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Universities and public research institutes as collaboration partners for firms

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Abstract

We examine how firms assess the value of R&D partnerships with two types of public research organisations: public research institutes (PRIs) and universities. Survey data on Swedish engineering and manufacturing firms suggest that contacts to universities provide firms with impulses to innovation and offer opportunities to learn to a higher extent than contacts to public research institutes. Guided by a view of institutes as more oriented towards applied R&D than universities, we also test whether managers perceive institute contacts to contribute more strongly to short-term R&D projects than universities. This hypothesis can not, however, be verified. 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. Implications for current discussions about the role of PRIs in national research and innovation systems are discussed.

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1. Introduction

The impact of university-industry collaboration on innovation has received much attention in the innovation literature. It has been argued that government funded science has an important role to play not only for the economy per se, but also as a source of ideas, impulses and support of technological development for individual firms (Mansfield, 1998). However, the focus in existing literature on universities has left a part of the public science system out of systematic study: the role of public research institutes (PRIs). Our knowledge about the role of PRIs in collaboration networks is very limited. This chapter contributes by focusing upon the role of PRIs in collaboration networks and by comparing the perceived effects of collaborating with universities and PRIs, respectively, from the firm's perspective.

There are many different types of public research organizations (PROs). While universities have a broader mandate including teaching and basic research, the primary objective for public financing of PRIs and laboratories is to interact with the private sector and to develop industrially relevant technology. Universities and PRIs thus constitute different institutional set-ups. Previous research has demonstrated that the institutional setup of public research affects the nature of interaction with the private sector. Due to institutional differences, we can expect differences between public research institutes and universities in terms of mission, culture and research scope (Bozeman, 2000). The literature on external relations in innovation offers convincing arguments that patterns of cooperation are different for different types of aims and scope of collaboration, but the link between different rationales for collaboration and the choice of collaboration partner has not been adequately studied.

In spite of substantial governmental spending on PRIs in many countries, the sector has been largely ignored in previous studies of PRO-industry linkages. In the scarce literature that exists (Crow & Bozeman, 1998; Lundvall, 1992), the PRI 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.

However, systematic empirical investigations of the proposition of potential differences are few and far between. Even when PRIs are included in studies on collaborative linkages between public and private R&D, the distinction between universities and PRIs is commonly ignored. For example, PRIs are included as a distinguishable group in e.g. the YALE and CIS surveys, but studies abstain from analysing collaboration with this particular group (c.f. Klevorick et al., 1995). Later literature similarly aggregates universities with PRIs into a general category of PROs, including many studies reporting from e.g. the PACE, KNOW and CIS surveys (c.f. Faulkner & Senker, 1993; Beise & Stahl, 1999; Cohen et al. 2002; Arundel & Geuna, 2004; Fontana et al. 2006; Cassiman & Veugelers, 2002; Tether & Tajar, 2008). Hence, existing literature has not yet distinguished between the benefits for firms of interacting with universities, as compared to PRIs, and this is therefore a contribution of this chapter.

While knowledge transfer from public research organizations to the wider economy has been found to take place through a number of different channels, firms report that the most important type of linkage to generate firm level benefits from interactions with PROs are interactions that are direct and formalised – a finding confirmed both for universities (Kaufmann & Tödtling, 2001) and PRIs (Adams et al., 2003). This chapter therefore also focuses upon direct, formalised interactions with universities and PRIs and especially how and why firm managers perceive them to generate firm-level benefits.

This chapter analyses the role of institutional differences by means of relating them to different objectives of firms engaged in formal interaction with the public research organisations, including both PRIs and universities. In particular, we build on the findings of Klevorick et al. (1995), Cohen et al. (2002) and Fontana et al. (2006), who report that academic research contributes to two distinct types of objectives: generation of new ideas and impulses or else development work which helps the firm complete innovation projects.¹ The difference between these two objectives can also be stated as the difference between “learning what you need to learn” and acquiring assistance in innovation projects already defined by the firm. The first question we pose is whether the different institutional setup of PRIs and universities make them differently suited to provide either one of these benefits to industrial firms?

