University–industry relationships and the role of the individual

Network ties and the diversity of knowledge transfer

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Abstract: *In recent years, considerable attention has been paid to the effectiveness of knowledge transfer processes between academia and industry. Although there is growing evidence that the characteristics of individual researchers are important when explaining cases of successful transfer, few studies have taken the individual researcher as their unit of analysis. This study uses social network theory techniques to gain a better insight into knowledge transfer processes. In particular, the authors study how the characteristics of ties among individuals and the interdisciplinary and pervasive nature of research affect the diversity of knowledge transfer activities. To this end, an empirical study was conducted among researchers in the field of nanotechnology, a sector chosen for its interdisciplinary nature and expected pervasiveness. Data were collected using a survey carried out in Spain and The Netherlands, allowing the authors to correct for environmental and contextual effects.*

Keywords: *knowledge transfer; university–industry relationships; interdisciplinarity; strength of ties; network ties*

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It is widely argued that mechanisms and agreements for knowledge transfer are key elements in the production and dissemination of cutting edge knowledge (Murray, 2001; Powell, 1990). Through knowledge transfer, individuals from different organizations and with different interests can progressively adapt their procedures and goals (Bozeman, 2000) and explore scientific and technological knowledge in order to expand their current capabilities (Murray, 2001).

Paradoxically, and despite considerable efforts by governments, there are particular problems with the transfer to commercial businesses of new knowledge

developed in universities (Meyer *et al*, 2004). Academic staff have found that the locus of control in scientific collaboration lies more with individuals than the institutions they represent: this is particularly true for universities (Bozeman and Corley, 2004; Liebeskind *et al*, 1996). The know-how and information that researchers acquire over time represents their personal stock of knowledge (McFadyen and Cannella Jr, 2004): as a result, the exchange of knowledge takes place primarily between individuals and in the context of personal relationships (Oliver and Liebeskind, 1997). Transfer activities relating to collaborative knowledge are, therefore, intrinsically social processes where individuals, not institutions, are the key participants (Katz and Martin, 1997; Oliver *et al*, 1997; Powell, 1990). This implies a complex and dynamic interaction between the individuals concerned, guided less by formal structures of authority and more dependent on the relationship between individuals (Bozeman *et al*, 2004; Powell, 1990; Uzzi, 1996).

Despite the growing interest among academics and policy makers in developing a better understanding of university–industry linkages and the increasing awareness of the particular social and relational aspects of knowledge transfer processes, there are remarkably few studies that focus on individuals as the unit of analysis (Palmberg, 2008). We suggest that such studies would provide a better understanding of the relational aspects underlying knowledge transfer processes: this paper contributes to addressing this gap in the literature.

Our starting point is the characteristics of the scientists' research, since they form the basis of the relationship of the scientists with commercial businesses. We analyse whether the potential of individual researchers for transferring knowledge is linked with the characteristics of their research. We then analyse the impact that different types of social ties have on knowledge transfer. Our aim is to identify which characteristics of the links between academic researchers and businesses contribute to more diverse interaction in terms of the channels for knowledge transfer used in a given relationship.

The structure of the paper is as follows. The next section discusses findings in the literature on the relationship between knowledge characteristics and knowledge transfer channels, and the hypotheses we derive from that literature. This is followed by a similar study of the literature on the relationship between the features of individual ties and the use of knowledge transfer channels. We then present our methodology and data and our analysis and findings. Finally, we discuss the results and offer conclusions.

Diversity of knowledge transfer channels and knowledge characteristics

Academic research usually involves novelty. In their search for new ideas or tangible products, scientists often combine multiple sources of knowledge, diverse methodologies and varied competences (Zander and Kogut, 1995). Novel research is often interdisciplinary; furthermore, interdisciplinary research may lead to pervasive technologies – that is, technologies characterized by multiple uses within the same, and across different, industrial sectors (Salerno *et al*, 2008). It is likely that the more the research is interdisciplinary and pervasive, the less explicit will be the knowledge produced and hence the transfer of the knowledge to business will be more complex. Despite these complexities, businesses remain interested in pursuing knowledge transfer. It could be argued that the more pervasive and interdisciplinary the knowledge to be acquired, the greater will be the potential gains for the business. This is because the greater the complexity of the knowledge incorporated by a business, the more difficult it is for competitors to replicate it (Barney, 1991). It is therefore to be expected that businesses will make substantial investments in time and resources to access complex and tacit knowledge.

