In particular, the two arguments seemingly counterbalance each other in predicting which of the two PRO systems can be expected to be most strongly associated with impulses for innovation and open-ended search efforts. We therefore hypothesise that the differences between the two systems are perceived as greater by firms with advanced R&D capabilities than by firms with low or highly application-oriented R&D capabilities. In particular, we hypothesise that the relationships described in H1 and H2 are stronger for more advanced firms (proxied by firms which apply for patents) than for firms with no or purely application-oriented R&D capabilities (proxied by firms which do not apply for patents).

H3: Firms with advanced R&D capabilities are more likely to report different types of benefits from interaction with universities and institutes, respectively, than firms with no or purely application-oriented R&D capabilities.

[2] Note that while firms with advanced R&D capabilities are predicted to find high potential for both exploration and exploitation in interactions with the public research system, firms with non-advanced R&D capabilities are only predicted to be able to find strong support for exploration. Together with the observation that firms with non-advanced R&D capabilities normally do not engage in R&D activities only for learning purposes, our predictions match the established stylised fact that firms with advanced R&D are much more likely to interact with PROs than other firms.

4. DATA AND DESCRIPTIVE RESULTS

To test our hypotheses, we collected data from Swedish industrial firms. We expect this setting to be a good choice to test our predictions about how organisational and cognitive distances shape the outcomes of firm-PRO interactions. The Nordic countries are interesting test beds for studying university-industry collaboration, since activity levels in these countries are higher than in other EU countries, as revealed by the CIS. There are thus reasons to expect Nordic firms to have relatively long experience of collaboration, and to have developed strategies for interaction with universities and public research institutes. Similar to many other settings, the Nordic institutes mainly target the engineering sector. We therefore choose to restrict our data collection to this sector. With these sampling choices, we expect that our stylised view that universities and institutes have different rules, norms and incentives will be relevant in the empirical setting.

A short survey was constructed focused on the variables of interest to this study. To test its feasibility and guide the formulation of the questions, a series of test interviews with Swedish R&D managers was undertaken. The survey of 425 workplaces in the Swedish engineering sector was conducted during the summer of 2007. The workplaces were randomly selected and stratified by size. All workplaces were contacted by telephone and asked to identify the best respondent for our survey. In declining order of priority, the workplace was asked to identify its R&D manager in charge of external relations, general R&D manager, technology manager, production manager or site manager/CEO. The respondents were then contacted by e-mail and given the opportunity either to respond to the survey electronically or to indicate that they did not want to participate. A reminder e-mail was sent after one week. In parallel, respondents who had not reacted to the survey were contacted by telephone and given the option of responding to the survey questions orally. After three weeks of intensive efforts, a final e-mail was sent. In total, 68 per cent of the respondents completed the survey. A further 6 per cent gave incomplete answers.

In the stratified sample, 37 per cent reported collaborative relations with public research institutes, and 64 per cent with universities. A further 11 per cent reported that they were interacting with universities exclusively through student projects. For the purpose of this paper, the latter are considered non-collaborators. Finally, 32 per cent reported collaboration with both public research institutes and universities. To control the validity of the data, we tested whether they could replicate previous findings on the determinants of interaction with public research. This test, which is reported in Appendix I, confirms that in our data, as in previous studies (Laursen and Salter, 2004), firm size and R&D intensity – proxied as dummies for patent applications and for the sector registered as R&D performing – drive interaction.[3]

[3] Comparing predicted values and observed values, we find that 70 per cent of all predictions of university collaboration are correct, in the sense that a non-collaborator is assigned a prediction of less than 50 per cent probability to interact and collaborators assigned a prediction of over 50 per cent. The corresponding share of correctly predicted observations in the institute model is also 70 per cent. There are thus reasons to expect that

