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# HOW INDUSTRY INVENTORS COLLABORATE WITH ACADEMIC RESEARCHERS: THE CHOICE BETWEEN SHARED AND UNILATERAL GOVERNANCE.

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# How Industry Inventors Collaborate with Academic Researchers:

# The choice between shared and unilateral governance forms

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**Abstract**

We investigate under what circumstances firms (industry inventors) are more likely to engage in interactions where governance of the relationship is shared between the firm and the university, as opposed to interactions where the relationship is governed unilaterally by the firm. Using PIEMINV, an original dataset of European industry patents in the Italian region of Piedmont, we analyse the characteristics of inventors with diverse experience in projects involving interactions with universities, governed by institutional contracts or personal contracts. Our results suggest that reliance among inventors of the two forms of governance is almost equal, and that unilateral governance forms are preferred when there are high levels of trust among the parties based on embeddedness in local social and education networks. This is likely because it involves less cumbersome and more direct interactions. We find also that knowledge characteristics are not particularly important discriminants of the choice between governance forms: the advantage of shared governance seems to reside mainly in the possibility to mitigate monitoring and asymmetric information problems in contexts of relatively low levels of mutual knowledge and trust.

**Key words**: academic knowledge, university-industry knowledge transfer, governance of R&D collaborations.

**JEL codes:** O31 - Innovation and Invention: Processes and Incentives; O32 - Management of Technological Innovation and R&D; O34 - Intellectual Property Rights.

## 1. Introduction

Ongoing debate on the nature and implications of the so-called knowledge based economy highlights the contribution of academic knowledge to economic development in general, and to industry innovation in particular. The objectives and outcomes of university-industry interactions, and their economic impacts at the regional, national and international levels have been investigated by a large and growing literature. It has been shown that firms generally prefer to use traditional open science channels, such as scientific conferences, publications and recruitment of graduates and doctoral students (see, e.g. Cohen et al., 2002; Giuri et al., 2007), to access university knowledge. However, direct interactions between industrial and academic scientists are also important and several output indicators, for example, number of joint university-industry patents and publications, point to an increase in these activities (Henderson et al., 1998; Hicks and Hamilton, 1999; Geuna and Nesta, 2006).

University-industry interactions can take many forms. They may be formal, supported by contractual agreements between the parties with respect to the division of labour and the rules for joint decisions and actions, or informal. A non-exhaustive list of frequent types of formal contractual interactions includes: collaborations between firms and university research teams in the context of projects financed (entirely or in part) by public funds; contracts involving university research teams, funded wholly by the firm; personal contracts with individual academic researchers; exchange programmes for firm and university scientists; recruitment of PhD students for specific firm projects; use by firms of university infrastructure; and joint university-industry research centres.

The literature includes numerous detailed analyses of firm and individual determinants of the different channels of university-industry interaction (D'Este and Patel, 2007; Boardman and Ponomariov, 2009; Giuliani et al., 2010; Perkmann et al., 2013). A small number of studies offer insights into governance decisions related to various knowledge objectives (Cassiman et al., 2010), and across firms with different characteristics and strategies (Bodas Freitas et al., 2013). However, we know less about the individual choice to engage in collaborative innovation under different forms of governance. The present chapter explores the characteristics of industry inventors who collaborate with academic researchers in arrangements where governance is shared between the firm and the university (institutional collaboration), compared with those of inventors involved in interactions governed unilaterally by the firm (personal contracts).

Institutional collaboration usually involves bilateral contracts that precisely detail the parties' responsibilities and often include safeguards and specific rules on the assignation of intellectual property rights emerging from the collaboration. These contracts are signed by the university (department, school, technology transfer office, etc.) and regulate institutional collaboration between university researchers and companies. In direct arrangements with individual researchers, contracts are coordinated and monitored by the firm, which retains full control over the outputs of the activities carried out in the context of the relationship. The personal contractual collaboration of an individual academic researcher (or her private company) with a firm is regulated by a private contract signed by the two parties (Geuna and Muscio, 2009; Bodas Freitas et al., 2013).

The empirical part of this study relies on data from the PIEMINV dataset of European patent inventors working in companies located in the Italian region of Piedmont (the population is the universe of company researchers resident in the region who are listed as an inventor on at least one European patent application between 1998 and 2005).

Our results suggest that in contexts of high trust between the parties based on embeddedness in local social and education networks, unilateral governance forms are preferred, probably because they are more straightforward. The advantage of shared governance seems to be the possibility to mitigate monitoring and asymmetric information problems in context of relatively low mutual knowledge and trust. Finally, knowledge characteristics do not seem to be important determinants of the choice between governance forms.

The chapter is organized as follows. Section 2 describes the two governance forms in detail; Section 3 introduces the PIEMINV dataset and discusses the main characteristics of university-industry interactions in Piedmont. Section 4 investigates the individual and organizational characteristics that might influence the choice of each stylized form of governance. Section 5 presents the econometric methodology; Section 6 presents the empirical results; and Section 7 provides conclusions and some implications for policy.

## 2. Governance of university-industry interactions

Several studies examine the determinants of different governance modes for inter-organizational relationships and link them to the relevant transaction costs (Oxley, 1999; Nickerson and Zenger, 2004; Hoetker and Mellewigt, 2009; Gulati and Nickerson, 2008). Most work along these lines classifies different forms of governance of inter-organizational interactions according to their proximity to the 'market' or 'hierarchy' ends of the governance spectrum, and discusses the relative costs of interactions governed by each form.

We argue that insights derived from this area of research can be applied to analysis of university-industry knowledge transfer. Most formal university-industry interactions are based on contracts that would be categorized as midway between 'market' and 'hierarchy'; however, they differ crucially in relation to how control over the interaction is split between the parties. This control can be unilateral, that is, mostly in the hands of one of the parties, or shared by the parties (Oxley, 1997).

Table 1 summarizes key features of these two models, and their main characteristics when applied specifically to the governance of university-industry interactions.[1] In the case of unilateral governance, an academic expert is contracted to support a project organized and directed by the firm: control is mostly in the hands of the firm. This form of governance gives the firm control over the organization of the collaboration and the appropriation of its results; it has low coordination requirement since the contract is directly with the researcher and is not intermediated by the university administration; the firm has to invest effort in monitoring the collaboration.

In the case of contracts involving shared governance between the firm and the partner university, the parties agree to share resources and information in order to undertake the project. Institutional governance involves negotiation between the firm and the university which increases the amount of coordination effort associated with the interaction. Since the academic works on the project in the capacity of an employee of the university, the need for the firm to monitor the relationship may be reduced. Working on a project within the context of the researcher's university employment provides the scientist with reassurance that the collaborative work will adhere to the

[1] Table 1 is a refinement of the analysis presented in Bodas Freitas et al. (2013).

norms and standards accepted by the scientific community, and that the project will not be terminated summarily if it does not bear immediate results, which should increase the scientist's commitment to the project (Lacetera, 2009). However, this form of governance limits the degree of the firm's control over project scope and content, and appropriation of results.