In addition, different channels for knowledge transfer are likely to have different strengths and weaknesses with regard to transferring tacit and complex knowledge; and the success of a particular channel cannot always be predicted at the outset. As a result, if a business wants to increase the chances of successfully absorbing knowledge generated elsewhere, it will tend to make use of multiple knowledge transfer mechanisms. Consequently, the resulting pattern of interaction for knowledge transfer will be more diverse. This leads us to the following hypotheses:

- **Hypothesis 1.1:** The more interdisciplinary a researcher's work, the more diverse the knowledge transfer channels between the researcher and the commercial business.
- **Hypothesis 1.2:** The more pervasive a researcher's work, the more diverse the knowledge transfer channels between the researcher and the commercial business.

Diversity of transfer channels and network ties

In social network theory, scholars traditionally distinguish between strong and weak ties. Strong ties are based on trust, reciprocity, and frequency of interaction (Granovetter, 1973). Weak ties are defined as casual acquaintances between participants, characterized

by infrequent interactions (Granovetter, 1973) and based neither on trust nor reciprocity. According to the seminal work of Granovetter (1973), weak ties involve behaviour that is more efficient for innovation because they are likely to provide partners with novel information. However, when information and knowledge are considered to be of a sensitive nature and partners involved might apply for intellectual property rights in the future, individuals may act with considerable caution when sharing knowledge (Bouty, 2000). In this context, the hazards of opportunistic behaviour are reduced among exchange partners who develop close, trust-based relationships that reduce the risk of misappropriation of property rights (McFadyen and Cannella Jr, 2005). It has also been argued that weak ties are not adequate for the transfer of complex knowledge (Hansen, 1999; Uzzi, 1996). The transfer of tacit and complex knowledge usually requires frequent interaction between those involved. As the tie strengthens, the exchange of knowledge becomes more efficient. Strong relationships result in shared understandings and experiences, trust and a common language (McFadyen *et al*, 2004), all of which facilitate the development of common goals (Hussler and Ronde, 2007) and the planning of shared activities to reach such goals. However, the maintenance of strong relationships requires considerable investments in time, energy and resources (Boorman, 1975). For both academic researchers and commercial businesses, the resources available to allocate to relationships are usually limited. In order to maximize the investments already made in the relationship, therefore, participants will tend to use these relationships for a range of diverse purposes. It is therefore to be expected that as the tie between a researcher and a business becomes stronger, the channels used for the transfer of knowledge will be more diverse. Consequently, we developed the following hypothesis:

- **Hypothesis 2.1**: The stronger the link between a university researcher and a business, the more diverse the knowledge transfer channels used.

Previous studies stress the importance of the geographical location of exchange partners involved in knowledge transfer. A number of such studies assert that participants are inclined to choose associates in close proximity because the coordination costs increase with distance (Hussler *et al*, 2007; Mollenhorst *et al*, 2008). For instance, when participants are located far away, it is more complicated and costly to arrange meetings, reducing the opportunities for directly shared experiences (McFadyen *et al*, 2005) and the effectiveness of the knowledge transfer. Therefore, because close-distance relationships reduce the interaction costs of transfer channels and increase the shared experiences between partners, participants will tend to rely more on these types of relationship than on long-distance ones. In addition, it is also widely accepted that spatial proximity helps in strengthening relationships (Bozeman *et al*, 2004; Katz *et al*, 1997). Inkpen *et al* (2005) support the idea that proximity helps the formation of network ties and, especially, interpersonal interactions through which knowledge flows. Such relationships can be particularly valuable when dealing with those having different goals and knowledge bases (as is the case with universities and businesses). Hussler and Ronde (2007) argue that knowledge transfer between those who do not share similar goals and knowledge bases is more difficult than when it occurs between those who do. In addition, in the case of university–industry interactions, geographical proximity will facilitate knowledge transfer between such dissimilar participants. Furthermore, as the transfer of complex knowledge might depend, as argued above, on a variety of transfer mechanisms (each of which includes its own transaction cost), we can argue that the relationships characterized by spatial proximity will show a more diverse use of knowledge transfer channels since the transaction cost of each channel increases with distance. Based on the above, we formulate the following hypothesis:

- **Hypothesis 2.2:** The closer a university researcher and a business are located, the more diverse the knowledge transfer channels used.