Since our analysis of organisational and cognitive distances is built on an assumption of differing incentives, norms and cultures between universities and institutes, a first task for our empirical analysis was to check the extent to which the PROs identified by the firms as interaction partners meet these descriptions. Respondents were asked to nominate the one to three public research organisations they perceived as "most valuable partner" among all their domestic linkages to PROs. Of the 59 PRO nominations that were made, 16 were of institutes and 43 of universities. Thirteen of the nominated institute partners were of the three institute groups SWEREA, SICS and SP. These three groups consist of institutes which are strongly oriented towards industrial-type R&D and towards interactions with firms (see Appendix II for details). The most frequently cited universities were, as expected, those with large, research-oriented technical faculties. We interpret this indicative evidence as supporting our assumption that the Swedish engineering sector is a relevant test bed for our stylised view that universities largely follow an academic agenda, while institutes largely follow an industrial agenda.

Respondents were presented with questions regarding their formal interactions with five categories of PRO: universities[4] in their own county (administrative region), domestic universities outside their own county, foreign universities, domestic public research institutes and foreign public research institutes. When designing the study, we first considered asking respondents to identify partner organisations, and then asking respondents to evaluate the interaction with each of these partners. The potential advantage of this approach is that it would have allowed us to control for heterogeneity among both universities and institutes. However, survey tests suggested that the categorisation approach was preferable. First and foremost, it reduced the complexity of the survey. It also avoided problems linked to the fact that some managers felt uneasy about revealing details of their interaction networks. Hence, asking about categories was preferred on the basis of response rate maximisation. Furthermore, experience and empirical evidence suggests that the relevant characteristics vary at least as much between departments of a single university as between universities (Bercowitz and Feldman, 2008). Thus, a proper control of characteristics would probably have had to go beyond the university level, which would have further strengthened concerns about willingness to respond to the survey. We also note that the categorisation approach leaves the weighting of different experiences of interaction within each category in the most competent hands available: those of the respondent.[5]

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interaction with both types of organisation is also driven by additional factors, which are unobserved in the present model. Differences in terms of firms' orientation and organisation of R&D activities and differences in R&D intensity are likely to constitute important, unobserved factors for the decision to interact (Laursen and Salter, 2004).

[4] Since we did not want the respondents to differentiate between "true" universities and university colleges or polytechnics, the term "higher education institutions" was used in the survey.

[5] As in many other countries, the Swedish higher education sector includes a broad range of actors: old multi-faculty universities, single faculty universities focused on engineering and medicine, new universities, and regional colleges (Ljungberg et al., 2009). Among all the higher education institutions that received more than five nominations as "most valuable partner", two are polytechnic colleges which are focused on higher education and applied research. To ensure that heterogeneity among higher education institutions does not affect the results, all econometric results

For each of five PRO categories, respondents were asked to state whether his/her workplace had had R&D collaboration with a partner in this category in the period 2004–2006. For each category, respondents were then asked to evaluate three possible benefits from the collaboration on a three-level Likert scale ("not at all" / "to some extent" / "to a significant extent").

A1: Interaction has helped the firm suggest and formulate new innovation projects
A2: Interaction has contributed to the execution of long-term innovation projects
A3: Interaction has contributed to the execution of short-term innovation projects

Guided by a series of interviews with R&D managers in engineering firms, the notion of "short-term innovation projects" was operationalised as "projects which resulted in improved or newly introduced products or processes within 12 months of the termination of the project". The notion of "long-term innovation projects" was accordingly defined as having a time horizon of longer than 12 months.

For each respondent, between 0 and 15 assessments of collaboration have thus been made. From these assessments, we construct measures corresponding to our two hypotheses:

open-ended[6]	= 1 if A1 > max(A2, A3)	(1)
focus on short term effects	= 1 if A3 > A2	(2)

By constructing the two transformed variables *open-ended* and *focus on short-term effects* in this way, we gain two important methodological advantages. First, as is usual when Likert scales are applied, there is a tendency to respond with the middle alternative in the data (in this case, "to some extent"). The transformed variables allow us to study the probability that a respondent not only agrees with all three statements without further reflection, but is actively making a judgement differentiating between the three different questions posed. Second, we base our empirical enquiry on differences in the subjective judgements of different linkages by each respondent, rather than on more dubious inter-personal subjectivity (i.e. we avoid the problem of determining whether "to a significant extent" has the same meaning for two different respondents).

