11 University–industry interactions: the unresolved puzzle

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1. INTRODUCTION

Theoretical advances in the economics of knowledge and innovation since the 1980s conceptualize knowledge as partly tacit, sticky, context-dependent and idiosyncratic, and see knowledge creation as a collective, localized and path dependent process (Antonelli, 2005). Consistent with this view of knowledge is the argument that interactions among economic agents to acquire particular skills, are fundamental to the production and exchange of knowledge – particularly 'qualified' interactions that last over time and often involve the establishment of organizational frameworks to support the collaboration (as opposed to 'spot' market transactions) (Lundvall, 1985; Nooteboom, 2004).

The term 'university–industry knowledge transfer' is used to indicate a wide range of interactions at different levels, involving various activities aimed mostly at the exchange of knowledge and technology between universities and firms. These interactions on the side of universities are often described as 'third stream' or 'third mission' activities. They include, for example, collaborative research with firms, contract research and academic consulting commissioned by industry, the development and commercialization of intellectual property rights (IPRs), the creation of start-up firms to exploit university inventions, co-operation with firms on graduate training, and training and exchanges with industry researchers (Debackere, 2004; D'Este and Patel, 2007).

In most advanced economies since the 1980s, views have changed regarding the role of universities in the economic system. From being seen as 'ivory towers' where academics performed research in isolation, the contemporary university is seen as an economic organization that engages actively with external stakeholders. At the same time, the scale and scope of university–industry knowledge transfer activities have increased. These increases can be measured quantitatively in terms of university-assigned patents (Henderson et al., 1998; Geuna and Nesta, 2006), papers co-authored with industry (Hicks and Hamilton, 1999), income from royalties (Feller, 1990; Argyres and Liebeskind, 1998; AUTM, 2002), and industry funding for academic research (Slaughter and Rhoades, 1996; Geuna, 1999). The period 1980–2000 was characterized by a marked transformation in the mode of governance of university–industry interactions. The traditional models were personal contracts between academic scientists and company researchers, and intermediation through dedicated public research centres. However, new methods have been developed to achieve prompt transfer and exchange of knowledge, which is crucial for firms facing continuously increasing competition from low cost producers, and rapid obsolescence of products. Many attempts (in different countries) have been made to develop a new institutional infrastructure able to support knowledge diffusion between universities and firms (Block, 2008; Geuna and Muscio, 2009). A

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central tenet of these new systems is that the university must take an active part in the governance of knowledge transfer. Knowledge transfer is becoming institutionalized, and seen as a new role conferred on the university, rather than on individual university researchers or public research organizations. This qualitative change in the nature of the relationships between industry and academia has been accompanied by the emergence of visible new organizational forms such as university–industry liaison offices, technology licensing offices, technology transfer offices, industry–university research centres, research joint ventures, university spin-offs and technology consultancies (Peters and Etzkowitz, 1990; Cohen et al., 2002; Rothaermel and Thursby, 2005; Link et al., 2007). It has also entailed the development of a new set of 'rules of engagement' to coordinate the interactions between academic and company scientists.

This chapter focuses on the knowledge transfer processes involved in university–industry research collaborations based on contractual arrangements – personal and institutional – as opposed to purely commercial relationships based on the exchange of intellectual property, or student placements and staff secondments. It attempts to explain the rationales behind different forms of governance for university–industry collaboration, and the factors for success in a dynamic context. Although several studies examine the determinants of university–industry collaboration, very little work has been done on their modes of governance. Thus, we do not know what are the effects of personal contractual as opposed to institutional governance, on knowledge transfer and subsequent economic development, or what might be the best form of governance for these collaborations. The discussion is limited to universities since, in most countries, public research centres have become relatively less important since the 1990s (Senker, 1999).

This chapter is organized in three main sections. Section 2 discusses the context surrounding university–industry relationships and tries to explain why some 30 years of policy action have not yet succeeded in creating an organic infrastructure to support interactions between firms and universities. We argue that in order to understand these interactions it is necessary to understand the different governance models for university–industry collaboration (personal contractual and institutional). Failure to appreciate the specificities of these two models, their mutual feedbacks and the historical reasons for their persistence, has led to policies that overlook an important part of the knowledge transfer phenomenon and create incentives that can impede rather than support knowledge flows. We suggest that policy often emphasizes the role of institutionalized knowledge transfer channels, at the expense of less visible, but equally important personal contractual channels. We propose a framework to analyse the advantages and limitations of these governance models. Section 3 discusses the complexity of university–industry interactions. It reviews and synthesizes the large body of empirical evidence on university–firm interactions across countries, focusing on three main levels of analysis, the firm, the university and the researcher (Sections 3.1, 3.2, 3.3). We then discuss the measurement problems that affect the study of the phenomenon (Section 3.4). Section 4 describes a specific case of university–industry collaboration in the Piedmont region, in the north of Italy, and provides evidence of the coexistence and importance of personal and institutional governance structures. The data were collected via two original surveys (one addressed to a sample of regional firms and the other to a sample of industry inventors resident in the region), which provide detailed information on both types of interactions and the impact of interaction on innovation in companies. Section 5 offers some conclusions.

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2. A CRITICAL FRAMEWORK TO ANALYSE UNIVERSITY–INDUSTRY RELATIONSHIPS

There is empirical evidence of more intense university–industry collaboration since the 1980s. There are several arguments in the economics of knowledge production and use as to why interaction with universities has become more attractive for firms, and why policymakers are putting pressure on universities to engage in knowledge-based transactions with industry partners.

The economic understanding of knowledge has changed considerably since the 1950s (Dosi et al., 2006). Initially, knowledge was seen as equivalent to information – that is, the symbolic representation of the knowledge content that is tangible and transmissible. In discussing the properties of information as an economic good, Arrow (1962) highlighted appropriability issues related to information being non-rivalrous, non-excludable and asymmetric in terms of assessments of its content (which leads to the so-called 'Arrow's paradox'). These problems have resulted in the failure of decentralized markets to provide a sufficient amount of this good. Scientific knowledge in particular, was regarded as possessing many of the features typical of durable public goods: '(i) it does not lose validity due to use or the passage of time per se, (ii) it can be enjoyed jointly, and (iii) costly measures must be taken to restrict access to those who do not have a "right" to use it' (Dasgupta and David, 1994: 493). Nelson (1959) showed that private investment in basic research activities is likely to be suboptimal, because of the serendipity, large externalities and uncertainty that characterize research outcomes, and which cause their social returns to be larger than their private returns. To overcome the market inefficiencies associated with basic research, public intervention is required (Mowery, 1983): governments can engage directly in the production of knowledge, making it freely available for use, or they can provide subsidies to private knowledge producers in return for research outcomes being made public (Dasgupta and David, 1994). The latter scheme corresponds to the academic research system: businesses accept a system of taxation, which results in revenue being transferred to academia, which, in its turn, manages the open science system of knowledge production (Antonelli, 2008a).