**Table 1 Characteristics of shared and unilateral governance**

| | **Unilateral governance (authority-based)** | **Shared governance (consensus-based)** |
|---|---|---|
| **Coordination (setting up and organization) of the interaction** | Performed by one of the partner organizations: firm hires a scientist as an external consultant to work on a firm project | Shared between partner organizations: firm contracts with the university for a joint project |
| **Control of project activities** | Held by one or a few of the partner organizations: firm decides scope and content of the project | Shared between partner organizations: firm organizes project scope and content that are amenable to the university organization |
| **Monitoring the interaction** | Performed by one of the partner organizations: firm organizes and monitors project activities, scientist works on the project as a self-employed external consultant | Shared between partner organizations: firm and university jointly organize and monitor project activities, scientist works on the project as a university employee |
| **Control (and appropriation) of project outcomes** | Held by one of the partner organizations: firm fully appropriates the results of the project | Shared between partner organizations: firm negotiates with the university the results that will be diffused publicly, and those that the firm will appropriate |

The above describes two extremes. In practice, collaborative research in which firm and university collaborate in (often publicly funded) research as partners, or in a joint venture where both partners contribute financially, is closer to the shared governance end of the spectrum, while personal contracts with individual academics are closer to the unilateral end. Forms of interaction involving the university institution, and wholly funded by the firm (such as contract research and academic consulting activities mediated by the university) include some element of shared governance (because of the greater bargaining power of the university compared to the individual academic) although the firm's control of funding allows it to govern some aspects of the relationship unilaterally.

There is a large literature on the characteristics and determinants of many types of university-industry interactions, but most studies focus only on university-mediated interactions, such as university-industry joint ventures, research collaborations and research contracts. Studies that focus on unilateral forms of governance generally consider only academic consulting contracts mediated by the university institution (Rebne, 1989; Meyer-Kramer and Schmoch, 1998; Cohen et al., 2002; Beath et al., 2003; Abreu et al., 2008; Perkmann and Walsh, 2008; Jensen et al., 2010); they ignore direct contracts between firms and individual academics that are not mediated by the university because information on this is less easily available (Bodas Freitas et al., 2010).

In a previous study (Bodas Freitas et al., 2013), we investigated the choice between engagement in personal (individual researcher) contractual interactions not mediated by the university institution (characterized by more unilateral governance), and engagement in interactions mediated by the university institution (characterized by more shared governance). We found both governance forms to be equally important, but to apply to firms with different characteristics. Firms that favour personal contractual interactions with individual researchers tend to be smaller, are more likely to belong to traditional sectors such as textiles, and appear to prefer open innovation processes based on multiple collaborations with external partners and integration of internal and external research and development (R&D). Interactions mediated by the university institution are preferred by larger firms with more absorptive capacity, and belonging to the processing industries. This suggests that both governance forms play a role in knowledge transfer and, in particular, that personal contractual interactions are important for knowledge transfer to small firms that may find difficult to use more complex institutional channels.

*[FIGURE 1 ABOUT HERE]*

Figure 1 depicts the perceptions of industry inventors in Piedmont (see Section 3 for description of PIEMINV survey data) of the effectiveness of each governance mode in

R&D projects with different objectives. Personal contracts are considered more effective for applied research projects to develop new products (61%), and for applied research projects for production activity (66%). It is interesting also that they are more effective in the case of student recruitment (54%), one of the most frequent ways to access university knowledge. Personal contracts are seen as more (43%) or equally effective (41%) for ideas for new product development. With the exceptions of non-competitive (basic research) projects (34%) and keeping up to date with new knowledge developments (31%), institutional collaborations are never considered the most effective and even in these two cases, a larger share of respondents considered both governance forms to be equally effective (respectively 42% and 45%). Overall, the evidence from the PIEMINV survey suggests that personal contracts are more effective for transfering academic knowledge in more applied projects, and are equally (or even more) effective for projects aimed at basic research. The two typologies of governance of the interaction should be considered as at least partial substitutes rather than alternative forms aimed at different types of knowledge exchange as assumed in the literature, which treats personal contracts as a restricted form of consultancy related only to applied research projects.

## 3. The PIEMINV survey

A problem related to the analysis of different forms of governance of university-industry interactions is the difficulty involved in obtaining detailed information about the characteristics of these interactions. Specific surveys are needed, of employees engaged in R&D activities, who are generally better informed about interactions with academic scientists than managers – the most frequent targets of innovation surveys. Also, studies that analyse different knowledge transfer channels usually do not distinguish between governance forms in ways that allow them to capture the distinction between shared and unilateral governance. Data recorded at the university level include only shared governance interactions. To overcome these problems we conducted an original survey specifically to investigate aspects of university-industry interactions, and particularly interactions mediated by the university institution (institutional contract) based on shared governance, and direct interactions between firms and academic scientists (personal contractual) based on unilateral governance.

The PIEMINV survey questionnaire[2] was sent to the population of inventors with addresses in Piedmont who had applied for at least one European Patent Office (EPO) patent in the period 1998-2005 (3,922 patents and 3,027 inventors were identified). Addresses were collected from EPO patent applications and updated using telephone registry information and by calling up companies. After cleaning and confirming the address data, we administered 2,916 questionnaires to industry inventors by email and surface mail between autumn 2009 and spring 2010. We obtained 938 valid responses (response rate 31%).

The questionnaire was in four parts each asking for different types of information.

1. General information about the inventor (age, gender, education, mobility) and her inventive activity (age at first patent, office where patents were first filed, invention to innovation ratio).
2. Role of university knowledge in the development of their inventions.
3. Frequency and nature of their involvement in university-industry interaction.
4. Assessment of the economic impact of university knowledge.

Additional information on the firms employing the inventors was collected from the CERVED database of Italian companies' accounts, and other public online sources.[3] This information was available for 298 out of 363 firms in the sample (or 738 inventors); it was difficult to find information about non-public small/micro firms. We also collected number of patents filed by the respective companies during the 1998 to 2005 period, from the Derwent Innovations Index. Information was gathered on inventors' patents (number of patent applications and granted patents between 1998 and 2005, types of assignees, average number of backward citations, average number of forward citations, citations to academic papers, date of first patent application, most common technology class).[4] These data were available for all inventors. Finally, 23 inventors were removed from the database because, at the time of the patent invention, they were not employed in industry, but at a public institution (university, public research organization, government body), which left 915 industry inventors in for the analysis.

[2] For a detailed analysis of the PIEMINV survey see Cecchelli et al. (2012). The database is available upon request from aldo.geuna@unito.it
[3] Firm-related information classifications are according to United Nations ISIC (Rev.4) (UN, 2008).
[4] Classification by macro-technology classes is according to OST-DT7 (OST, 2004).