Supplementary data on sector codes, firm and workplace size and location were supplied by Statistics Sweden. Data on the number of patent applications filed at the Swedish patent bureau and the European Patent Office (EPO) by the firm to which the workplace belongs were

reported in section 5 were re-run excluding all linkages that could be traced back to these two institutions. This did not change any results.

[6] It should be noted that a reported focus on open-ended search, as defined here, can reflect two types of experience. It is either a consequence of a deliberate strategy on behalf of the firm, or as a positive side-consequence of one or several failed attempts to interact with PROs in existing projects. From the theoretical base driving our hypotheses, it makes no difference which case is which. However, it should be noted that both types of explanation are not equally likely for all firms. We expect that those firms in our sample that lack advanced R&D capabilities would be less likely to consider it worthwhile to interact with PROs with the generation of impulses (exploration) as a deliberate focus. For these firms, we suspect that such responses reflect beneficial serendipity.

obtained from the PATSTAT database of the EPO. Table 2 provides an overview of the variables with their respective means and standard deviation.

Table 2: Summary of the variables used

Name	**Description**	Mean	Std. Dev.
Link-specific variables			
open-ended	the link is assessed as contributing more to impulses for innovation than to implementation of existing R&D projects (=1)	.12	.36
focus on short-term effects	the link is assessed as contributing more to the execution of short-term R&D projects than to R&D projects with a long-term perspective (=1)	.16	.37
strategic importance	at least one link to PROs is assessed as contributing to the firm's innovation activities "to a significant extent"	.50	.50
institute	link to public research institute (=1) rather than university (=0)	.40	.49
county	link within county (=1) or outside (=0) county	.20	.40
foreign	link to foreign partner (=1) or domestic (=0) partner	.40	.49
Workplace-specific variables			
urban	situated in a region with major urban centres and significant academic resources (=1)	.10	.31
local access	a logged measure of the number of academic researchers in technical fields that are employed in the county of the workplace	4.8	2.2
metals	classified as a producer of basic metals or simple metal products (=1)	.20	.40
machinery	classified as a manufacturer of machinery (=1)	.42	.49
transport	classified as a manufacturer of transport equipment (=1)	.17	.38
r&d	classified as a performer of technical R&D (=1)	.21	.41
size1	20–49 employees (=1)	.25	.43
size2	50–99 employees (=1)	.17	.37
size3	100–199 employees (=1)	.19	.39
size4	200–499 employees (=1)	.25	.44
size5	500+ employees (=1)	.14	.35
Firm-specific variables			
number of workplaces	number of workplaces in firm	.14	4.2
patent applicant	at least one patent application recorded in PATSTAT database	.56	.50

N=1455.

In a first test of our hypotheses H1 and H2, we studied the differences between the reported linkages to universities and those to institutes. The first panel of Table 3 shows that among the observed linkages, firms are more likely to focus on open-ended search in interactions with universities, seemingly supporting H1. When focusing on short-term effects, however, firms are equally likely to work with both types of public research partner. There is thus no support for H2 from a simple group mean comparison. The second and third panels of Table 3 suggest partial support for H3: for firms with advanced R&D capabilities, interaction with universities is more likely to be *open-ended* than interaction with institutes, but the difference between universities and institutes is not significant for non-advanced firms. Furthermore, the means-comparison test does not indicate that H2 is supported for either group of firms.