Progressively, contributions from various sources have led to the emergence of a different view of knowledge, characterized by different and more complex economic properties than those encompassed by either fully public or fully private goods. Even before the 1970s, studies of human learning were demonstrating that individual learning always includes a tacit, non-expressible dimension and, consequently, that knowledge exchange is not instantaneous, but requires practice and the active participation of learning partners (Ryle, 1949; Polanyi, 1966). The recognition that knowledge cannot be reduced to information, undermines some of the assumptions that underpin the conventional economic interpretation of knowledge-producing activities. First, since knowledge is often specific to the context in which it was generated, it may be difficult to transfer without the assistance of its creator and, consequently, its imitation costs may be high: certain forms of knowledge have quite high levels of in-built appropriability and exclusivity (Levin et al., 1987). Second, attention to the tacit dimension of knowledge has led scholars to re-examine the nature of scientific research activity leading to agreement that scientific knowledge is to an extent tacit. It draws upon skills and techniques 'that are acquired experientially, and transferred by demonstration, by personal instruction

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and by the provision of expert services (advice, consultations, and so forth), rather than being reduced to conscious and codified methods and procedures' (Dasgupta and David, 1994: 494). This blurs the distinction between scientific and technological knowledge: both types of knowledge contain tacit and codified elements.[1] Third, there is increasing agreement that the production of new knowledge often requires the recombination of knowledge from several sources. Interactions among agents possessing different cognitive resources are considered crucial for the production of new knowledge (Nooteboom, 2004): the semantic ambiguity that results from these relationships is a powerful mechanism for innovation (Lane and Maxfield, 1997, 2005; Fonseca, 2002). These interactions need to be longer lasting than spot market transactions in order to reduce the cognitive distance among the agents involved, to facilitate communication. Knowledge transmission requires cognitive, geographical, cultural and social proximity among agents (Balconi et al., 2004).

The importance of these types of relationships has increased over time for several reasons. First, the production of new knowledge requires the integration and recombination of existing sources of knowledge. The complexity of the knowledge base of innovative firms increases depending on its cumulative (building on existing knowledge), complementary (requiring the integration of complementary types of knowledge), and composite (requiring the combination of different 'bits' of knowledge held by multiple agents) nature. Several studies support the claim that, as technological knowledge cumulates and expands, firms become increasingly dependent on a wider range of knowledge fields to develop innovations (Powell et al., 1996; Pavitt, 1998a; Nesta and Saviotti, 2005). Over time, the increased complexity of products and processes induces firms to seek complementary competences outside their boundaries. Second, uncertainty plays a role. In addition to uncertainty about the outcome of research activities – in terms of timing, direction, potential to open up new avenues of research – the economic context in which firms operate is another major source of uncertainty. The increasing pace of organizational and technological change generates what Lane and Maxfield (2005) define as 'ontological uncertainty' or situations that render economic agents uncertain about what processes and what other agents are likely to impinge on their actions. In these conditions, agents become not only unable to formulate a probability distribution for a set of outcomes – as in the concept of non-probabilizable risk which characterizes Knightian uncertainty – but may be unable even to conceive a tentative list of outcomes. Firms that face ontological uncertainty have a strong incentive to pursue qualified interactions with other organizations, in order to exert some influence over the many complex processes that ultimately will affect the results of their own activities. Organizations can counter uncertainty by constructing long lasting inter-organizational structures (what Lane and Maxfield (1997) call 'scaffolding structures'), which provide relatively stable contexts for shorter-term inter-organizational interactions and planning. Examples of scaffolding structures are inter-firm alliances, user organizations, forums, trade associations, fairs and exhibitions, standards setting organizations, and so on.

The increasing uncertainty of the economic environment combined with the increased complexity of technological systems, is driving innovation processes to become more open and distributed (Chesbrough, 2003; Powell and Grodal, 2005). In such conditions of high uncertainty and complexity, pursuing qualified interactions with universities can be advantageous for firms (Rossi, 2010):

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- they can access wide, international networks of scientists with heterogeneous competences; this provides increasing opportunities to establish relationships with high potential to generate innovations (Lane and Maxfield, 1997; Antonelli, 2008a), especially as industrial production has a growing scientific and technological content (Geuna, 1999; Mokyr, 1990);
- they can hedge against uncertainty through the opportunity to monitor numerous innovation processes at the same time and keep up to date with scientific developments (Meyer-Krahmer and Schmoch, 1998);
- learning and research opportunities are enhanced by the possibility to access new knowledge in the form of infrastructures (laboratories, databases) and secondments of researchers and scientists to academic institutions.

Thus, university–industry interaction as a means of access to and development of knowledge cannot be one-off (Meyer-Krahmer and Schmoch, 1998; Cohen et al., 2002).

Interaction with universities can also be cost effective for firms. The economics of knowledge shows that the costs of knowledge production are lower in the academic than in the private research system because of the split structure of academic salaries (Dasgupta and David, 1994). University researchers' fixed costs are covered by the payment received for their teaching activities, so that 'the compensation schemes practiced in the academic system allow the supply side to operate on a variable cost base' (Antonelli, 2008a: 12). Also, a university affiliation signals quality and competence, based upon the institution's reputation in the open science system: the existence of an independent system that confirms the competence of academic researchers lowers firms' search costs for high quality competences and reduces the agency problems inherent in collaborations with knowledge workers whose skills are difficult to assess (Antonelli, 2008a).