The second question that we investigate is whether PRIs and universities have different ability to support firms in more “basic” R&D and in applied R&D, respectively. Following Aghion et al. (2008), we use the terms of basic and applied R&D as related to the distance between the current innovation phase and a marketable product, rather than to the classical definition, by which basicness is related to the degree of appropriability (Nelson, 1959; Arrow, 1962). In works following this classical approach, the analysis of the basic nature of research is conceptualised as related to the knowledge involved per se. In contrast, by adopting the reification of Aghion et al., the distinction between basic and applied research can be used to discuss and empirically investigate interaction outcomes from the market-oriented perspective of the firm.

This chapter is based upon data collected through a survey of Swedish firms in engineering and manufacturing sectors, to examine collaborative linkages, and the data is assessed in a sample selection probit framework. There was a 68% response rate. Totally, responses from 425 workplaces are analyzed.

The chapter is organised as follows: Section 2 discusses how the existing literature helps generate the two hypotheses for why differences in organisational setups may give universities and public research institutes different roles as collaboration partners for industry. Section 3 presents data collected to test the two hypotheses derived in the previous sections and Section 4 presents the modelling framework within which the data is tested, and the results of these tests. Section 5 concludes the paper.

2. The complementary role of industrial public research institutes

This paper adds to a growing stream of research that seeks to improve our understanding of the role of public sector R&D in modern economies by turning attention to the role of a number of interrelated institutional factors such as organisation, research management, incentives and (local) culture (Bonaccorsi, 2007; Carayol & Matt, 2004). While many recent studies have investigated how institutional differences shape differences in academic collaboration patterns (Heinze & Kuhlmann, 2008; Boardman & Corley, 2008), there is a parallel interest in how technology transfer from public organisations is mediated by institutional factors. Bozeman & Crow (1991) sample 134 government labs and 139 university labs in the United States. They find that labs 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 about immaterial property. Lach and Schankerman (2008) show that those universities in the United States that

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, 2012).

provide stronger royalty incentives to faculty scientists generate greater license income, controlling for university characteristics. When comparing two types of organisational forms for universities (public and private), the authors find that the impact of incentives is larger in private universities. Ponomariov (2007) estimates the effect of select university characteristics on the propensity of individual scientists to interact with firms. He finds that academics active at institutions with many industrial establishments on campus and, interestingly, with relatively low academic prestige, are most likely to report interaction with firms.

Only a handful of previous studies have empirically contrasted the knowledge base of public labs and institutes with that of universities, and almost all of the available studies describe the situation in the United States. Crow and Bozeman (1998) discuss how U.S. government labs are characterised by more “applied” research, whereas universities are said to be oriented towards “basic” research. Somewhat contrasting evidence is presented by Jaffe & Trajtenberg (1996) and Jaffe & Lerner (2001) who find that while the labs lagged behind universities both in terms of patenting volume and patent quality in the 1970s and early 1980s, that gap was closed during the 1990s, making the public labs more similar to universities. A corresponding European trend towards convergence between the functions of different actors within the broader public research organizations has been reported by Senker (2006).

The first question addresses whether universities and PRIs are differently well equipped to provide firms in their networks with impulses and novel ideas for innovation, and with concrete assistance in R&D projects, respectively. In this chapter, we focus on institutional differences driven by differences in terms of organisational mission, in relation to benefits for the firms. We view a university as an institution governed by academic rules, norms and incentives (Dasgupta & David, 1995). Researchers are exclusively rewarded on a basis of peer review and on the impact of academic publications. Importantly, individual scientists retain the right to decide what projects to take on. In contrast, we view a PRI as a hybrid form organisation, where one key mission is to perform R&D relevant for innovation and to interact with private businesses. This mission is manifested as managerial control and coordination mechanisms (Bozeman, 2000; Gulbrandsen, 2011). Control mechanisms and a reward system only partly based on academic publication impact also give PRI researchers greater incentives to avoid the “publish or patent” problem of compromised academic freedom characterising many university-industry relationships (Lee, 1996).