Table 3: Differences in reported focus between assessments of university and institute linkages, group mean comparison

Variable	Linkages to universities	Linkages to institutes	Test for difference between means: t-value
Linkages reported by all firms			
open-ended	.14 (.35)	.08 (.27)	1.76 (**)
focus on short-term effects	.16 (.37)	.17 (.38)	–0.32
Linkages reported by firms with at least one patent application			
open-ended	.14 (.35)	.06 (.24)	2.24 (**)
focus on short-term effects	.11 (.31)	.16 (.36)	-1.21
Linkages reported by firms with at no patent applications			
open-ended	.18 (.39)	.15 (.36)	0.45
focus on short-term effects	.20 (.40)	.23 (.43)	-0.35

Notes: Mean values for the binary variables *open-ended* and *focus on short-term effects* for the full sample and the divided sample are reported. Standard deviations in parenthesis.

To allow for generalisation of these results, however, we need to undertake a more thorough analysis. First, we need to control for factors that, independent of the organisational form of the public science partner, may drive these assessments. Second, we need to control for the selection bias problem invoked by the fact that managers of firms can only report assessments of linkages of which they have experience. In particular, since most firms collaborating with institutes also collaborate with universities, but almost half of the firms collaborating with universities do not collaborate with institutes, there may be systematic differences between the two groups that, if not properly controlled for, could bias the result.

5. MODEL AND RESULTS

In this set-up, there are 1455 observations (5 categories of assessment for each of 291 firms) of each variable available in the data set. However, only 453 assessments are actually observed, since firms can only assess collaboration of the types of which they have experience. Almost two-thirds of all observations on the dependent variables thus have a missing value. Theoretically, the dependent variable is only observed if a particular condition ($sel_i = 1$) is met. We therefore use a sample selection probit model, as is common practice in the literature.[7] The selection variable is modelled as:

$$sel_i = 1 \quad if \quad z_{i,j} \cdot \beta_j + \upsilon_i > 0 \quad else\, sel_i = 0\,. \tag{3}$$

[7] While the probit model with sample selection is a consistent estimator, simulation experiments have show that difficulties in numerical maximisation may induce bias in the estimates (Freedman and Sekhon, 2008). To control this kind of bias and ensure the robustness of our results, we have estimated our model with both the built-in implementation of the estimator in STATA (heckprob), and the alternative implementation of the estimator given by Miranda and Rabe-Hesketh (2006). The results, which are available on request, show some differences in estimates of control variables, but all results of relevance to our hypotheses are unaffected by the choice of estimator implementation. In Tables 4 and 5, results from the standard implementation of the estimator are reported.

where z_{ij} is a vector of observations of the covariates (*j*) for the linkage *i*, whether observed or not. The observed response *i* is modelled as:

$$focus_i = 1 \quad if \quad x_{i,j} \cdot \delta_j + \varepsilon_i \quad > 0 \quad else\ focus_i = 0 \quad . \tag{4}$$

where x_{ij} is a vector of observations of the covariates (*j*) for the observed linkage *i*. The residuals υ_i and ε_i are assumed to have a bivariate normal distribution, and the two equations are estimated by maximum likelihood in a two-step procedure. $z_{i,j}$ and $x_{i,j}$ should differ in at least some of their components, that is, they should not be made up of the same variables.

In modelling the selection equation, we follow previous studies in using variables capturing the size of the firm, the size of the workplace and the sectoral characteristic of the workplace to predict the probability that a firm has been interacting with PROs (Laursen and Salter, 2004; Fontana et al., 2006). To control for the possibility that local availability affects a firm's likelihood to interact with PROs, a measure of the local pool of technical academic researchers (*local access*) is also included. We further include linkage-specific dummy variables on geography, as regional linkages are reported more frequently and linkages to foreign PROs less frequently than domestic (non-regional) PROs (*county, foreign)*, and a dummy to indicate whether the linkage is to a university or an institute (*institute).*

In the second step, we model the focus of the linkage as a function of seven dummy variables. The variable in focus is *institute*. We control for whether the link is foreign or domestic, as considerable geographical distance could be thought to hinder learning and short-term effects (Broström, 2009). We also add a workplace-specific variable indicating whether the respondent has assessed any link to PROs as contributing to any of our three effects "to a significant extent". The rationale for including this variable, called *strategic importance*, is that it is a proxy for whether interaction with PROs is an important activity in the innovation processes of the workplace, or a more marginal activity. We also include workplace-specific controls for the technology level of the firm, proxied by *patent applicant*, and for the sector of the workplace.