Methodology and data

To test our hypotheses, we needed to analyse a group of researchers in a field that offers at least the possibility of interdisciplinary work, as well as some degree of pervasiveness. We selected scientists working in the field of nanotechnology, an area characterized by its interdisciplinary nature and pervasiveness (Meyer *et al*, 2004; Salerno *et al*, 2008). We consider that, given nanotechnology's interdisciplinary characteristics, possible pervasiveness and the many policy initiatives designed to enhance university–industry collaboration in this area, nanotechnology is a suitable exemplar for testing our hypotheses; and the field is sufficiently varied to permit the expectation of a sufficient degree of variance in the interdisciplinary and pervasiveness variables. 'Nanotechnology' is a very broad and inclusive term, with vague boundaries (Meyer *et al*, 2004): research in nanotechnology includes areas as diverse as medical applications, materials science, electronics, robotics, metrology, instrumentation, environment, and more. It is therefore difficult to

identify the population of 'nano-researchers'. To deal with such heterogeneity and obtain a controlled and homogeneous sample, we focused this study on the relationships maintained by businesses and publicly-employed scientists whose main research topics are in the area of advanced materials at nanoscale.

Data were gathered using an on-line survey of researchers based in Spain and the Netherlands. To develop the target group, public research centres specializing in advanced materials, and other research centres working on 'general' nanotechnology and having at least one group working on advanced materials, were selected. Selection was based on interviews and public reports. After pilot testing and subsequent improvement, the on-line survey was sent out to 1,868 researchers: 967 from Spain and 901 from the Netherlands. 409 responses were received, a 22% response rate. From this group we removed inappropriate cases and selected only those who reported at least one link with a business. To eliminate errors that would result from possible intersectoral differences, we incorporated two qualifying questions in the questionnaire, to test whether the respondent was in fact working on 'advanced materials at nanoscale'. The result was a final, dyadic data set comprising 71 individuals, 52 Spanish and 19 Dutch, who reported a total of 124 ties with businesses.

To collect the data on our dependent variable (diversity of knowledge transfer channels used within a given relationship between a researcher and a business), we asked our respondents to indicate, for each relationship, the knowledge transfer channels used. Table 1 summarizes the responses received. We assigned a numerical value to three relationship variables: a value of 1 if the researcher was engaged with business through just one type of channel; a value of 2 if the researcher and the business use two channels; and a value of 3 if they are linked through 3 or more channels. Because earlier studies have shown that dissimilar social contexts lead to different ways of interaction between agents (Mollenhorst *et al*, 2008), we included two control variables in our analysis, to compensate for national differences in the patterns of interactions of researchers in Spain and the Netherlands. We also used control variables to accommodate issues of academic seniority. Table 2 summarizes the independent variables used in our study. Note that we have used several indicators in order to measure the strength of the tie: this is discussed in more detail below.

Analysis and findings

We used ordered logit regressions to test our hypotheses; and the Huber–White sandwich estimator for estimating standard errors. Working with dyadic data can imply violation of the assumption that the observations are independent. Since a single researcher can have relationships with different industrial partners, our respondents were entitled to report multiple relationships and this may affect the error terms in the regression, given that they can be correlated across observations from the same source. To solve this problem, we used a cluster option in the estimation, to indicate that the observations (relationships) are clustered into individuals and that the ties reported may be correlated within the responses given by one particular individual, but would be independent between the 71 researchers. The robust cluster technique affects the estimated standard errors and variance–covariance matrix of the estimators, but not the estimated coefficients. As our analysis will show, we found no major differences using these two different techniques.

Table 3 shows the two models we constructed to test our hypotheses. The first model contains the compiled measurement for the strength of the tie. In the second model, we have replaced measurement of the strength of the tie with that of its five underlying indicators: communication frequency, years in contact, friendship, trust, and reciprocity.

Table 1. Knowledge transfer channels.

Knowledge transfer channel	Total times mentioned
(i) *Training* – the academic offers training services to employees of the business and/or places students at the business; joint supervision of MSc or PhD students.	23
(ii) *Consultancy agreement* – work commissioned by the business, not requiring original research (for example, conducting routine tests, providing advice).	26
(iii) *Joint research or contract research agreement* – original research work done in collaboration between the business and the public academic research institution, or contracted by the business to the academic.	109
(iv) *Co-authored papers.*	38
(v) *Creation of new physical facilities* (for example, new laboratories or new buildings on campus, etc) *and/or new organizations.*	16
(vi) *Other* (specified by the respondent).	4

Table 2. Descriptive statistics of independent and control variables.