At the same time, universities have become more interested in collaborating with firms. On the one hand, the historical context, such as the reduced drive to fund university research for military reasons, and the move towards reduced government intervention in the economy, have encouraged universities actively to seek commercial transactions with external stakeholders in order to reduce their dependence on public grants (Geuna and Muscio, 2009). On the other hand, many governments have introduced incentives for universities to engage in third stream activities, premised on the expectation that university–industry interactions will increase the rate of innovation in the economy (Spencer, 2001). The argument that enforcement of property rights could foster the emergence of efficient markets for knowledge, was the justification for the introduction, in the 1980s and 1990s, of policies to promote patenting by universities, while the interpretation of knowledge as partly tacit, cumulative and collective, has fostered the view that the transfer of knowledge requires purposeful interaction among economic agents, and justified the creation of incentives for universities to engage in direct interactions with industry in the context of qualified relationships. Since the 1970s, governments have supported numerous such programmes (Cohen et al., 2002). In the US, the National Science Foundation established the first set of university–industry cooperative research centres in 1975, in the first steps towards instituting direct knowledge transfer to industry as a university mission. In 1980, the Stevenson–Wyndler Act in the US, mandated that Federal Laboratories spend part of their funds on technology transfer activities, and

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encouraged them to engage in direct collaborations with state and local governments, universities and private firms. These measures were followed by many others aimed at strengthening the basis for collaboration between universities and firms (for example, the 1985 Federal Technology Transfer Act, the 1986 National Competitiveness Technology Transfer Act, the 1989 Small Business Research and Development Act). Similar measures were introduced in Europe. In 1983, the UK launched the Alvey Programme to support university–industry research projects in information technology. This was followed by a range of government programmes aimed at strengthening links with industry, which culminated in the launch of the Higher Education Innovation Fund in 2001. University–industry interactions were a part of the ESPRIT programme (started in 1983) and one of the building blocks of the European Commission's Framework Programmes, the first of which was launched in 1984.

Most of the policies introduced to promote university knowledge transfer activities emphasize the role and importance of institutional university–industry relationships mediated by specialized units such as knowledge transfer organizations (KTOs), or by university departments and other administrative units. Consequently, in most cases, the creation of an institutional infrastructure for knowledge exchange between universities and firms has been the outcome of policy actions oriented to the creation of structured third stream activities within the university (Macdonald, 2010). Exceptions include Stanford and Katholieke Universiteit Leuven, where the creation of such an infrastructure was based on a request for institutional support from the academics involved in these interactions and the universities' desire to regulate and benefit from industry contracts.

A problem with this approach to knowledge transfer policy is that it ignores the specificities of the socio-economic-institutional context and the fields of research. It is possible that different disciplines and research areas, and also different types of higher education institutions embedded in different local contexts, would fit with different models of knowledge transfer. There is, in fact, another important mode of governance for university–industry collaboration: formal personal contractual collaborations between university researchers and firm engineers and researchers (Geuna and Muscio, 2009). This type of governance is based on participation in the same social and professional networks (Colyvas et al., 2002), and some form of trust (sometimes a common educational background, as in the case of alumni members or of the *esprit de corps* of the French Grandes Écoles and the Italian Politecnici). However, these interactions generally are not informal: they are usually defined in binding contracts and agreements which are not mediated by university structures. Historically, personal contractual collaboration predates the institutionalization of university–industry linkages: individual collaborations between academics and industry scientists were taking place at the end of the nineteenth century in Germany, and in the early twentieth century in the US (Meyer-Thurow, 1982; Liebenau, 1985; Swann, 1989; MacGarvie and Furman, 2005). This type of governance structure tends to be dismissed as being of lesser importance, sometimes confused or mixed with personal informal relationships or subsumed under 'consulting' and assumed to be 'soft' rather than 'hard' research. However, empirical evidence confirms that these relationships involve knowledge production as well as the transfer and application of existing knowledge (see empirical analysis in Section 4).

Gibbons et al. (1994) and Etzkowitz and Leydesdorff (2000) argue that the supposedly

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more efficient new institutional knowledge transfer model is substituting for the older model, which as a result is disappearing. We would suggest instead that these models of governance are coexisting and have important positive and negative interdependencies that need to be understood for the development of an effective and efficient knowledge transfer infrastructure. We would argue that, although (for the reasons described above) qualified interactions mediated by university institutional structures may be more attractive when firms need to manage complex projects characterized by uncertainty and technological complexity, personal contractual interactions present advantages in terms of immediacy, flexibility and convenience. Different firms may be inclined to use different forms of collaboration depending upon the resources they can dedicate to cooperative activities and the organizational forms they rely on to innovate. In addition, use of these two models of governance of collaboration by a firm is not mutually exclusive: firms can choose between modes, depending on their needs and the types of support they need to access. Finally, and relatedly, the policy framework is important in driving firm choice: that public funds often are available only for university-mediated interactions, for example, is an important determinant of the firm's choice to set up an institutionalized form of collaboration. In countries where there are fewer public policies to support the institutional model, we would expect both models of governance of university–industry relationships to thrive in response to different knowledge exchange needs. Section 4 provides some evidence of the co-existence of these two models in Piedmont, and discusses their specificities and relative advantages for knowledge transfer.

An exclusive focus on the institutionalization of knowledge transfer has informed a large number of attempts to improve firm–university interactions, which are sometimes much less successful than expected. For example, income from technology transfer is very skewed, with very few universities making much money from patents and licences (Charles and Conway, 2001; Bulut and Moschini, 2006), the direct costs of IPR usually exceed revenues (Charles and Conway, 2001) and many university technology transfer offices struggle to be profitable (Kenney, 1986). It appears also that technology transfer offices play a very small part in establishing links with industry (Colyvas et al., 2002), most of which are based on the personal contacts of academics (Jansen and Dillon, 2000). Thus, culture, history and values affect the impact of economic incentives in the development of new institutional set ups. The analysis below of the evolving problems and failures in university–industry interactions sheds interesting light on the complexities characterizing the developing disintegrated market for knowledge and the related governance structures.

3. WHAT WE KNOW AND DON'T KNOW ABOUT UNIVERSITY–INDUSTRY RELATIONSHIPS

University–industry relationships involve collaboration between at least two types of organizations, a firm and a university – a department or a faculty, and perhaps mediation by a Knowledge Transfer Office (KTO). They are based on collaboration (or contracting) between academic researchers and firm researchers/project managers. We provide a brief review of the literature based on evidence collected in recent years on the characteristics of firms, universities and researchers. Although we can point to some stylized facts,

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no clear cut picture emerges. We also discuss the conceptual and measurement problems associated with lack of a clear understanding of the governance of university–industry collaboration and specifically personal contractual collaboration arrangements.