In a first step, we test H1 and H2. When applying the controls discussed in section 4, we find support for H1 but not for H2. This relationship is shown in Table 4.

Table 4: Estimation results, probit model with sample selection.

	open-ended	focus on short-term effects
Outcome equation		
institute	–.452 *** (.169)	.096 (.154)
strategic importance	.341 ** .166	.016 .135
foreign	–.404 ** (.202)	–.414 ** (.175)
patent applicant	–.132 (.170)	–.116 (.147)
r&d	–.231 (.233)	–.496 ** (.224)
machinery	–.318 (.205)	–.219 (.182)
transport	–.189 (.243)	–.389 * (.236)
constant	–1.22 *** (.264)	–1.12 *** (.201)
Wald chi2(12)	20.9 ***	16.6 **
Selection equation		
urban	.490 *** (.127)	.475 *** (.122)
foreign	–.586 *** (.087)	–.579 *** (.086)
county	.275 ** .107	.318 *** (.101)
institute	–.227 *** (.085)	–.205 ** (.085)
local access	.008 (.019)	.009 (.018)
size dummies	Yes	Yes
sector dummies	Yes	Yes
constant	–.907 *** (.150)	–.928 *** (.147)
LR test of independent equations: chi2(1)	3.23 **	8.11***

Notes: Reported standard errors (in parentheses) are Huber/White robust for heteroskedasticity. N=1455. Legend: * 10% significance, ** 5% significance, *** 1% significance[8]

Interestingly, we also find that firms which report PRO contacts to be important (as measured by the variable *strategic importance*) are more likely to focus the scope of their different contacts with? PROs. Our interpretation of this finding is that firms for which interaction with PROs is an important and prioritised activity learn to organise their contacts with different PROs in a way that allows them to focus their activities in a way that suits them. It is also noteworthy that the alternative measures of a firm's competence (*r&d sector* and *patent applicant*) are negative and largely insignificant. It thus seems that if advanced firms behave differently to non-advanced firms, it is in the form of a more distinct emphasis on the pursuit of long-term, well-defined

[8] As stratified sampling procedures may induce heteroskedasticity problems, we test for such problems using standard F-tests on variance equivalence. The only problem indicated by such test refers to the variable *r&d*, which is a dummy indicating that a workplace is registered as mainly active in R&D. Huber/White robust standard errors have been applied to avoid potential problems of this kind.

R&D objectives in their interaction with PROs. A possible interpretation is that these firms are more likely than non-advanced firms to interact with PROs in work related to the development of generic technology or technology standards.

In order to test our remaining hypothesis, H3, we next introduce an interaction term between the variables *patent applicant* and *institute*. An interpretation of the combined impact of a change in *institute* from 0 to 1 is made through the use of prediction by the delta method as implemented in the Stata software. The result of predicting the probabilities for two artificial observations, differentiated only by the different values of *institute* and the interaction term, and subsequently comparing the two predicted probabilities by subtraction are reported in Table 5. This approach, which is advocated by Zelner (2008) and Berry et al. (2007), recognises that focusing on the estimated coefficient of an interaction term in a probit model is neither sufficient nor necessary to determine the full impact of a change in the underlying variable.

Table 5: Estimation results, probit model with sample selection. Test results of combination effects, when controlling for the same factors as in Table 4

	open-ended	focus on short-term effects
	Coef.	Coef.
institute	–.192 (.285)	.047 (.245)
patent applicant	–.037 (.194)	–.138 (.175)
institute * patent applicant	–.392 (.353)	.065 (.297)
Wald chi2(8)	21.6 ***	16.6 **
Difference in probability invoked by change in *institute* from 0 to 1	–.584 *** (.211)	.112 (.180)