Variables	Description	Mean	Std dev
Control:			
Country	Dummy variable which equals 1 for Spanish researchers and 2 for Dutch researchers.	–	–
Seniority	Number of years the respondent has been employed in research or at an academic institution.	17.8	9.969
Independent:			
Interdisciplinarity	Total number of different disciplines the respondents considered that best characterize their current work. Summative scale of ten most relevant disciplines for nanotechnology research (see Schummer, 2004).	2.27	1.171
Pervasiveness	Total number of relevant industrial application areas of respondents' research. Summative scale of the ten most relevant industrial areas (see European Commission, 2004; Salerno et al., 2008).	2.99	1.488
Geo distance	Distance in kilometres between the academic and the people from the business with whom they interact most often. Six-point ordered scale.	3.85	1.982
Tie strength	Tie strength measurement that combines each of the five indicators (communication frequency, years in contact, degree of friendship, degree of trust, and reciprocity) with equal weight, as suggested by Granovetter (1973). Each of these is ranked on a five-point scale.	16.1	3.11
Tie strength indicators:			
Communication frequency	Indicates the frequency of contact between the researcher and the business, ranging from weekly to yearly.	2.86	0.965
Years in contact	Years the researcher has been in contact with her main contact person at the business.	3.19	1.157
Friendship	The *degree of friendship* reflects the emotional intensity of a relationship (Gibbons, 2004). We consider that a friend is an individual who the respondent identifies as such. We ask respondents to indicate to what extent they agree with the following statement: 'I consider this person my friend' (where 'this person' refers to the respondent's main contact person at the business).	3.06	1.046
Trust	The *degree of trust* refers to the intimacy (mutual confiding) between the two persons. The concept of trust in a relationship reflects the actors' vulnerability to each other (Uzzi, 1996) and influences the kind of information they are willing to share (Gibbons, 2004). We ask respondents to specify to what extent they consider his/her main contact person from the business trustworthy.	3.90	0.844
Reciprocity	We constructed the measure of reciprocity following Friendkin's (1980) measurement of tie strength. He defines strong ties 'as those in which *both* faculty members' current research activity has been discussed, (. . .)' (Friedkin, 1980). We adapted this to our context, by asking whether the researcher 'asks the main contact person for personal and professional advice'. We also asked this question the other way around (whether the contact person asks the researcher for advice), and then averaged the results.	3.01	0.971

Both models confirm that there is a strong, positive and significant relationship between pervasiveness and the diversity of knowledge transfer channels. Thus, Hypothesis 1.2 can be accepted. However, we found no significant relationship for interdisciplinarity, so Hypothesis 1.1 must be rejected. The results from our first model also support Hypothesis 2.1, that the strength of the link between the business and the researcher has a significant and positive effect on the diversity of knowledge transfer channels used by both participants in each relationship. In contrast, we reject Hypothesis 2.2 (dealing with the impact that geographical distance has on the diversity of channels). We observed instead an effect that was not originally hypothesized. We expected that an increase in distance would result in a decrease in the diversity of knowledge channels: in fact, we found a significant, opposite effect. Our data reveal that researchers do not necessarily interact more often with businesses that are geographically close (see Table 4).

In the second model, we have used the five different indicators of strength of the tie. Not all the indicators of tie strength are significant. We find that three out of five indicators have a significant and positive relation with diversity of the knowledge channel (that is, frequency of communications, years in contact, and reciprocity). Interestingly, the two subjective measurements of tie strength, friendship and trust, are not significant. This is a first indication that the combined measurement is not necessarily very robust. We have also included the correlation matrix of the individual indicators (Table 5). Based on Granovetter's definition of tie strength, we would expect all of these indicators to be highly correlated: instead, we see that the frequency of communication is not correlated with any other

Table 3: Ordered logit regression analysis. Dependent variable: interaction pattern between the researcher and the business regarding knowledge transfer activities.