The mean age of the inventors in the survey sample is 48, with most between the ages of 41 and 50 (36.7%). Mean age is lower for women (41.6), who constitute 8.2% of the sample (higher than the Italian (6%) and the European shares (5%) observed in the 2012 INNOS&T survey). Most inventors surveyed are employed by firms in five main technology sectors: manufacture of fabricated metal products (except machinery and equipment); manufacture of computer, electronic and optical products; manufacture of electrical equipment; manufacture of machinery and equipment n.e.c.; manufacture of motor vehicles, trailers and semi-trailers, and most (61%) inventors work in large firms (>250 employees). However, if each firm is counted only once (i.e. excluding repeats caused by multiple inventors per firm), the share of large firms decreases to 31.3%.

The group of inventors is characterized by fairly low levels of education, and career mobility: 79.6% of inventors attended primary and secondary schools in Piedmont; 31.3% of inventors have worked in the same organization since the end of their studies; 60.7% have changed jobs less than five times throughout their careers; only 8% have changed employment more than five times. Older inventors are on average less highly educated: 59.3% of inventors have a tertiary degree and 3.8% have a PhD, but among younger inventors (aged 40 and under) 76.4% are university graduates and 5.6% have doctorates.

Almost two-thirds of inventors have patented less than five inventions during their careers; the average is 1-2 patented inventions each. The share of inventors with more than 16 patented inventions is 7.9%. The number of non-patented inventions is almost double the number of patented inventions (average is 3 to 5 non-patented inventions). This is in line with evidence for other regions and countries (Acs and Audretsch, 1988; Arundel and Kabla, 1998). However, that although most inventors (865) responded to the question about number of patented inventions, information on non-patented inventions was provided only by only 290 inventors. For 16.9% of respondents none of their inventions became innovations, while 43.4% of inventors declare that 1-2 of their inventions eventually became innovations (i.e., became commercialized products or were used in a production process).

*3.1 University-industry interactions and their governance*

Since our respondents are firm inventors, that is, the responsible of the inventive process occurring in a company, we could asked them whether their (and of the firm) inventive processes had benefited from academic knowledge. Specifically, we asked about the share of inventions that had benefited significantly (all resources, ideas, clarifications, and verifications obtained via formal or informal interactions) from academic knowledge. Over a third of inventions had benefited directly from academic research in their development: 34% said they had benefited from university knowledge and nearly 9% stated that academic knowledge was instrumental to the development of 50% or more of their inventions. Of these, 3% benefited from university knowledge for the development of all their inventions.

As in previous studies, the survey included a standard question on the use and importance of a set of channels for accessing academic knowledge. The question was modified to include both institutional and personal contracts (the difference was explained clearly in the question). Table 2 shows that the most frequently used channels are scientific papers and other publications (more than 50% of respondents used these channels, and 33.8% and 28.3% respectively ranked them as highly important), and participation in conferences and workshops (52.2% of respondents ranked this channel as useful and 20.7% considered it highly important). This is consistent with evidence from several international surveys which shows that firms most often rely on open science dissemination methods in order to access university knowledge (Cohen et al., 2002; Arundel and Geuna, 2004; Abreu et al., 2008). Personnel exchanges and secondments between university and industry, contacts with academic spin-offs, and shared facilities were the lowest ranked channels. Personal contracts with individual university researchers were used by 25.8% of inventors, while institutional research collaborations (financed either by the company or by public funds) were used by approximately a quarter of respondents, with institutional contracts financed by the company being slightly more frequent and important. For the sample of respondents involved in either institutional collaborations or personal contracts, one-third had participated only in institutional collaborations, one-third in only personal contractual collaborations, and one-third had had involvement in both types of governance of the collaboration. Consistent with previous evidence (Bodas Freitas et al., 2013), personal contracts are as important as institutional contractual collaborations.

**Table 2 Importance of different channels of interaction with universities**

| Types of knowledge transfer channels | Channels of Interaction | Used – not important | Used – very important | Used |
|---|---|---|---|---|
| University-industry research collaborations | Institutional research collaborations between your company and the university (department, faculty, university, technology transfer office), *financed by the company* | 15.3% | 12.8% | 28.1% |
| | Institutional research collaborations between your company and the university, *financed through public funds* (regional, national or international) | 14.4% | 11.4% | 25.8% |
| | Personal contracts between your company and *individual university researchers* | 14.2% | 11.6% | 25.8% |
| | Informal, personal contacts between your company and university researchers | 18.0% | 9.0% | 27.0% |
| | Contacts with university Spin-offs | 9.9% | 4.7% | 14.6% |
| | Shared facilities (e.g. labs, equipment) with the university | 10.9% | 7.1% | 18.0% |
| Education and employment-based | Collaboration based on co-supervision of Masters or PhD students | 16.1% | 11.1% | 27.2% |
| | University researchers or staff employed part-time or on a temporary basis by your company | 11.6% | 6.7% | 18.3% |
| | Your staff employed part-time or on a temporary basis at a university | 3.8% | 0.8% | 4.6% |
| | University students working for you company as trainees | 22.6% | 12.8% | 35.5% |
| | Full time hiring of university graduates or researchers | 20.0% | 19.5% | 39.5% |
| Open science and training | Participation in conferences and workshops | 31.5% | 20.7% | 52.2% |
| | Scientific papers in journals | 25.2% | 33.8% | 59.0% |
| | Other publications, including professional publications and reports | 32.7% | 28.3% | 61.0% |
| | Attending university organized business training or initiatives to Promote knowledge transfer | 15.3% | 6.8% | 22.0% |
| | Reading university patents | 15.9% | 5.6% | 21.4% |

Inventors were asked to indicate which universities they collaborated with, and how often. Only 815 inventors responded to this question. Table 3 shows that the Politecnico of Turin is ranked first for frequency of all kinds of interactions, followed by other Italian universities. The other two Piedmontese universities (University of Turin and University of Western Piedmont) are less important, though there is a clear localization effect, with 58% of inventors declaring collaboration with one of the three Piedmontese universities. 46.6% of company inventors interact at least every two years with a non-Piedmontese university, and 29% with a foreign university (13.4% with a US university) indicating a high level of internationalization in the university-industry interactions of Piedmontese innovative companies.

**Table 3 Frequency of interactions with different universities**

| University | Frequency of interaction: | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Very frequent | | Frequent | | Not frequent | | Rare | |
| Politecnico of Turin | 44 | 5.4% | 73 | 9.0% | 127 | 15.6% | 207 | 25.4% |
| Other Italian Uni. | 47 | 5.8% | 67 | 8.2% | 80 | 9.8% | 140 | 17.2% |
| Other European Uni. | 23 | 2.8% | 37 | 4.5% | 51 | 6.3% | 89 | 10.9% |
| University of Turin | 13 | 1.6% | 26 | 3.2% | 41 | 5.0% | 102 | 12.5% |
| US university | 7 | 0.9% | 17 | 2.1% | 33 | 4.0% | 52 | 6.4% |
| Other foreign university | 8 | 1.0% | 6 | 0.7% | 23 | 2.8% | 43 | 5.3% |
| University of Western Piedmont | 5 | 0.6% | 10 | 1.2% | 19 | 2.3% | 40 | 4.9% |

Note: Rare is 1 interaction every 2 years; not frequent is once or twice a year; frequent is 3-6 times a year; very frequent is every 1-2 months. There was also an alternative (not reported here) of no interaction.