3.1 Firm Characteristics

Organizational characteristics, such as size, technological capabilities, industry and level of internationalization, affect the innovative objectives of firms and their motivations to collaborate with universities over research and development (R&D). Several studies show that firm size influences both the decision to interact with a university, and the content of the interaction. Larger firms and spin offs benefit most from public research, even after controlling for industry (Cohen et al., 2002; Belderbos et al., 2004b). For large firms, collaboration with universities may be a strategy designed to strengthen their skills and knowledge, and to gain access to non-core technologies; for small firms, university collaboration tends to focus on problem solving in core technological areas (Santoro and Chakrabarti, 2002) and gaining access to university facilities. Small firms do not seem to differ from larger ones in the use of students, publications, patents and labour mobility as channels of knowledge transfer. Small firms are less likely to engage in 'collaborative or contract research' to access university knowledge, mostly due to their limited financial and skills resources (Bekkers and Bodas Freitas, 2008). However, university spin-offs, and high-tech companies more generally (as in the case of the biotechnological industry), tend to engage in intensive interactions with universities and university researchers (Zucker et al., 2002). Evidence shows also that firms that invest heavily in R&D, especially within a diversified portfolio of innovative activities, have the absorptive capabilities to learn, and to maintain linkages with universities and public research institutes (Cohen et al., 2002; Fontana et al., 2006a; Bodas Freitas et al., 2011). Large firms that are active in R&D can derive benefits from collaboration across a wider spectrum of research/innovation activities. Collaboration with universities is more likely among firms that put greater effort into searching for external knowledge by screening publications databases, and that signal their competence by patenting (Laursen and Salter, 2004; Belderbos et al., 2004b; Fontana et al., 2006a). Collaboration with universities and government research institutes enables firms to improve their access to an even wider pool of sources (Bodas Freitas et al., 2010). Feldman and Kelley (2006) find that firms involved in collaborative research projects with universities financed by public grants develop more diverse sets of linkages to other firms and exhibit greater openness in terms of communicating their research results, than firms that do not engage in such projects.

The level of competition seems also to affect the likelihood of a firm innovating and collaborating with external actors (Laursen and Salter, 2006). Therefore, if the firm's largest market is the international market, it will be more likely to interact with public research organizations (Laursen and Salter, 2006; Bodas Freitas et al., 2011). Similarly, firms with very challenging innovation strategies are also more likely to collaborate. In particular, firms involved in radical innovation and integration of market and production objectives, generally are more likely to collaborate with public research organizations (Belderbos et al., 2004a; Bodas Freitas et al., 2011).

Finally, based on industry differences in patterns of technological change and innovation development, interaction with and access to knowledge developed at universities

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may be uneven across industries (Pavitt, 1984; Marsili, 2001; Salter and Martin, 2001; Grimpe and Sofka, 2009). Cohen et al. (2002) show that public research is critical for a small number of industries, and 'moderately important' in most of the manufacturing sector. Industry–university interaction is crucially important for science-based technologies when product innovation is based on a recent scientific discovery (Beise and Stahl, 1999; Koumpis and Pavitt, 1999; Schartinger et al., 2002; Monjon and Waelbroeck, 2003). Indeed, in industries where the technology develops fast, firms need to explore multiple technological trajectories, which often involves collaboration with universities (Belderbos et al., 2004a). For this reason, university collaboration is widespread in the biotechnological and pharmaceutical industries, which depend heavily on academic knowledge and very basic scientific research (McMillan et al., 2000; Cohen et al., 2002). However, science-based industrial activities may not be similar across countries. In some countries firms operating in science-based activities seem more dependent on collaboration with public research organizations; in others these firms follow a more market-oriented collaborative strategy for innovation development (Bodas Freitas et al., 2011). Also, Beise and Stahl (1999) find that the share of sales from products based on public research does not depend on whether or not the firm sector is R&D-intensive. University–industry collaboration may play different roles and be configured in different ways, in different industries. Meyer-Krahmer and Schmoch (1998) show that in science-based fields, university collaboration is focused on basic research and keeping abreast of knowledge developments, while in other fields, university collaboration focuses mainly on finding solutions to technical problems. Similarly, Bekkers and Bodas Freitas (2008) find that the differences in the use of a wide variety of channels do not depend on the industrial activities of firms, but rather on the context and the characteristics of the underlying knowledge and of the researchers involved.

3.2 University Characteristics

The propensity of universities to collaborate with firms varies and is strongly related to the disciplinary focus of the university. Other characteristics, such as research quality and technology transfer policies, may also have an effect.

Work on industrial firms shows that the more basic sciences (that is, mathematics, physics and biology, but not chemistry) tend to be seen as less important than applied science and engineering disciplines (Klevorick et al., 1995; Cohen et al., 2002). Industry is much more interested in collaborating on applied science, especially in disciplines like materials and computer science. However, as several authors note, the basic sciences are extremely important for the development of industrial innovation, although their effect is more often channelled through the applied sciences and engineering fields (Klevorick et al., 1995; Pavitt, 1998b; Cohen et al., 2002; Meyer-Krahmer and Schmoch, 1998). Based on interviews with industry and university researchers, Bekkers and Bodas Freitas (2008) find that the disciplinary origin of the knowledge affects the form of interaction used for the development and transfer of knowledge between academia and industry.

The research orientations of university departments have an impact on attitudes to knowledge transfer to industry. University departments focused on applied research and technological development tend to be more involved in the processes of knowledge transfer to industry (Lee, 1996; Bozeman, 2000; O'Shea et al., 2005). The organizational

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characteristics of research centres and faculties, on the other hand, seem not to affect the level and intensity of interactions with industry. For instance, Bozeman (1994) shows that there is no relationship between the effectiveness of technology transfer activities and the organization of university departments in terms of size, administrative intensity, hierarchy and number of organizational levels (that is, principal investigator, departments, projects, others).