Notes: N=1455. The same model as that reported in Table 4 was estimated with the addition of the interaction variable institute * patent applicant. Only the three estimates that are relevant to the test are shown. Reported standard errors (in parentheses) are Huber/White robust for heteroskedasticity. Legend: * 10% significance, ** 5% significance, *** 1% significance

Since the difference reported in the first column of Table 5 is statistically significant at the 1 per cent level, we find partial support for H3. That is, we conclude that for patent applicants, public research institutes are less associated with a focus on open-ended search than for non-patent applicants. The corresponding difference in the estimation of the right-hand column is not, however, significant.[9]

[9] Both findings are confirmed when the models in Table 4 are estimated on the divided sample of only patent applicants and non-patent applicants, respectively. In the latter case, however, the entire model is rejected as explaining the variation in the outcome to an insufficient degree. Thus, we are not able to draw conclusions about which factors drive non-patentees to focus on impulses to innovation or on short-term effects in a certain type of linkage to public research organisations. Note that in contrast to this inability to properly identify determinants to *how* non-patentees use contacts to PRO, we are able to identify the *determinants for interaction* with public research institutes much better for the non-patenting group than for patentees (see Appendix I). These findings remind us

6. CONCLUSIONS

This paper examines how firms assess the value of R&D partnerships within two parallel systems of PRO: public research institutes and universities. In spite of substantial government spending on institutes in many countries, the sector has been largely ignored in previous studies of PRO-industry linkages. In the literature that does exist (Crow and Bozeman, 1998; Lundvall, 1992), the institute sector is described as a complement to universities, dedicated to applied R&D and to interaction with industry, whereas universities are typically associated with "curiosity-driven" research.

We linked these descriptions of institutes to the role of institutes in innovation networks through an analysis that draws on the theoretical concepts of organisational and cognitive distances. In view of the fact that institutes are described as hybrid organisations, it is argued that the institute system is positioned at a shorter *organisational distance* to private firms than the university system. Following these suggestions, we hypothesised that compared to contacts with universities, contacts with institutes would be both less likely to have a focus on open-ended search and more likely to have a focus on short-term effects. To this discussion, we added an analysis of how the *cognitive distance* between a firm and the two systems of public research would shape the focus of each type of interaction. It was found that for advanced firms, the cognitive distance argument strengthens the prediction of the organisational distance argument. For non-advanced firms, however, we found that the arguments on cognitive and organisational distances partly off-set each other.

In order to test these propositions empirically, we asked R&D managers at 425 workplaces in the Swedish engineering sector to assess the utility of all existing partnerships with both kinds of PRO. We used these assessments to characterise each observed firm-PRO linkage in terms of whether it was perceived to have a focus on open-ended search or a focus on short-term effects. Our results show some evidence for the first hypothesis: that a partnership with public research institutes is less likely to be focused on generation of impulses to innovation, compared to a partnership with universities. However, in line with our theoretically derived expectations, this finding is only relevant for the subset of firms with a positive number of patent applications. For this group, our findings confirm and go beyond those of Laursen and Salter (2004), in that we provide evidence of how managerial choice is shaping not only the propensity to interact with PROs, but also the pattern of purposes that different types of PRO interaction serve for the innovation activities of the firm.

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how little the existing literature has to say about the innovation processes of low-tech engineering firms and about the role of external contacts in innovation for this group.

Surprisingly, we find no evidence supporting our second hypothesis, namely that interaction with institutes is more likely to be focused on the execution of short-term innovation projects than contacts with universities. A failure to establish that institute linkages are more likely to be focused on short-term effects may seem remarkable, in the sense that it refutes the idea of the application-oriented project with a limited time-perspective as a special "niche" in the systems of public research organisations occupied by institutes. A possible interpretation is that our empirical test does not correspond to the stylised view of the institutional differences between the two types of PRO, which we call universities and institutes throughout the text. Bearing in mind that certain PROs may share the rules, norms and incentives of universities, but not be higher education institutions (e.g. the Max Planck society of Germany or the CNRS of France), one may speculate that the reason that respondents do not perceive institute contacts as more focused on short-term effects than university contacts is that, when reporting experiences from institute contacts, respondents are referring to a diverse set of actors that do not fit the assumptions made in the analysis. We do not, however, find this interpretation plausible. Our pre-understanding, seemingly corroborated by our survey data (see the discussion in section 4 and Appendix II) is that in the empirical setting that we have chosen for our test – the Swedish engineering industry – the relevant PROs fit our assumption of institutional differences quite well. A more plausible interpretation is that firms are able to use contacts with individual university-based researchers for application-oriented projects, thereby reducing the organisational distance between themselves and the university researcher; for example, by increasing the degree of control that the firm can exercise over the project (Antonelli, 2008).