The prevalence of interactions with the Politecnico may be benefiting from an 'alumni effect' since the Politecnico is an elite technical university that specializes in disciplines that tend to dominate in inventors' technology classes (especially mechanical and electrical engineering). Many of the inventors in our sample (208) are Politecnico graduates. Table 4 shows the share of inventors that graduated from each of the universities (rows) who subsequently interacted with each university (columns). Although some subsamples are relatively small (FOREIGN), there is a strong correlation between the degree awarding institution and the university with which the inventor interacts. This confirms the importance of networks of relationships, such as alumni networks, for driving university-industry relationships.

**Table 4 Graduates by institution and interactions with different universities**

| | UNIVERSITY OF GRADUATION | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | University of Turin | | Politecnico of Turin | | Other Italian university | | Foreign university | |
| No. of graduates | 87 | | 208 | | 92 | | 19 | |
| No. interacting with the following universities: | N | % | N | % | N | % | N | % |
| • University of Turin | 57 | 25.8% | 36 | 9.8% | 23 | 6.3% | 1 | 4.3% |
| • Politecnico of Turin | 59 | 26.7% | 157 | 42.9% | 41 | 21.9% | 10 | 43.5% |
| • University of Western Piedmont | 15 | 6.8% | 11 | 3.0% | 13 | 6.3% | 0 | 0.0% |
| • Other Italian University | 50 | 22.6% | 93 | 25.4% | 63 | 43.8% | 4 | 17.4% |
| • Foreign university | 40 | 18.1% | 69 | 18.9% | 42 | 21.9% | 8 | 34.8% |
| Total no. of interactions | 221 | 100% | 366 | 100% | 182 | 100% | 23 | 100% |

Note: The information on highest educational qualification was supplied by 708 inventors (almost 60% stating that they had a tertiary degree), while the name of awarding institution was supplied by only 406 inventors. An inventor can have interactions with more than one university.

## 4. A framework to explain the choice of governance forms

The determinants of the choice of governance form for formal interactions between firms and universities are likely to be numerous and to be related in complex ways. Among the many factors likely to play a role in shaping the choice of governance form, we can include: (a) individual motivations and preferences (often built on the basis of prior experience) on the part of both industry and academic researchers; (b) skills and resources available in the firm; (c) project specific characteristics; (d) policy-related incentives linking public funding to use of specific governance forms; (e) institutional incentives within the university institution; and (f) other idiosyncratic individual, firm and project factors.

Although numerous aspects are likely to contribute to the choice of governance form, we expect the commissioning firm to be the main driver. In the empirical analysis, to avoid biases in the choice of governance driven by policy incentives, we consider only collaborations fully funded by the firm. In the case of industry-funded collaborations, we argue that the choice is drive by firms' search for efficient and effective governance mechanisms according to the web of social interactions and routines of industry inventors. In this context, we explore a number of possible determinants related to the social network of the industry inventor involved, and the nature of the collaborative project, controlling for numerous features of the collaborating firm and inventor.

The presence of established social networks of industry and university personnel reduces the cost of searching for appropriate partners, and increases the probability to collaborate routinely with a given set of academic researchers. Graduation from the same university or secondary education institution (especially for the older generation with lower levels of education) simplifies the process of identification and selection of potential academic partners, creating incentives to rely on unilateral forms of governance that carry lower coordination costs.

Belonging to the same social network can also increase the trust between parties. Broadly defined, interorganizational trust describes the organization's expectation that the other organization will not act opportunistically (Bradach and Eccles, 1989). According to the large economics and sociology literatures, trust lowers the transaction costs for all kinds of exchange relationships where there is a risk of opportunism (for a discussion, see Gulati and Nickerson, 2008). For example, trust can depend on prior experience of collaboration, which can reduce the information asymmetries among the parties (van de Vrande et al., 2009) and allow each party to better monitor the effort and quality of the other party's output. This is particularly important in the context of projects that create radically new knowledge (where, by definition, it is impossible to specify in advance the content of the knowledge that will be transferred; Oxley, 1999), and in the context of projects where the firm finds it difficult to assess the content and the value of the knowledge to be transferred (e.g. because the knowledge is far from the firm's knowledge base; van de Vrande et al., 2009). Hence, trust can mitigate the appropriability problems that arise particularly in the context of more basic research projects, and can reduce the need for coordination forms based on shared governance.

Also, we expect the nature of the collaborative project undertaken to play a role in the choice of governance form, since different governance forms are relatively more efficient for supporting the production and transfer of different types of knowledge (Nickerson and Zenger, 2004; Alkaersig, 2010). Nickerson and Zenger (2004), point out that projects differ in the optimal forms of solution search. Less complex, decomposable problems are solved more efficiently through directed search, which can be pursued independently by various actors: new combinations of knowledge are derived by altering design elements one at a time, observing the resulting change in solution value, and continuing along the same search path or returning the design to its original form and adjusting a different element. In the case of highly complex problems, heuristic search is more efficient: a cognitive map of the solution landscape is formed in advance of selecting trials that will maximize the probability of rapid discovery of a high value solution. This type of search requires the development of heuristics that derive from multiple and dispersed knowledge sets and, hence, requires collaboration among different knowledge holders. According to Nickerson and Zenger (2004), unilateral forms of governance are more appropriate when the optimal mode is directed search (i.e. in the case of less complex, decomposable problems). In these cases, a central project coordinator can direct the search, which is performed independently by different contracted parties. When the optimal mode of search is heuristic search (i.e. for more complex, integrated problems), shared governance is more appropriate because it promotes horizontal communication channels that support broad knowledge sharing among peers (a central project coordinator would suffer cognitive limitations to organizing this complex search).

Therefore, we can expect that forms of shared governance that support broader search of the knowledge landscape rather than exploration of a narrow region, are more suitable for projects which focus on more general and complex innovations (Alkaersig, 2010). We would expect inventors whose inventions have more general application and build on a more complex knowledge base, to be more likely to favour shared governance forms.

## 5. Econometric estimation

### *5.1. Empirical strategy*

We want to estimate the probability of using of a specific form of governance in the relationship with university researchers. The dependent variables are two dichotomous variables: *Unilateral-governance* which indicates whether the inventive activity of the inventor relies on personal contractual relationships with university researchers, involving unilateral/authority governance by the firm; and *Shared-governance* which provides information on whether the inventive activity of the inventor relies on institutional collaborations with universities, involving shared firm and university governance. The two governance forms are not mutually exclusive; inventors can use both modes and, therefore, their standard errors may be correlated. This requires us to estimate the use of unilateral and shared governance simultaneously, using the bivariate probit maximum likelihood estimation method.