There is empirical evidence suggesting that the university's technology transfer policy may influence the level of interaction with industry. US universities, which give higher percentages of royalty payments to their faculty members, are involved in more intense and more efficient technology transfer activities such as spin-offs and start-ups (Link and Siegel, 2005). Other studies show that the entrepreneurial activity of the research departments, measured as spin-off activity, decreases the higher is the share of the university licensing royalties allocated to inventors and their department (O'Shea et al., 2008; Markman et al., 2004).

Institutional differences in terms of amounts of industry financing received and quality of the university (obviously correlated) are good predictors of the involvement of scientists with industry (Ponomariov and Boardman, 2008). This appears to be related to the fact that top universities seem to provide easier access to the diverse set of resources required to create start-ups (Di Gregorio and Shane, 2003, O'Shea et al., 2008). Finally, D'Este and Patel (2007) show that the quality of university research does not affect the intensity of industrial interaction; in the case of UK universities, institutional characteristics are not as important as the characteristics of individual scientists, which is the subject of the next subsection.

3.3 Researcher Characteristics

The characteristics of individual researchers matter for the process of knowledge transfer. Highly productive tenured and senior academic researchers are more experienced and are more willing to participate in collaborative projects with industry (D'Este and Patel, 2007). Bozeman and Corley (2004) analyse the collaborative behaviours of scientists and find that researchers who take on mentoring roles (that is, help junior colleagues and graduate students by collaborating with them) are more enthusiastic about working with industry.

There is no strong evidence of substitution or crowding-out between patenting and publishing (Agrawal and Henderson, 2002; Jensen et al., 2003; Lee and Gaertner, 1994) and the most scientifically productive researchers are often those with the most patents, although this is likely to differ significantly across scientific fields with more basic fields showing some evidence of crowding-out (Geuna and Nesta, 2006; Stephan et al., 2007; Crespi et al., 2011). In basic science, researchers who interact with industry in a minor way (that is, the returns from this activity do not exceed 15 per cent of the researcher's budget), are more productive than those that do not collaborate with industry at all (Manjarrés-Henríquez et al., 2008). Also, researchers who interact with industry are more likely to obtain higher funding from competitive public sources than those who engage only in research (Bozeman and Gaughan, 2007; Manjarrés-Henríquez et al., 2008). However, the productivity of the highest performing scientists decreases with involvement in long-term relationships with one specific industry-related sponsor (Goldfarb,

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2008). Researchers that own several patents and who are more entrepreneurial are more willing to engage in knowledge transfer to industry (Zucker et al., 2002; D'Este and Patel, 2007). Researchers who become entrepreneurs are likely to be older, to have a good scientific record and to be extroverts, and to have worked in departments that have produced prestigious scientists and have a track record for entrepreneurialism (O'Shea et al., 2008). At the same time, several studies find that academic entrepreneurship is driven mainly by the expectation of generating results that will improve the researcher's academic position, creating stimuli for further research activities, and resulting in prestige and reputation as a leading academic rather than as a business entrepreneur (Baldini et al., 2007; Fini et al., 2009; Baldini, 2008; Franzoni and Lissoni, 2009).

The importance attributed by academic and industrial researchers to university–industry interactions, the forms and channels of and barriers to these interactions, are related to the researchers' characteristics in terms of experience in patenting, in being entrepreneurial and in publishing (Bekkers and Bodas Freitas, 2008). Also, the research environments in universities and industries with a specific disciplinary emphasis and different focus on basic, applied and technological developments, create different incentives to use particular knowledge development and transfer mechanisms (Bekkers and Bodas Freitas, 2008).

3.4 A Conceptual and Measurement Puzzle

The discussion above shows how much work has been done on the characteristics of university–industry collaboration, and how little attention has been paid to the forms of governance of this relationship. There is no consensus on whether there is, or what is, the best form of governance, or on actual results in terms of level of knowledge transfer and specific contribution to economic development. Most empirical studies focus on high-tech industries, although the availability of Community Innovation Survey (CIS) type data has enabled the development of econometric analyses controlling for sector and technological differences. Discrepancies in the conclusions reached by these analyses are often associated with the methodology, with detailed interview-based case studies tending to highlight the importance of personal contacts and mobility in the transfer of knowledge, and quantitative studies underscoring the success of informal contacts and formal knowledge transfer channels managed by universities.

One reason for these inconsistent results is that most studies rely on imprecise measurements due to a lack of standardized, validated data on university–industry relationships. In addition to the common problem of data availability and comparability (most studies are based on one-off survey data or internal university information that is not standardized across universities), there are some conceptual and empirical sources of mis-measurement.

Although work on identifying communication channels has become quite sophisticated, it is limited by the implicit assumption that personal contacts are mainly informal, and thus considers more formal channels of knowledge transfer to be university-managed. Some firms and researchers may be bound by strict contracts which are managed personally without going through the university administration (personal contractual collaborations, in our framework). Many studies are based only on data made available by KTOs and, thus, capture only the set of interactions managed directly

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by the university (see, for example, Joly and Mangematin, 1996; Thursby et al., 2001). In the Anglo-Saxon context, where consultancy (formal personal contracts) is allowed and is formally regulated (depending on contracts and university regulations, faculty are usually permitted to spend one day a week on consulting) and reported (faculty are required to submit annual reports on outside professional activities), a few studies have considered formal academic consulting explicitly as a channel for knowledge transfer distinct from university-managed collaborations (see for example, Rebne, 1989; Cohen et al., 1998; D'Este and Perkmann, 2007; Jensen et al., 2010). These studies highlight the importance and specificity of personal arrangements.

Empirically, several studies use data collected via surveys of academics or/and firms, allowing consideration of a wider range of alternative knowledge transfer channels. However, these channels are investigated from different viewpoints and often are categorized differently. There is disagreement in the literature on their relative importance, although there is some consensus that several different channels often are used at the same time and that formal channels allowing commercialization of university knowledge (that is, spin offs, licences, patents) are among the least frequent (Schartinger et al., 2001; Cohen et al., 2002; D'Este and Patel, 2007). For example, Mowery and Sampat (2005) show that conferences and publications are more frequent channels of communication than patents and licences, and Cohen et al. (2002) confirm that formal transfers of IPR are not necessarily the most successful and common form of interaction.[2] According to Bruneel et al. (2009), for firms, conference attendance and graduate recruitment are the main types of interaction with universities, while Abreu et al. (2008) suggest that the most frequent types of interactions are within networks of collaborative research. D'Este and Perkmann (2007) analyse universities in the UK; they find that collaborative research projects, including consultancy, are a more important source of income than licensing. A study by Schartinger et al. (2001) highlights crucial inter-sectoral and interdisciplinary differences with respect to the intensity with which the different channels are used. In categorizing knowledge transfer channels, Perkmann and Walsh (2006) propose a distinction between socialized and non-socialized collaborations, that is, between collaborations that involve the establishment of social relationships (sponsored research projects, research consortia, collaborative joint ventures, research centres) and those that are purely contractual (licensing, specific ad-hoc consultancy). However, other scholars highlight that all knowledge transfer channels, including less personalized ones, such as access to scientific publications and university patent licensing, are accompanied by the establishment of social relationships (Meyer-Krahmer and Schmoch, 1998; Bozeman et al., 1995).