The question of how to (re)organise public research, such as by merging public laboratories, establishing closer connections between laboratories and universities and so on, has been on the innovation policy agenda for at least a decade, and remains hotly debated in many European countries (Preissl, 2006). Studies of the role of the organisation of public research, however, are only just emerging, and therefore the policy debate has had very little robust research to draw on. To our knowledge, this is the first empirical assessment of whether the two parallel systems of PRO serve different functions as collaboration partners with industry. On balance, only limited evidence could be found that institutes complement universities in this sense. Since an assumption of complementarity underlies the funding rationale for this sector, we believe that these findings call for further research, for example, to investigate other models of how institutes complement universities in systems of innovation. We also believe that the framework of organisational and cognitive distances that was developed in this study will make a useful starting point for further research on how the organisation of public research affects patterns of R&D interaction.

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Appendix I: Model explaining determinants for collaboration for divided sample

	Full sample		Firms with patent applications		Firms without patent applications	
	interacts with university	interacts with institute	interacts with university	interacts with institute	interacts with university	interacts with institute
patent applicant	.235***	.392***				
local access	-.001	.004	.005	.005	-.026	-.026
machinery	-.307***	-.243***	-.363***	-245***	-.211***	-.374***
transport	-.476***	-.652***	-.444***	-.433***	-.539***	-1.52***
r&d	.901 ***	.489***	1.13***	.242***	.759***	.965***
size2	.325***	.292***	-.325***	-.123***	.719***	1.02***
size3	.780***	.439***	.370***	.379***	1.02***	.595***
size4	1.04***	.739***	.811***	.0975	1.16***	1.80***
size5	.841***	1.28***	.861	1.02***	-.412**	.610***
urban	.375***	.378***	.555	.373***	.299**	.774***
antarbst	.0025	.0022	-.0126	-.0055	.0380***	.118***
_cons	-.339***	-1.07***	.156	-.260**	-.525***	-1.70***
LR chi2(10)	810	866	436	303	336	531
Pseudo R2	0.142	0.151	0.160	0.092	.123	0.255

Notes: Probit models. Coefficient estimates. *** denotes 1% significance levels, **denotes 5% significance levels and * denotes 10% significance levels.

Appendix II: Characterisation of the three most frequently cited institutes

	Private ownership	Private funding	Number of employees	Number of articles 2005–2007
SWEREA	51 %	55 %	280	60
SICS	40 %	25 %	100	7
SP	0 %	70 %	570	48

Sources: Annual reports; ISI Web of Science. Data in the first three columns is for 2007.

The results under number of articles is the outcome of a search on the Science Citation Index Expanded (SCI-EXPANDED) database of the ISI Web of Science for the years 2005–2007. Relatively low publication frequencies are mirrored by significant levels of private ownership and private funding.

Note that we conducted the same search on publications data for all universities that were listed as "most valuable partner" by at least five respondents. The three most cited universities have over 5500 articles and just below 5800 employees (full-time equivalents) in their faculties of science and/or technology. A search of the the Max Planck Institutes in Germany, which are oriented towards basic scientific research and employ about 13000 people, produced over 18000 articles using the same search criteria as those applied above.

Together, these figures suggest that the institutes which firms refer to in our survey are mainly "non-academic", and as such have a different profile in terms of incentives, culture and institutional set-ups than that which we may expect to find in a university.