The bivariate probit estimator could be biased by self-selection into collaborating with universities. For example, inventors that are involved in less basic research and fewer inventive projects may also be less likely to collaborate with universities. This would lead to an upward bias in the  effect of basic research and number of projects on the specific governance form. To address this bias, we estimate bivariate probit models that account for selection into interpersonal interactions with university researchers. The selection considers all types of university-industry collaboration and education-employment based knowledge transfer channels used by inventors (see Table 2), not just the two contractual governance forms considered here.[5] The model is estimated employing the Maximum Simulated Likelihood Method using the GHK simulator (Gates, 2006).[6]

### *5.2. Selection variable and dependent variables*

The selection and dependent variables are based on the survey question about the use of different channels of knowledge transfer from universities (see Table 2). The selection variable is equal to 1 if the inventor used any of the university-industry collaboration and education-employment based channels. Table 5 provides an overview of the different governance forms and how they are used. The relevant question was answered by 826 inventors; our final model uses 741 observations (some of the independent variables had missing values). Table 5 shows that 31% of these 741 inventors stated not using collaborative knowledge transfer channels with universities, to produce their inventions. However, a majority stated that interactions with universities informed their inventions. Of these, 58% stated that they used contractual agreements to engage in research partnerships with universities. Institutional and personal contracts seem almost equally important, with 42% of collaborating inventors using institutional contracts (shared governance) and 38% using personal contracts (unilateral governance). These represent our two overlapping dependent variables; 22% of collaborating inventors use both. While 516 inventors use university knowledge transfer channels, only 440 are observed in the second stage equation due to missing values in some of the explanatory variables.

[5] Open science or training channels are not included as they do not require the firm to activate a structured organization.

[6] We use the user-written command cmp in Stata to estimate the selection bivariate probit models (Roodman, 2009). To calculate marginal effects we insert the inverse Mills ratio into a standard bivariate probit estimate.

**Table 5 Use of different governance forms**

| 741 inventors | | number | % |
|---|---|---|---|
| No university knowledge channels used | | 225 | 30.7% |
| Some university knowledge channels used | Selection variable | 516 | 69.3% |
| Formal governance forms | | 300 | 58.1% |
| shared governance | Dependent variable | 216 | 41.9% |
| unilateral governance | Dependent variable | 196 | 38.0% |
| Only shared governance | | 104 | 20.2% |
| Only unilateral governance | | 84 | 16.3% |
| Both | | 112 | 21.7% |

*5.3. Independent variables*

As indicate by the theoretical framework, different individual characteristics may drive the choice of different governance forms. We focus principally on the socio-education networks of inventors, and the characteristics of their portfolios of inventions.

To measure the extent to which industry inventors can rely on established networks of personal relationships with university researchers, we use two inventor-based variables. *Local education* measures the inventor's embeddedness in local networks of relationships based on completion of secondary education in Piedmont (80% of inventors). This implies that the inventor has greater social, relational and cultural proximity, which increases mutual trust, to the university researchers with whom she collaborates (58% of inventors stated that they had collaborated locally) since a large number of university employees were also educated in Piedmont. This is particularly applicable to older inventors who are less likely to have had a university education, and traditionally consider their secondary education affiliation as important. We expect *local education* and *age* to be associated with the unilateral governance form.

*Alumni* captures the inventor's closeness to the university awarding their highest degree. We suggest that an inventor will be more likely to have contacts with researchers in the university awarding her degree, and to have greater social, relational and cultural proximity to university researchers in her *alma mater:* 60% of researchers have a higher university degree, and 70% of these have developed research contracts with their old university (alumni interactions). We include three alumni measures for: Politecnico of Turin, the University of Turin, and other Italian universities. The number of inventors that graduated from a foreign university is too low to be included as a separate measure.

The increased trust resulting from involvement in the same socio-education networks could mitigate appropriability problems and reduce the need for coordination forms based on shared governance, resulting in a positive correlation between *Alumni* and personal contract.

We proxy project characteristics using various measures based on EPO patent applications. We build all our patent measures based on EPO inventions filed between 1998 and 2005, the base period for our survey.[7]

*Generality* of an inventor's patent portfolio measures the extent to which, on average, the inventor's patents have been used to develop a variety of technologically diverse inventions (Trajtenberg et al., 1997). The index is built as follows:

$$Generality_i = 1 - \sum_{j-1}^{J} \left(\frac{F_{ij}}{F_i}\right)^2$$

where $J$ is the overall number of technology classes, $F_{ij}$ is the number of forward citations to patent $i$ in class $j$, and $F_i$ is the overall number of forward citations to patent $i$. We implement the same correction for the downward bias that occurs when patents have few citations and average this index across all of an inventor's patents filed between 1998 and 2005. This index specifies if the invention has an influence on many and diverse technological fields.

The originality (Trajtenberg et al., 1997) of an inventor's patent portfolio measures the extent to which, on average, the inventor's patents build on a technologically diverse knowledge base. The more an invention builds on many different sources of knowledge, the more encompassing and, hence, complex is its knowledge base (Czarnitzki et al., 2008). This means we can consider it as a proxy for the complexity of the knowledge underlying the project, and can call this variable *Complexity*. The index is built as follows

[7] A relevant problem in using these data is that the choice of governance form is associated with the knowledge characteristics of a specific project, while our data refer to each inventor's entire portfolio of projects. However, 56% of the surveyed inventors had only 1 patent application during the period 1998 to 2005, consequently, the governance decision that was reported, refers, in most cases, only to one or a few invention projects.

$$Complexity_i = 1 - \sum_{j=1}^{J} (\frac{B_{ij}}{B_i})^2$$

where *J* is the overall number of technology classes, $B_{ij}$ is the number of backward citations to patent *i* in class *j*, and $B_i$ is the overall number of backward citations to patent *i*. We implement a correction to correct for the downward bias that occurs when patents receive very few citations (Hall, 2005), and average this across all the inventor's patents filed between 1998 and 2005. According to our previous argument, both greater *Generality* and greater *Complexity* should be linked to a greater likelihood to use shared governance.

We control for firm characteristics that may influence employees' use of shared or unilateral relationships with universities. Firms may favour different governance forms depending on their innovation resources. The cost of negotiating comprehensive bilateral contracts could be quite high (it may require legal and administrative competencies beyond those possessed by small firms), which may render unilateral governance more attractive to small firms (Bodas Freitas et al., 2013). We do not have a measure for innovative resources and staff diversity; we therefore rely on the proxy of *Firm size*, measured as number of employees. We follow the parameters suggested by the European Commission to define company size based on number of employees; thus, firms with fewer than 50 employees are *small firms*, 50 to 249 employees are *medium sized firms*, and more than 249 employees are *large firms*. In addition, to capture some company heterogeneity, we include *technology dummies* (most common technological class in the patent portfolio of company inventors) and, in some robustness specifications,[8] number of company patents as a measure of *technological capability*.