The development of CIS surveys is providing researchers with comparable data to study university–industry linkages. However, the information is limited since these surveys simply ask whether firms have relationships with universities and, if so, for an indication of their importance. The CIS includes a question about the type of cooperation partner the firm found most valuable for its innovation activities. But respondents are not asked about the nature or governance of these relationships, which confuses university-mediated, institutional relationships with personal (formal or informal) collaborations. In addition, surveys are often responded to by managers who are probably more aware of commercial/business rather than science-related activities. An analysis of the responses to the CIS indicates that universities or other higher education institutions

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are generally considered not very important sources of information (in CIS-4 only 3 per cent of firms considered universities and other higher education institutions as highly important sources of information), and that companies collaborate with universities less frequently than with other partners. Such results are often emphasized in the policy literature, and point to a secondary role of university research as a source of knowledge for the innovation processes of companies (Paravan, 2007). However, when we consider the results of surveys, such as Yale (US), Carnagie-Mellon (US), and PACE (EU), which focus exclusively on knowledge flows and surveyed large R&D performing companies (and were addressed to R&D managers), the importance of university research increases (Cohen et al., 2002; Arundel and Geuna, 2004). The difference in part can be ascribed to the sampling procedure (CIS considers firms of all sizes) and to the fact that CIS results are not weighted by R&D spending. Arundel and Geuna (2004) show that for comparable samples, CIS results tend to be similar to PACE results showing higher importance of university research. Firm size, however, does not explain all the difference found. Indeed the focus of the survey on knowledge flows rather than on company innovation in general (such as CIS) can steer the attention of the respondents to a specific topic. Fontana et al. (2006b), using data from the KNOW survey (a survey focused on knowledge flows) of small and medium sized enterprises in Denmark, France, Germany, Greece, Italy, the Netherlands and the UK, find higher importance and higher use of university research than the CIS.

University–industry relationships have also been measured through international surveys addressed to inventors (company researchers) rather than R&D or other managers. Two recent examples are the European Community Inventor Survey – PatVal (Giuri et al., 2007) and Georgia Tech/RIETI Inventor Survey for the US and Japan (Walsh and Nagaoka, 2009). Analysis of the results of these surveys indicates high importance for university research. Although in Europe, research from universities seems to be less important than results from other sources (only public research organizations are considered less important than universities), it is considered highly important by 14 per cent of the respondents (compared to 19 per cent for suppliers) and much more important than in the case of the CIS survey. For the US (but not Japan), universities are on a par with competitors and suppliers as sources of research. Similarly, when we look at co-inventors and collaborative partners, universities are ranked just below suppliers and customers (Walsh and Nagaoka, 2009).

The evidence from survey-based measurements of university–industry collaboration indicates possible respondent and sample biases. First, comparing responses from managers, R&D managers and inventors, the importance and use of university research increases. Second, in CIS, sources of knowledge include universities, scientific publications and conferences: the focus is on knowledge channels rather than on knowledge contributions. However, this framing of alternatives does not include many of the channels of knowledge transfer from universities discussed in the literature. It also biases downwards the ranking of university knowledge, as the overall source of knowledge is the sum of the knowledge directly obtained from universities and the knowledge obtained from scientific publications and conferences that is mainly produced by academics. Policy often considers only statistics related to 'university and other higher education institutions', overlooking the fact that academic researchers are involved in the majority of scientific publications and conference presentations. Third, the aim and focus of CIS

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and surveys of knowledge flows are on capturing innovation (business) related activities and sources, which orients the respondents to focus upon industry, accountable, 'concrete' types of activities and sources. This usually results in comparative bias, that is, respondents are inclined to rank the most concrete sources of knowledge highest, and to understate the importance of interactions (for example personal contracts) that do not involve a clearly identified organization. It should be remembered also that sampling strategies (in relation to size and R&D) affect the way that academic knowledge is seen as contributing to firm innovation. This makes the use of aggregate statistics questionable, since smaller and less innovative firms are over represented while it is well known that radical innovation is concentrated in few large (or very small) high-tech companies and that its diffusion in the economy happens via user-producer interaction. Academic knowledge absorbed by large R&D intensive companies is subsequently transferred to the rest of the economy via commercial linkages, more efficiently than being transferred directly from universities (or university researchers). Small companies that lack the resources for interaction with universities inevitably will rank commercial sources as much more important than academic sources.

The evidence presented in this section together with the theoretical discussion in Section 2, emphasizes the complexity in the interactions between science and innovation represented by university–industry relationships. It highlights the need for a better understanding of their governance and points to the need for better conceptual and empirical measurement of the university–industry complex to inform policy action.

4. THE CASE OF UNIVERSITY–INDUSTRY RELATIONSHIPS IN PIEDMONT

In this section, we provide some evidence on the two non-exclusive governance models of university–industry interactions presented in the previous section in the case of the Piedmont region in the North-West of Italy. We rely on two original surveys conducted in 2008–09: UIPIE (firm level) and PIEMINV (inventor level). We underline that the firms surveyed are all located in Piedmont, that is, in the same institutional, social and economic setting. This is important because it allows us to control for some of the determinants of different types of interactions.