	Model 1 (combined tie strength indicator)					Model 2 (tie strength indicators)				
		Standard errors using OIM		Standard errors using clustered robust			Standard errors using OIM		Standard errors using clustered robust	
	Coefficient	Std error	*p*-value	Std error	*p*-value	Coefficient	Std error	*p*-value	Std error	*p*-value
Control variable:										
Country	−0.37	0.53	0.483	0.48	0.445	−0.51	0.57	0.369	0.58	0.377
Seniority	0.01	0.22	0.655	0.03	0.716	0.16	0.23	0.478	0.03	0.609
Nature of research:										
Interdisciplinarity	−0.24	0.17	0.156	0.20	0.241	−0.18	0.17	0.280	0.23	0.419
Pervasiveness	0.46	0.15	0.003**	0.17	0.009**	0.39	0.15	0.013*	0.17	0.023*
Geographical distance	0.19	0.10	0.056†	0.09	0.043*	0.24	0.10	0.024*	0.10	0.023*
Tie strength	0.32	0.08	0.000**	0.09	0.001**					
Tie strength indicators										
Comm frequency						0.70	0.23	0.003**	0.29	0.015*
Years in contact						0.45	0.21	0.036*	0.25	0.073†
Friendship						−0.22	0.25	0.382	0.27	0.421
Trust						0.33	0.32	0.309	0.38	0.386
Reciprocity						0.72	0.27	0.009**	0.35	0.041*
Number of observations (relationships)	124					124				
Number of clusters (individuals)	71					71				
Log likelihood	−100.73					−96.42				
Pseudo R^2 McFadden	0.1854					0.2203				

**$p<0.01$; *$p<0.05$; †$p<0.1$.

indicator. The remaining indicators all correlate with each other, but only friendship, trust and reciprocity are highly correlated.

Table 4. Frequency values for geographical distance.

Scale	Frequency	Percentage
0–20 km	32	25.8
20–50 km	4	3.2
50–100 km	10	8.1
100–300 km	20	16.1
300–700 km	20	16.1
<700 km	38	30.6

Table 5: Correlation matrix of tie strength indicators.

Indicators	1	2	3	4
Communication frequency				
Years in contact	−0.140			
Friendship	0.170	0.181*		
Trust	0.107	0.228*	0.544**	
Reciprocity	0.173	0.251**	0.506**	0.402**

Table presents Spearman's rank correlation coefficients.
**$p<0.01$; *$p<0.05$.

Discussion and conclusions

Our analysis, based on a sample of researchers in the field of nanotechnology, shows that the link between a single academic researcher and a single business tends to include several (and simultaneous) transfer channels. The fact that multiple channels invoke extra costs suggests that businesses are willing to invest in such resources in order to connect with and use the knowledge base of academic researchers. In line with our initial hypothesis we find evidence that there is a strong, positive and significant relationship between the degree of pervasiveness of the technological field and the diversity of knowledge transfer channels. However, we also found that the extent to which multiple channels are used is not related to the degree of the interdisciplinary nature of the technical field in question, a result which contradicts our initial hypothesis. While businesses seem to be interested in making investments to access pervasive technologies, they do not make the additional investments needed to develop strong links to access a complex, interdisciplinary knowledge base. Importantly and, again, contrary to expectations, we have found that diverse knowledge transfer channels occur more often if

the geographical distance between the partners is greater. One possible explanation is that, for novel research, a good match between an academic researcher and a commercial business is relatively rare. It seems that once the appropriate partner is found, the investments to establish the link are made, regardless of the geographical distance separating the partners and regardless of the higher transaction costs associated with such a greater distance. This is in agreement with the findings of Azagra (2007) who argues that academic staff prefer to establish links with technologically advanced businesses which may not necessarily be located geographically near to the researchers. It is also likely that distant partners increase their degree of commitment through the formalization of common activities by using multiple knowledge transfer channels. Although spatial proximity seems to encourage collaboration, such collaboration is often done in an informal manner (Katz *et al*, 1997; Bozeman *et al*, 2004). It can therefore be expected that relationships in which the partners are geographically close do not need as much formalization as those in which the distance is significantly greater, to ensure the transfer of knowledge between the participants. On the basis of these results, we cannot claim that researchers tend to collaborate more often with partners in close proximity: in fact it seems that researchers work almost as often with partners situated more than 700 km away as they do with partners located within 50 km of the research establishment (Table 5).

We found that the common set of indicators used to measure the strength of the tie, the essence of Granovetter's work, does not – in our context – result in a robust scale. We recommend that studies in this area do not use only a combined scale but also consider the various indicators separately.

Finally, we found no appreciable difference between Spanish and Dutch researchers, despite the wide differences in institutional structures and organizational practices in the two countries. The results we have obtained seem to be independent of the context of the institution in which research is conducted. This further supports the use of analytical methodologies that focus on the individual as the subject of research. We accept that the results may vary across disciplines and research fields, but this study shows that the insights that can be obtained from this methodological approach can contribute to theoretical development.

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Acknowledgement

This research has been partially supported by a grant from the Spanish National Research Plan (Project reference: SEJ2005–05923/EDUC).