We also include controls for *gender*, a dummy for female inventors, which represent 8.2% of the total sample and 10% of the sample after selection. We include the simple average number of forward and backward citations to an inventor's patents (*FwCit / BwCit*). An inventor with patens with a high average number of forward citations is assumed to work on projects of higher economic and technological value. At the same time, forward citations might indicate patenting in a very crowded area of research

[8] The number of company patents is available only for a subsample of researchers and, therefore, is not included in the main model.

(Czarnitzki et al., 2008) rather than being a measure of the value of the knowledge per se. Backward citations measure the body of existing inventions upon which the invention builds or to which it is related (without accounting for its diversity). This is usually seen as indicating that an invention is incremental because it builds on a larger body of prior art (Lanjouw and Schankerman, 2004).

### *5.4. Independent variables in the selection equation*

In the first stage selection equation the inventor's *education, productivity* and *university work experience* serve as exclusion restrictions that predict the use of university knowledge, but do not influence the choice of a specific form of governance of collaboration. These exclusion restrictions are supported since none of the three variables significantly influences the choice of governance form when included in the second stage.

*Education* indicates whether the inventor has a university degree. We can assume that inventors who are university graduates will be more likely to seek university knowledge for their inventions. 60% of firm inventors have a university degree. Inventor's *productivity* is measured as the number of patents filed by the inventor between 1998 and 2005. The average number of patent applications filed between 1998 and 2005 is 2.3, with 53% of inventors filing just 1 patent during the entire period. *University work experience* measures whether the inventor worked in a university for at least one month during employment in a private company. This experience is expected to relate directly to the inventor's propensity to seek university knowledge. Only 8% of inventors have academic experience. We include inventor's *age* and *gender* as controls.

The characteristics of the company employing the inventor affect her probability to collaborate actively with a university. The literature (Cohen et al., 2002; Mohnen and Hoareau, 2003; Laursen and Salter, 2004; Fontana et al., 2006) shows that large, research intensive firms have a higher probability of developing interactions with a university. We use as control variables *firm size*, whether the firm is a *foreign company*, firm *technological capability,* and *technology* dummies.

**Table 6 Descriptive statistics**

| | Selected observation (2nd stage) | | | | |
|---|---|---|---|---|---|
| | mean | sd | min | max | count |
| Shared governance | 0.37 | 0.48 | 0.0 | 1 | 440 |
| Unilateral governance | 0.40 | 0.49 | 0.0 | 1 | 440 |
| Local Education | 0.80 | 0.40 | 0.0 | 1 | 440 |
| Age | 47.90 | 9.94 | 30.0 | 88 | 440 |
| Alumni | 0.51 | 0.50 | 0.0 | 1 | 415 |
| Alumni_Uni To | 0.11 | 0.32 | 0.0 | 1 | 415 |
| Alumni_ Poli To | 0.26 | 0.44 | 0.0 | 1 | 415 |
| Alumni_Other | 0.13 | 0.34 | 0.0 | 1 | 415 |
| Generality | 0.11 | 0.27 | 0.0 | 1 | 440 |
| Complexity | 0.21 | 0.31 | 0.0 | 1 | 440 |
| Small firm | 0.15 | 0.35 | 0.0 | 1 | 440 |
| Medium firm | 0.16 | 0.36 | 0.0 | 1 | 440 |
| Large firm | 0.70 | 0.46 | 0.0 | 1 | 440 |
| Forward citations | 0.97 | 1.43 | 0.0 | 9 | 440 |
| Backward citations | 2.36 | 2.80 | 0.0 | 37 | 440 |
| Gender (Female) | 0.10 | 0.30 | 0.0 | 1 | 440 |
| Company patents (log) | 4.59 | 2.23 | 0.0 | 9 | 345 |
| | Full sample (1st stage – Selection equation) | | | | |
| | mean | sd | min | max | count |
| Collaboration | 0.70 | 0.46 | 0.0 | 1 | 741 |
| Education | 0.60 | 0.49 | 0.0 | 1 | 669 |
| Productivity | 2.23 | 2.48 | 0.0 | 24 | 741 |
| University work experience | 0.08 | 0.27 | 0.0 | 1 | 741 |
| Age | 48.12 | 10.22 | 29.0 | 88 | 741 |
| Gender (Female) | 0.08 | 0.28 | 0.0 | 1 | 741 |
| Foreign firm | 0.11 | 0.31 | 0.0 | 1 | 741 |
| Small firm | 0.19 | 0.39 | 0.0 | 1 | 741 |
| Medium firm | 0.18 | 0.38 | 0.0 | 1 | 741 |
| Large firm | 0.63 | 0.48 | 0.0 | 1 | 741 |

Table 6 presents the descriptive statistics for all the independent variables the selected sample and for the full sample. Table 7 provides separate descriptive statistics for inventors that use only shared, only unilateral, or both governance forms. We find significant differences between the three categories for inventor’s age, firm size and share of alumni from the University of Turin. Inventors using unilateral governance are significantly older and less often employed at large companies.

**Table 7 Descriptive statistics for collaboration and governance form**

| | Both | | | Unilateral-gov only | | | Shared-gov only | | |
|---|---|---|---|---|---|---|---|---|---|
| | m | sd | ct | m | sd | ct | m | sd | ct |
| Local Education | 0.79 | 0.41 | 87 | 0.83 | 0.38 | 75 | 0.76 | 0.43 | 88 |
| Age* | 48.95 | 10.45 | 87 | 50.04 | 11.23 | 75 | 45.08 | 8.40 | 88 |
| Alumni | 0.68 | 0.47 | 85 | 0.56 | 0.50 | 70 | 0.59 | 0.49 | 79 |
| Alumni_Uni To* | 0.20 | 0.40 | 85 | 0.13 | 0.34 | 70 | 0.08 | 0.27 | 79 |
| Alumni_ Poli To | 0.31 | 0.46 | 85 | 0.27 | 0.45 | 70 | 0.30 | 0.46 | 79 |
| Alumni_Other | 0.15 | 0.36 | 85 | 0.16 | 0.37 | 70 | 0.22 | 0.41 | 79 |
| Generality | 0.14 | 0.30 | 87 | 0.16 | 0.33 | 75 | 0.14 | 0.30 | 88 |
| Complexity | 0.26 | 0.32 | 87 | 0.19 | 0.29 | 75 | 0.22 | 0.31 | 88 |
| Small firm | 0.14 | 0.35 | 87 | 0.21 | 0.41 | 75 | 0.11 | 0.32 | 88 |
| Medium firm | 0.11 | 0.32 | 87 | 0.17 | 0.38 | 75 | 0.14 | 0.35 | 88 |
| Large firm* | 0.75 | 0.44 | 87 | 0.61 | 0.49 | 75 | 0.75 | 0.44 | 88 |
| Forward citations | 0.93 | 1.33 | 87 | 1.09 | 1.37 | 75 | 1.17 | 1.86 | 88 |
| Backward citations | 3.02 | 2.85 | 87 | 2.34 | 1.96 | 75 | 2.74 | 4.46 | 88 |
| Gender (Female) | 0.08 | 0.27 | 87 | 0.11 | 0.31 | 75 | 0.11 | 0.32 | 88 |
| Company patents (log) | 4.90 | 2.06 | 71 | 4.25 | 2.30 | 60 | 5.00 | 2.12 | 66 |

* statistically significant difference between the three categories (Anova)

## 6. Results

Table 8 and 9 present the bivariate probit estimates of use of unilateral and shared governance modes with selection. Table 8 presents the results including local education and age variables. Table 9 presents the effects of the alumni network. Our results suggest that the socio-education network and the characteristics of the inventor's portfolio of inventions explain the heterogeneity of inventor's experience in shared and unilateral governed relationships with university.