Before discussing the governance of university–industry relationships in Piedmont we briefly examine the importance of universities as a source of information and as innovation partners for companies and inventors on the basis of the information contained in the CIS and PatVal surveys. We use weighted data for the companies extracted from the national statistical office, ISTAT, CIS database. Universities are ranked as a highly important source by only 1.2 per cent of the respondents and 85 per cent consider this source of information as not useful.[3] When we look at co-operation partners, 5.3 per cent of companies collaborated with universities. This is similar to the rate of collaboration with competitors (5.4 per cent) and clients (5.1 per cent) and slightly lower than with suppliers (7.6 per cent) and consultants and other private research centres (7.0 per cent). Using information from the PatVal dataset for the sample of Piedmontese inventors, we find that the share of inventors reporting university laboratories and faculty as highly important sources of information is 8.2 per cent unweighted (24 per cent had used this

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Table 11.1 Choice of governance mode for university–industry collaborations (firms)

	Observations	Share (%)
Sample	1 052	100
No collaboration	865	82.2
Institutional collaboration	104	9.9
Personal collaboration but no institutional collaboration	83	7.9

source), fourth after Customers (1), Competitors (2) and Suppliers (3) but higher than the score in the CIS.[4] The evidence presented confirms the discussion in Section 3 on differences in the various measurements of university–industry interaction. The importance (use) of universities for industry innovation varies depending on who responds to the survey, and on its objectives and structure.

Next we look at the co-existence of the personal and institutional modes of governance for university–industry interactions. Based on data from the UIPIE survey[5] of Piedmontese firms (Bodas Freitas et al., 2010), Table 11.1 reports the shares of: firms that engaged in institutional collaborations with universities; firms that engaged only in personal contractual collaborations with individual university researchers; and firms that did not collaborate at all.

Based on data from the PIEMINV survey of Piedmontese inventors,[6] Table 11.2 presents the shares of inventors and the channels of knowledge-transfer within different governance modes.

The results of these two surveys are consistent in showing that personal contractual collaborations are as important as institutional cooperation. Thus, a focus on the latter overlooks an important part of this phenomenon. The managers' survey (Table 11.1) shows that in 2006–08, 10 per cent of Piedmontese firms engaged in institutional collaboration and 8 per cent in personal contractual collaboration. Among the inventors surveyed (Table 11.2), at least 25 per cent reported engaging in institutional collaboration with a university and just less than 25 per cent had collaborated through personal contracts. As expected, surveying inventors rather than firms, where a manager is the respondent, increases the importance and use of university research.

Table 11.3 shows that there is positive correlation between the use of either governance form as well as some other forms: in other words, firms use the various governance forms in complementary ways. This applies particularly to different kinds of institutional collaborations where a very high share of firms collaborating with universities with the support of public funds, also engage in institutional contracts financed by the firms themselves. The correlations are positive but lower for institutional and personal contractual collaborations, and for these and informal contacts, indicating that a number of firms uses only one of these governance forms. This suggests that different types of firms may use different forms of governance for university–industry collaborations.

Bodas Freitas et al. (2010), based on UIPIE data, show that larger firms that invest internally in innovation through R&D or design are more likely to enter an institutional collaboration with a university. Firms that collaborate through personal contractual linkages tend also to be smaller than non-collaborators. These firms also invest more in acquiring knowledge through patents and know-how than firms that collaborate

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Table 11.2 Governance modes in university–industry collaborations (inventors)

Types of knowledge transfer channels	In order to make your inventions, how important were the following ways of accessing university knowledge?	Used, but of little importance (%)	Used and of high importance (%)	Used (%)
University–industry research collaborations	Institutional research collaborations between your company and the university (department, faculty, university, technology transfer office), financed by the company	14.0	12.4	26.4
	Institutional research collaborations between your company and the university, financed through public funds (regional, national or international)	13.4	11.2	24.6
	Personal contracts between your company and individual university researchers	12.6	11.3	23.9
	Informal, personal contacts between your company and university researchers	16.9	8.0	24.9
	Sharing facilities (e.g. laboratories, equipment) with the university	9.8	7.3	17.1
Open science channels	Participation in conferences and workshops	28.8	18.8	47.6
	Scientific papers in journals	22.3	31.1	53.4
	Other publications, including professional publications and reports	29.0	25.7	54.7
Commercial channels	Attending university organized business training or initiatives to promote knowledge transfer	14.0	6.1	20.1
	University researchers or staff employed part-time or on a temporary basis by your company	9.4	4.2	13.6
	Reading university patents	14.9	5.3	20.2
Education and employment-based channels	Your staff employed part-time or on a temporary basis at a university	3.6	0.7	4.3
	University researchers or staff employed part-time or on a temporary basis by your company	10.6	6.4	17.0
	Collaborations based on co-supervision of Masters or PhD students	14.5	11.3	25.8
	University students working for your company as trainees	21.0	12.0	33.0
	Full time hiring of university graduates or researchers	18.8	18.6	37.4

Source: PIEMINV survey.

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Table 11.3 Forms of governance for collaboration: Pearson correlation coefficients

	Institutional research collaborations financed through public funds	Personal contracts between your company and individual university researchers	Informal, personal contacts between your company and university researchers
Institutional research collaborations financed by the company	0.542***	0.421***	0.306***
Institutional research collaborations financed through public funds		0.434***	0.360***
Personal contracts between your company and individual university researchers			0.386***

Source: PIEMINV survey.

Table 11.4 Effectiveness of institutional and personal collaborations with university across innovative objectives

Objectives	Institutional collaborations more effective (%)	Personal contracts more effective (%)	Both equally effective (%)
Non-competitive (basic research) projects	**32.6**	20.8	**34.2**
Applied research projects to develop new products	14.8	**49.4**	26.0
Applied research projects for production activities	12.7	**48.4**	25.6
To identify the best students for recruitment	20.9	**41.8**	27.2
To keep up to date on new knowledge developments	28.6	17.6	**40.6**
To get ideas for new product development	15.5	**34.3**	**37.3**

Source: PIEMINV survey. Question: 'In order to reach the following objectives, which is more effective: collaborations with a university or personal contracts with individual university staff?'

institutionally, and are more likely to adopt 'open' innovation strategies based on the exchange of technological knowledge with external partners than firms that do not collaborate at all. Hence, personal contractual collaborations with individual university researchers, as opposed to institutional collaborations, may be more appropriate for small firms, because they are more flexible and easier to manage.

The choice of a governance form for collaboration may be related also to the type of knowledge being developed and shared. Table 11.4 uses information from the PIEMINV survey to show the effectiveness of institutional and personal contractual collaborations for specific industrial knowledge development goals.