Based on such differences, we expect PRIs to be better positioned than universities to interact with firms on the basis of agreed contracts. These contracts should give the firm the ability to control the interaction, so that the focus remains on a problem or task specified by the firm. In the terminology of principal-agent theory, we expect firms to face a greater agency problem when dealing with university researchers, as compared to PRI researchers. Furthermore, a relationship where the principal’s influence over the agent is strong may not be flexible enough to stimulate the emergence of new ideas and interactive learning (Liebeskind et al., 1996; Blanc and Sierra, 1999). For both these reasons, interaction with a PRI should be less likely to generate new ideas, while in contrast, it is reasonable to expect that interactions with a university could contribute to the generation of new ideas and generation of impulses to innovation, rather than support innovation projects already defined by the firm. We formulate this expectation as the following hypothesis:

H1: Interaction with universities is more likely to be focused on the generation of ideas and impulses to innovation as compared to interaction with PRIs

Our second question tackles the differences between two types of projects, which firms may undertake in interaction with PROs. The first type is long-term development of technology and exploratory R&D, which are not expected to result in new or significantly improved products or processes within the timeframe of a year. The second type are projects related to well-specified product and process development in mature development stages, and this is typically thought of as very applied R&D. The two types can be thought of as “early-stage” and “late-stage” R&D in a process of continuous refinement where the end result is a marketable product (Aghion et al., 2008). We expect researchers in universities to have lower incentives than their colleagues in PRIs to engage in interaction in projects with firms where the objective is short-term development. This expectation builds on a stylized view of such short-term project as typically not generating academic research results, whereas universities are governed by academic rules, norms and incentives. Even though previous research has shown that university researchers can use contacts with applied research problems in firms to inspire further research and help university researchers fund their departments (Lee, 2000), the total incentive of the typical university researcher should be lower than the typical PRI-employed researcher. Furthermore, previous research suggests that academic quality is positively associated with firms’ interest in engaging in joint-venture research and other forms of interaction associated with exploratory rather than with strictly applied purposes (Scharfetter et al., 2002). In consequence, we expect the following:

H2: Interaction with PRIs is more likely to contribute to the execution of short-term innovation projects than contacts with universities

To summarize, we predict that firms are more likely to use universities as “listening posts” for ideas and impulses and to use PRIs as suppliers of applied services to complete development projects defined by the firm. These hypotheses, if confirmed, would confirm a view of “division of labor” between universities and PRIs in a national innovation system (Nelson, 1993; Arnold et al., 1998).

3. Data, methodology, and descriptive results

Our hypotheses are tested on data about the interaction patterns of Swedish firms in the manufacturing and engineering sectors. The Nordic countries are interesting test-beds for studying university-industry collaboration, since the activity level in these countries are higher than in other EU countries, as revealed by the European Community Innovation Surveys (CIS). There are thus reasons to expect Nordic firms to have relatively long experience with collaboration, and to have developed strategies for interaction with universities and public research institutes. By restricting the study to engineering and manufacturing sectors, we focus on the sector most clearly targeted by Nordic PRIs, and the sector where the interest for interaction on applied research is as highest. We therefore predict that the potential for successful division of labour is as greatest in this sector.

3.1 Data and methodology

The main source of our data is a survey conducted during 2007. From the total population, 425 establishments in Swedish engineering and manufacturing sectors were randomly selected, stratified on establishment size. All establishments were contacted by phone and asked to identify the most proper respondent for our survey. The initial contact at the establishment was asked to identify the R&D manager in charge of external relations, general R&D manager, technology manager, production manager or site manager/CEO, in falling order of priority. The identified respondents were then contacted by e-mail and given the chance to respond to the survey electronically or to indicate that they did not want to participate. After one week, a second e-mail was sent, reminding them about the survey. In parallel, respondents who had not responded to

the survey were contacted by phone and asked to complete the survey through interviewing. After three weeks of intensive contact efforts, a final e-mail was sent out. In total, 68 % of the respondents completed the survey. A further 6 % gave partial, but incomplete answers to the survey.