The correlation across equations in the selection model is significant, indicating that self-selection into collaboration with universities is important. Consistent with the previous literature, the selection equation estimates indicate that highly educated inventors with high levels of technological productivity who work in larger firms, have a higher probably of being involved in interactions with university researchers.

The correlation across the two types of governance forms is significant, supporting their joint estimation. We are interested primarily in the difference between inventors engaging in only shared or only unilateral governance, or both. We report the marginal effects on the joint probabilities of observing these different cases and base our discussion of results on these marginal effects.

*Local education,* which measures the inventor's embeddedness in the local network, increases the probability of using a unilateral governance form in the absence of a shared governance form. The probability of unilateral governance in the absence of shared governance also increases with age, though the effect is very small. Conversely, the probability of using only shared governance decreases with age and is lower for inventors educated locally. We find some support for our hypothesis about the importance of local network and age for unilateral collaboration.

The joint probability of using both governance forms increases significantly with the generality of the inventor's patents. Thus, inventors that are more specialized in inventive processes with wide applicability are associated with both forms of collaboration. The complexity of inventor's knowledge base does not affect the choice of governance form. With respect to the control variables, the number of backward citations increases the joint probability of using both governance forms, and also the probability of using only shared governance (and is negatively, but not significantly correlated to unilateral governance forms). This indicates that inventors working on patents that build on a large body of prior art tend to favour institutional contracts. The number of forward citations does not have a significant effect on the choice of governance form, and firm size is also not significant, although, consistent with the results from previous studies (Bodas Freitas et al., 2013), we find a negative correlation between large firms and personal contracts and a positive correlation with institutional contracts.[9] Finally, female industry inventors seem to have a higher probability of choosing other forms of collaboration with university researchers compared to both institutional or personal contracts.

[9] As a robustness check, we included in the regressions, number of firm patents to see if higher technological capability of the firm has an effect on the choice of governance form. The coefficient is not significant while the results presented here are confirmed.

## Table 8 Bivariate probit of use of unilateral and shared governance modes

| | **Selection Biprobit - Coefficients** | | | **Marginal Effects of 2nd Stage** | | | |
|---|---|---|---|---|---|---|---|
| | 1st stage Collab. | Unilateral gov. | Shared gov. | $Pr(y_{shared}=1, y_{unilat}=1)$ | $Pr(y_{shared}=0, y_{unilat}=1)$ | $Pr(y_{shared}=1, y_{unilat}=0)$ | $Pr(y_{shared}=0, y_{unilat}=0)$ |
| Local Education | | 0.150 | -0.230* | 0.002 | 0.061* | -0.068* | 0.005 |
| | | (0.141) | (0.137) | (0.037) | (0.036) | (0.038) | (0.051) |
| Age | 0.004 | 0.008 | -0.014** | 0.000 | 0.004*** | -0.004*** | 0.000 |
| | (0.006) | (0.006) | (0.006) | (0.002) | (0.001) | (0.002) | (0.002) |
| Generality | | 0.333 | 0.320 | 0.102** | 0.048 | -0.010 | -0.140** |
| | | (0.210) | (0.209) | (0.049) | (0.060) | (0.066) | (0.069) |
| Complexity | | 0.017 | 0.089 | 0.027 | -0.026 | 0.040 | -0.041 |
| | | (0.183) | (0.182) | (0.052) | (0.046) | (0.050) | (0.072) |
| Medium firm | 0.171 | -0.165 | 0.031 | -0.070 | -0.046 | 0.022 | 0.094 |
| | (0.170) | (0.202) | (0.205) | (0.053) | (0.053) | (0.059) | (0.074) |
| Large firm | 0.477*** | -0.194 | 0.140 | -0.040 | -0.049 | 0.037 | 0.052 |
| | (0.142) | (0.167) | (0.169) | (0.049) | (0.048) | (0.053) | (0.069) |
| Forward Citations | | -0.013 | -0.017 | -0.003 | -0.001 | -0.000 | 0.005 |
| | | (0.041) | (0.043) | (0.010) | (0.011) | (0.012) | (0.014) |
| Backward Citations | | 0.027 | 0.075*** | 0.015*** | -0.005 | 0.012** | -0.022*** |
| | | (0.025) | (0.023) | (0.006) | (0.006) | (0.006) | (0.008) |
| Gender (Female) | 0.244 | -0.167 | -0.237 | -0.084 | -0.000 | -0.035 | 0.119* |
| | (0.227) | (0.198) | (0.194) | (0.052) | (0.050) | (0.054) | (0.072) |
| Education | 0.433*** | | | | | | |
| | (0.115) | | | | | | |
| Productivity | 0.090*** | | | | | | |
| | (0.028) | | | | | | |
| University work experience | 0.326 | | | | | | |
| | (0.217) | | | | | | |
| Foreign Company | 0.104 | | | | | | |
| | (0.184) | | | | | | |
| Elect. & Electronic Eng. | 0.051 | -0.005 | 0.551* | 0.024 | -0.125** | 0.150** | -0.049 |
| | (0.243) | (0.267) | (0.295) | (0.076) | (0.058) | (0.067) | (0.108) |
| Instruments | 0.378 | 0.126 | 0.387 | 0.041 | -0.053 | 0.077 | -0.064 |
| | (0.274) | (0.298) | (0.324) | (0.084) | (0.064) | (0.073) | (0.118) |
| Chemicals | 0.708** | 0.110 | 0.709** | 0.050 | -0.075 | 0.105 | -0.079 |
| | (0.336) | (0.311) | (0.340) | (0.090) | (0.070) | (0.079) | (0.126) |
| Pharmaceuticals | 0.806 | 1.051** | 0.217 | 0.123 | 0.148 | -0.113 | -0.158 |
| | (0.601) | (0.518) | (0.490) | (0.139) | (0.112) | (0.123) | (0.194) |
| Process Engineering | -0.373 | 0.028 | 0.573* | 0.083 | -0.076 | 0.119 | -0.127 |
| | (0.251) | (0.299) | (0.321) | (0.086) | (0.070) | (0.082) | (0.122) |
| Mechanical Eng | -0.069 | -0.119 | 0.339 | -0.003 | -0.093 | 0.103 | -0.007 |
| | (0.230) | (0.257) | (0.289) | (0.075) | (0.057) | (0.068) | (0.107) |
| _cons | -0.588 | -0.546 | 0.105 | | | | |
| | (0.380) | (0.478) | (0.476) | | | | |
| atanhrho_sel | | -0.449* | -0.480** | | | | |
| | | (0.260) | (0.239) | | | | |
| atanhrho_inst*pers | | | 0.471*** | | | | |
| | | | (0.091) | | | | |
| N (uncensored) | 741 | 440 | 440 | | | | |
| ll | -1014.885 | | | | | | |