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Results suggest that personal contractual collaborations are particularly important for solving problems related to product development and production activities, and to identify students to recruit. In the case of non-competitive basic-research projects institutional collaboration is preferred or is at least as relevant as personal contractual arrangements. This may be related to the infrastructure, resources and international networks of contacts that may be required to accomplish basic research projects. Both personal contractual and institutional collaborations are used to update knowledge and to get new ideas for product development – with the latter showing some preference towards personal contractual.

Overall, for university–industry interactions in Piedmont, both personal contractual and institutional arrangements are important, which means that both models of governance must be taken into account when studying the impact of knowledge transfer, and when designing science and technology transfer policies. The choice of governance form for a university–industry collaboration may be related to the characteristics of firms and the type of knowledge that is being developed and shared. Our evidence shows that institutional governance may be more effective when the basic research content of the industrial innovation objective is larger, while personal contractual arrangements seem to be particularly effective when the innovation objective is mainly applied research and problem solving. Smaller firms that are more reliant on the acquisition of external knowledge and favour more open innovation strategies based on the exchange of technological knowledge with external partners, are more likely to favour personal contractual rather than institutional forms of collaborations.

5. CONCLUSIONS

Theoretical developments in economic thinking (Freeman, 1974), and primarily the economic debate on knowledge-driven economic growth (Foray, 2004) have shaped how we look at the contribution of universities (teaching and research) to society. Models of growth driven by increased human capital show that increasing the stock of knowledge embodied in skilled workers increases the productivity of the inputs and, hence, leads to higher levels of per-capita output from the economic system (Lucas, 1988). Other endogenous growth theory models emphasize the role of disembodied knowledge as a non-excludable and non-rival factor of production that generates increasing returns to scale in the production function and drives the economy towards higher rates of aggregate output growth (Romer, 1990). For these reasons, augmenting the stock of knowledge produced in the economic system is increasingly considered the key to greater innovation and productivity growth. The most important agents in this process, based on their function as producers of new knowledge (in the form of scientific publications and human capital), are universities (Aghion et al., 2008). The central economic role of universities is highlighted in the broader discourse on the features of the 'knowledge economy', which is characterized by faster rates of technological progress and by the greater economic importance of the industries that produce and trade knowledge products (Quah, 1998). While the provision of higher education is still regarded as the main function of universities, especially in light of the increased numbers of higher education students thought to be essential for the knowledge economy, the role of universities in

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the direct transfer of new knowledge in the form of technologies and intellectual property is also increasing.

This chapter has provided a theoretical and empirical rationale for the different forms of governance of university–industry collaboration. We examined the knowledge transfer processes that occur through university–industry research collaborations – personal contractual and institutional – compared to purely commercial relationships based on the exchange of IP or on exchanges of personnel and students.

Section 2 examined the importance of university–industry relationships for dealing with the increasingly uncertain economic environment and ever more complex technological systems, which lead to more open and distributed innovation (Chesbrough, 2003; Powell and Grodal, 2005; Rossi, 2010) The existence and the role of personal contractual and institutional governance of university–industry collaboration was discussed in the light of the literature. The complexities of university–industry interaction and the existence of more than one mode of governance, reflects the multiple, non-linear relationships between modes of interaction and the characteristics and objectives of the actors, and also the empirical and conceptual issues involved. Section 3 presented evidence on how different knowledge development processes require specific forms of organization, with the result that firms, universities and researchers with different characteristics engage in specific linkages and modes of knowledge transfer. We discussed the issues related to the conceptualization and measurement of university–industry interactions and their consequences. This chapter highlights the need for a better appreciation of their governance and points to the need for better conceptual and empirical measurement of the university–industry context to inform policy action.

The analysis in this chapter used two new original databases providing information on university–industry relationships in the Piedmont region in the North-West of Italy, on the basis of which we discussed the co-existence and importance of personal contractual and institutional governance modes of collaborations. Evidence collected from firm managers, R&D managers and inventors in Piedmont suggests that personal contractual collaborations are as important as institutional ones and that the two are complemented by informal contacts. Our evidence suggests also that the choice of governance form for collaboration depends on the characteristics of firms and the type of knowledge that is being developed and shared. Institutional collaborations appear to be slightly more effective if the industrial innovation objective involves more basic research, while personal contractual collaborations are particularly effective when the innovation objectives involve mainly applied research and problem-solving activities. Smaller firms that are more reliant on external knowledge and adopt more open innovation strategies based on the exchange of technological knowledge with external partners, are more likely to favour personal contractual rather than institutional arrangements (Bodas Freitas et al., 2010).

The results in this chapter have important implications for policymakers. Both personal contractual and institutional governance models are important for interactions and knowledge transfer between university and industry and the former seems more appropriate for small companies. These results are somewhat paradoxical as policy support for the development of institutional forms of governance of university–industry relationships is based mostly on the view that universities are self-contained and unable to respond to the applied knowledge needs of small companies. Both personal

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contractual and institutional collaboration need to be considered in examining the contribution of universities to economic development. Instead of focusing only on supporting institutional collaborations (perhaps cumbersome for small firms) policy should aim at stimulating personal contractual collaborations through proper regulation of part-time professorships and consulting.

NOTES

1. Studies in the history and sociology of science and technology confirm that they are mutually dependent and often difficult to distinguish (Mokyr, 1990; Nelson and Rosenberg, 1996; MacKenzie and Wajcman, 1999).
2. Data availability means that most econometric analyses use IPR-related information.
3. Analysis of CIS-4 weighted responses for Italy indicates that only 2.1 per cent rate universities as a highly important source of information (ISTAT, 2008).
4. For all Italian respondents the values were 8.8 per cent and 26.5 per cent respectively.
5. The UIPIE questionnaire was administered in autumn 2008 to a sample of representative firms in the Piedmont region. From a representative sample of 1058 firms, we obtained 1052 valid responses. The sample was developed and validated by the local Chamber of Commerce, which sent out our questionnaires with their quarterly regional economic foresight survey.
6. The PIEMINV questionnaire was sent out in autumn 2009 and spring 2010 to the population of inventors with a Piedmont address, that had applied for an EPO patent in the period 1998–2005 (about 4000 patents and 3000 inventors in Piedmont). We obtained just over 865 valid responses from 2800 questionnaires (response rate 31 per cent).

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