Respondents were asked to answer questions regarding the formal interaction of their establishment with five categories of public research organisations (PROs), namely: universities² in own county, domestic universities outside own county, foreign universities, domestic public research institutes and foreign public research institutes. For each category, the respondent was asked to state whether his/her working place has had R&D collaboration with a partner in this category in the period 2004-2006. For each category, respondents have then been asked to assess three possible benefits from collaboration:

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

A respondent who reported experience from interaction with PROs in each of the five categories has thus made 15 assessments in total. Assessments were made on a three-level Likert scale, offering the alternatives “not at all”, “to some extent” and “to a significant extent”. From these assessments, we construct two measures corresponding to our two hypotheses:

focus on learning = 1 if $A1 > \max(A2, A3)$

focus on short term effects = 1 if $A3 > A2$

The results reported reflect ex-post assessment of recent contacts with PROs. Our discussion and the survey questions used here focus upon the managers' experience of what has actually been achieved through collaboration in recent years. To investigate similarities and differences between firm strategy (ex-ante) and managers' perceptions about the benefits of collaboration (ex-post), we conducted complementary interviews with a sub-set of 18 firms. These firms had answered the survey, and the interviews allowed us to explore the connection between firm strategy and the survey results in terms of managers' perceptions.

Through the interviews, we found no indications that ex-ante strategic objectives and ex-post outcomes differed substantially for larger firms with more advanced R&D capabilities and for firms with continuous contacts with PROs. However, we could identify a number of cases where those firms which were inexperienced in working with academics did report differences in expectations and experiences in terms of the three outcomes A1-A3 listed above. In particular, the interviews revealed examples where firms with less advanced R&D capabilities reported to have had engaged with PROs with the purpose of gaining assistance in existing R&D projects and failed to achieve these objectives. Where such experiences through beneficial serendipity generated ideas and impulses to further R&D, a linkage will be considered as having had a de-facto *focus on learning*.

For each firm who answers the survey, supplementary data on sector codes, firm and work place size as well as location have been 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 has been added from the PATSTAT database of the EPO.

² Throughout the text, we use the term 'universities' to characterise all higher education institutions (HEIs). However, it should be noted that in the survey, the term 'higher education institutions' was used. In Sweden, as well as in many other countries, the term 'university' refers only to the most research-intensive HEIs.

For the PROs most frequently identified as collaborators by answering firms, we have also gathered additional data about funding, employees and publications. See the appendix.

Our data on the managers' perceptions of benefits, or what we call assessments, are used so that each assessment is modelled in the framework of an ordered logit or probit model, with appropriate controls for selection bias. By adopting the two transformed variables *focus on learning* and *focus on short-term effects*, we gain two important advantages. First, as is usual when Likert-scales are applied, there is a tendency to respond with the middle alternative in the data, which would here be expressed as "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 also actively making a judgement differentiating between the three different questions posed. Second, because the group of firms interacting with public research organisations is clearly a selective group as compared to all firms, we should seek to compensate for selection bias. However, the decision to interact with a public research organisation and the assessment of the utility of that interaction can, theoretically, be thought of as outcomes of the same basic models. Therefore, we will not be able to control for the selection mechanism through which the data has been censored (i.e. that assessments only are observed for interacting firms) when modelling the assessments directly in a probit sample selection framework.³

3.2 Descriptive results

In the stratified sample, the responses indicate extensive interaction with PROs. Of the respondents, 32 % report collaboration with both public research institutes and universities. Of the total, 37 % report collaborative relations with public research institutes, and 64 % with universities. A further 11% of those who report to be interacting with universities report that they do so exclusively through student projects, such as Masters thesis. Given the purpose of this paper, these latter observations are considered non-collaborators as the student projects are not part of direct, formal interactions studied here.

Table 1 provides an overview and descriptive statistics of the variables.

Name	Description	Mean	Std. Dev.
<i>Link-specific variables</i>			
focus on short-term effects	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
<i>Establishment-specific variables</i>			
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

³ This theoretical problem is replicated in the data, as shown using an ordered probit approach with sample selection correction, evaluated using the *ssm* wrapper for the *gllamm* program in Stata (Skrodel & Rabe-Hesketh, 2003).