Robust standard errors in parentheses. Consumer goods are the omitted category for technology dummies.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In line with previous findings, firm size has an effect on selection into collaboration. Inventors working for large firms are more likely to source knowledge from universities through collaboration and employment channels, than inventors working for small or medium sized firms. Inventors with a university degree, and more productive inventors, are more likely to be involved in collaborations with universities. Inventor’s gender and age have no impact on collaboration decisions. Also experience of working in academia while employed by a firm does not affect selection.

Table 9 reports the results for the alumni measures. We find that the joint probability of using both governance forms increases significantly with being an alumnus, that is, having collaborated with individual researchers at the degree awarding university. If we distinguish between alumni of different institutions, we see that this effect is strongest for alumni of the University of Turin, which is also associated with unilateral governance. Thus, while there is a larger number of alumni from Politecnico of Turin, graduates from the University of Turin are more likely to maintain and use personal networks, resulting in a higher probability of personal contracts. Alumni from the Politecnico do not show a preference for personal networks and use institutional links with equal intensity. Being an alumnus of a university in another part of Italy is also associated with the joint probability of using both governance forms. The results seem to indicate that alumni network membership possibly simplifies the development of the more contractually complex forms of interaction with the university such as institutional, and personal contracts, compared to other less intensive organization based forms of interaction. The effects of other measures are similar to those reported in Table 8 and, for ease of reading, are not included in Table 9.

**Table 9 Bivariate probit of use of unilateral and shared governance modes**

| | Selection 1st stage Collab. | Biprobit - Coefficients Unilateral gov. | Shared gov. | Marginal Effects of 2nd Stage $Pr(y_{shared}=1, y_{unilat}=1)$ | $Pr(y_{shared}=0, y_{unilat}=1)$ | $Pr(y_{shared}=1, y_{unilat}=0)$ | $Pr(y_{shared}=0, y_{unilat}=0)$ |
|---|---|---|---|---|---|---|---|
| Alumni | | 0.467*** | 0.393** | 0.146*** | 0.046 | 0.008 | -0.200*** |
| | | (0.149) | (0.155) | (0.035) | (0.034) | (0.037) | (0.047) |
| atanhrho_sel* | | -0.023 | -0.269 | | | | |
| | | (0.451) | (0.442) | | | | |
| atanhrho_inst*pers | | | 0.388*** | | | | |
| | | | (0.098) | | | | |
| N (uncensored) | 687 | 419 | 419 | | | | |
| ll | -912.331 | | | | | | |
| Alumni_Uni To | | 0.687*** | 0.284 | 0.187*** | 0.104** | -0.038 | -0.254*** |
| | | (0.233) | (0.222) | (0.057) | (0.046) | (0.049) | (0.078) |
| Alumni_Poli To | | 0.380** | 0.358** | 0.115*** | 0.030 | 0.014 | -0.159*** |
| | | (0.172) | (0.176) | (0.041) | (0.037) | (0.040) | (0.056) |
| Alumni_Other | | 0.404* | 0.480** | 0.137*** | 0.019 | 0.035 | -0.191*** |
| | | (0.214) | (0.208) | (0.045) | (0.052) | (0.055) | (0.062) |
| atanhrho_sel* | | -0.117 | -0.316 | | | | |
| | | (0.443) | (0.434) | | | | |
| atanhrho_inst*pers | | | 0.404*** | | | | |
| | | | (0.105) | | | | |
| N (uncensored) | 687 | 419 | 419 | | | | |
| ll | -911.224 | | | | | | |

Robust standard errors in parentheses. All estimations include technology dummies and all variables from Table 8.
$^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

## 7. Conclusions

On the basis of the PIEMINV database which provides unique detailed information on the experience of industry inventors in projects that involved university interaction governed through institutional contracts or personal contracts with academics, we developed an analysis of inventors and knowledge characteristics underlying firms' choices of governance forms. Our results support the findings from other studies that highly educated inventors with high levels of technological productivity, who work for larger firms, are more likely to engage in collaborations with university researchers. Company inventors that engage in projects with more general applicability (greater *Generality*) and that build on a broader base of prior art (backward citations) are more likely to be involved in both shared and unilaterally-governed collaborations, as opposed to other forms of collaboration based on education channels. These results do not support our suggestion that greater knowledge generality should favour shared governance, but tend to support the use of both types of governance; the lack of strong effects of the variables capturing the knowledge characteristics of the projects in which a company inventor engages, suggests that other individual factors are more important (or that our measures of knowledge characteristics are weak). Indeed, social and education networks are important for choice of governance form. Older inventors who completed their secondary education in Piedmont are more likely to develop collaborations governed unilaterally by the firm, supporting our suggestion that embeddedness in local networks increases mutual trust and facilitates unilateral monitoring of collaboration. Also, being a graduate from the University of Turin increases the likelihood of being involved in unilateral governance, but – somewhat surprisingly - we do not find evidence of a similar alumni effect for company inventors who graduated from Politecnico of Turin.

These results have some implications for policy. In most countries since the late 1980s, the number of interactions involving shared governance arrangements between university and industry has increased, in no small part thanks to policy interventions. In fact, for numerous reasons, universities are often encouraged to increase their degree of control over interactions with external partners, and to shift to shared forms of governance rather than interactions characterized by greater control on the part of firms. This could have implications for the overall effectiveness of knowledge transfer processes if these different forms of governance serve different, but equally important purposes.

Our results suggest that inventors rely in almost equal measure on both forms of governance, and that unilateral governance forms are preferred when trust among the parties is high due to embeddedness in local social and education networks. Also, knowledge characteristics are not very important determinants of the choice between governance forms, suggesting that we can reject the argument that unilateral governance forms are suited to more specific, less general and less complex projects. Unilateral governance is preferred when trust levels are high, probably because it is less cumbersome and more direct. The advantage of shared governance seems to rest mainly in the possibility to reduce monitoring and asymmetric information problems in contexts of relatively low mutual knowledge and trust.

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**Figure 1 – Effectiveness of collaboration types for achieving different objectives**

(limited to those that collaborate through institutional (public and private financed) and personal contracts = 150 researchers)