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	.33
<i>Firm-specific variables</i>			
number of workplaces	number of workplaces in firm	1.1	4.2
age	firm age	13.2	7.0

Table 1: Summary of utilised variables. N=1455.

As demonstrated in Table 1, the observed establishments are distributed equally among the five size classes and among the four broad sectorial classifications - the exception being the machine manufacturing sector, to which two out of five observations belong. 1 out of 2 observed linkages are reported by firms for which PRO contacts are assessed as being of *strategic importance* as inputs for its innovation processes.

Table 1 also reveals that a majority of the observed firm-PRO linkages are not assessed as having a *focus on learning* or a *focus on short-term effects*. That is, the average link is assessed to contribute to project completion as least as much as to generation of new ideas. This suggests that the occurrence of useful impulses to further R&D in practise often is linked to the achievement of objectives related to ongoing R&D projects of the firm (Broström, 2014). The observation that long-term R&D objectives are a key driver of firm-PRO relationships also fits well with results from recent research about Sweden which suggests that firms engage universities in projects that consolidate the firm's technological project (Ljungberg and McKelvey 2012; Ljungberg et al 2013).

Table 2 shows that the same factors drive both types of collaborations, as evident by the estimation of a probit model, namely firm size and conducting R&D. The results indicate that our data replicate previous findings about the impact of firm size and R&D intensity (here proxied by dummies for patent application and for the sector registered as R&D performing) reported to influence the propensity to interact with universities in previous studies (Laursen & Salter, 2004).

	interacts with university	interacts with public research institute
patent applicant	.2350 (.127)	.3917** (.129)
machinery	-.3071* (.147)	-.2426** (.149)
transport	-.4762** (.183)	-.6520** (.196)
r&d	.9007** (.202)	.4885** (.180)
size2	.3250** (.190)	.2918** (.202)
size3	.7801** (.184)	.4389* (.194)
size4	1.038** (.186)	.7387** (.192)
size5	.8409** (.227)	1.281** (.228)
urban	.3754	.3777**

	(.216)	(.183)
number of workplaces	.0015 (.018)	.0022 (.014)
intercept	-.3391* (.162)	-1.070** .176
LR chi2(10)	107.96	115.52
Pseudo-R2	0.1423	0.1505

Table 2: Coefficient estimates, probit models. Standard errors in parentheses. * 5% significance, ** 1% significance

Comparing predicted values and observed values, we find that 70 % of all predictions of university collaboration are correct, in the sense that a non-collaborator is assigned a prediction of less than 50% probability to interact and collaborators are assigned a prediction of over 50 %. The corresponding share of correctly predicted observations in the institute model is also 70 %. There are thus reasons to expect that interaction with both types of organisations 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 likely constitute important, unobserved factors for the decision to interact (Laursen & Salter, 2004).

In a first test of our hypotheses H1 and H2, we study the differences between the reported linkages to universities and to institutes, respectively.

Variable	All linkages	Linkages to universities	Linkages to institutes	Test for difference: t-value
<i>Link-specific variables</i>				
focus on learning	.12 (.33)	.14 (.35)	.08 (.27)	1.76 *
focus on short-term effects	.17 (.37)	.16 (.37)	.17 (.38)	-0.32

Table 3: Differences in reported focus between assessments of university and institute linkages. * 5% significance

From the results in Table 3, we can conclude that among the observed linkages, firms are more likely to focus on learning in interactions with universities, seemingly supporting H1. However, when focusing on short-term effects, firms are equally likely to work with both kinds of public research partners. There is thus no support for H2 from a simple group comparison.

These results give a first analysis, but the analysis in the next section proposes a more thorough analysis, to allow for generalisation of these results. First, we need to control for factors that, independently 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 firm managers only can report assessment on linkages of which they have experience. In particular, since most firms collaborating with PRIs 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, would bias the result.

4. Model and results

Out of 1455 observations of managers' experiences (answers regarding 5 categories of PROs provided by managers from 291 establishments), only 453 assessments of linkage effects are actually observed - managers can only assess collaboration of the types from 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 utilise a sample selection probit model, as common practise in the literature.⁴

The selection variable is modelled as

$$sel_i = 1 \quad \text{if} \quad z_{i,j} \cdot \beta_j + v_i > 0 \quad \text{else} \quad sel_i = 0 \quad (1)$$

The observed response i is modelled as

$$focus_i = 1 \quad \text{if} \quad x_{i,j} \cdot \delta_j + \varepsilon_i > 0 \quad \text{else} \quad focus_i = 0 \quad (2)$$

The residuals v_i and ε_i are assumed to have a bivariate normal distribution, and the two equations are thus estimated by maximum likelihood in a two-step procedure. $z_{i,j}$ and $x_{i,j}$ should differ in at least some of its components, i.e. not be made up of the same variables.

In modelling the selection equation, we use the model of Table 2, which uses firm and workplace-specific variables to predict firm's probability to interact with PROs, as our point of departure. We furthermore 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 indicating whether the linkage is to a PRI rather than a university (*pri*).

In the second step, we model the likelihood of linkage being focused (*focus on learning* and *focus on short-term effects*, respectively) as a function of seven dummy variables. The variable in focus is *pri*. 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, 2010). We furthermore 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', i.e. whether PRO-linkages in general are identified as strategically important. The rationale for including this variable, called *strategic importance*, is that it proxies whether interaction with PROs is an important activity in the innovation processes of the establishments, or a more marginal activity. Lastly, we also include establishment specific controls for the technology level of the form, proxied by *patent applicant*, and for the sector of the workplace.

When applying the controls discussed in the previous section, we find support for H1, but not for H2. This relationship is shown in Table 4.

	focus on learning	focus on short-term effects
Outcome equation		
PRI	-.416 ** (.150)	.096 (.154)
strategic importance	.438 ** (.132)	.274 * (.135)
foreign	-.531 ** (.176)	-.372 * (.185)
patent applicant	-.160	-.153

⁴ While the probit model with sample selection is a consistent estimator, simulation experiments have show that difficulties in numerical maximization may induce bias in the estimates (Freedman & 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.

	(.149)	(.153)
r&d	-.246 (.207)	-.552 * (.228)
machinery	-.294 (.182)	-.186 (.184)
transport	-.318 (.234)	-.392 (.244)
constant	-1.90 (.353)	-1.74 ** (.366)
Wald chi2(12)	36.53 **	17.33 *
Selection equation		
urban	.523 ** (.114)	.497 ** (.115)
foreign	-.588 ** (.086)	-.580 ** (.086)
county	.262 (**) .103	.315 ** (.102)
PRI	-.229 ** (.085)	-.206 * (.086)
size dummies	Yes	Yes
sector dummies	Yes	Yes
constant	-.873 ** (.125)	-.886 ** (.125)
LR test of independent equations: chi2(1)	6.17 *	5.52 *

Table 4: Estimation results, probit model with sample selection. Standard errors in parentheses. * 5% significance, ** 1% significance⁵

Interestingly, we also find that firms which report PRO-contacts to be important (as measured by the variable *strategic importance*) are also more likely both to report a *focus on learning* and a *focus on short-term effects* in their linkages to PROs. Our interpretation of this finding is that firms for which interaction with PROs is an important and prioritized activity learn to organise their contacts to different PROs in a way that allows them to focus their activities in a way that suits them.

It is also noteworthy that two variables proxying for relatively high competence in R&D (*r&d sector* and *patent applicant*) are negative and largely insignificant. It thus seems that if advanced firms behave differently than non-advanced firms, it is in the form of a more distinct emphasis on the pursuit of long-term, well-defined 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.

5. Conclusions

In this chapter, we examined how firms assess the value of their interactions for R&D within two different types of actors which can both be considered public research organisations (PROs), namely public research institutes (PRIs) and universities. In spite of substantial governmental spending on PRIs in many countries, the sector has been largely ignored in previous studies of PRO-industry linkages. In the scarce literature that exists (Crow & Bozeman, 1998; Lundvall, 1992), the PRI 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’

⁵ 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 sector*. These problems do not seem to significantly affect the results.

research. Following these suggestions about their differing roles in technology development, we proposed and tested two hypotheses predicting that interactions with universities would be more likely to have a focus on learning while interactions with PRIs would more likely have a focus on short-term effects.

In order to test whether these two systems fulfil similar or quite different roles as R&D partners to industry, we asked R&D managers at 425 establishments in Swedish engineering and manufacturing sectors to assess the utility of all existing partnerships with both kinds of PROs, with a 68% response rate to the survey. We used the managers' assessments of the value of partnerships in order to characterise each observed firm-PRO linkage in terms of whether it was perceived to have a *focus on learning* and a *focus on short-term effects*, respectively.

The results provide evidence in support of our first hypothesis, namely that a partnership with universities is more likely to be focused on generation of impulses to innovation, as compared to partnership with public research institutes. To the extent that firms use contacts with PROs to generate ideas and as "listening posts", such arrangements are set up with universities and not with PRIs.

For the second hypothesis, that interactions with PRIs would more likely have a focus on short-term effects, we found no evidence to support it.

This result is quite interesting. Indeed, a failure to establish that linkages with PRI are more likely than linkages with university to be focused on short-term effects may even seem remarkable, in the sense that it refutes the idea that PRIs focus on application-oriented projects with a limited time-perspective and thereby have a special 'niche' in the systems of public research organisations. From the firm perspective, the PRIs do not provide more focused upon short-term effects and development projects than universities.

A possible interpretation is that the results of our empirical test show that the organizations involved do not correspond to the stylised view of the institutional differences between the two types of PRO, which we call universities and public research institutes throughout the text. One possibility is that the PRIs which firms engage with are quite similar to universities, 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). However, we do not find this interpretation plausible in this empirical context. Our pre-understanding, seemingly corroborated by our survey data and additional data collected (see the appendix) is that in the empirical setting that we have chosen for our test – the Swedish engineering industry – the relevant domestic and most frequently engaged foreign PRIs fit our assumption of institutional differences quite well. The PRIs reported as partners are not very focused upon research. Hence, the other and perhaps more plausible interpretation is that firms are able to use contacts with individual university-based researchers for application-oriented projects, thereby increasing the degree of control that the firm can exercise over the project (Antonelli, 2008).

Our results thus indicate interesting directions for future research as well as implications for public policy, as regards the division of labour amongst different types of public research organizations.

One key question is, Should universities be encouraged to orient their contacts with firms more towards research and further away from offering assistance in firms' short-term R&D ambitions? Previous research has indicated that star researchers may be able to both publish, patent and

commercialize their ideas (Zucker et al., 1998). However, while engagement with industry in general is neither negatively nor positively related to academic excellence (D'Este et al., 2013), activities such as extensive consulting engagements of university faculty are negatively related to the quality of research output (Rentocchini et al., 2014). This suggests that universities may be well-advised to carefully consider what types of relationships to industry they should seek to develop - and which relationships that should be actively discouraged.

Another question is, should PRIs be encouraged to more actively orient their contacts with firms towards applied, short-term R&D, so as to more clearly accentuate their complementarity to universities? Would closer integration between PRIs and universities facilitate such a development? The question of how to (re-)organise public research (e.g. merging public labs, establishing closer connections between labs and universities) has been on the innovation policy agenda for at least a decade, and remains hotly debated in many European countries (Preissl, 2006). The PRI model of public research organisation has been dismissed as providing "...a small fraction of the total amount of positive externalities that [universities] are able to provide" (Foray & Lissoni, 2009).

Systematic studies relating the role of public research organisation for effectiveness in terms of research and innovation output are however only just emerging. To our knowledge, this is the first empirical assessment of whether the two parallel systems of PROs (universities and PRIs) serve different functions as collaboration partners for industry. Therefore, our result that on balance, only limited evidence could be found that PRIs complement universities is relevant to this debate. Since an assumption of complementarity underlies the funding rationale for this sector, we believe that these findings call for further research, e.g. to investigate other models of how PRIs complement universities in systems of innovation.

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Appendix: 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 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.

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.

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