Diversity in knowledge transfer: A network theory approach

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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 aims to use social network theory techniques to gain a better insight into knowledge transfer processes. In particular, we study how the characteristics of ties among individuals, and the interdisciplinary and pervasiveness of research affects the diversity of knowledge transfer activities. To this end, we conduct an empirical study among researchers in the field of nanotechnology. This sector is chosen for its interdisciplinarity and its expected pervasiveness. Data was collected using a survey conducted in Spain and in The Netherlands, allowing us to correct for some environmental and context effects.

Keywords:
Knowledge transfer, social networks, interdisciplinarity

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

1. Introduction

Knowledge transfer mechanisms and agreements are widely argued to be a key element in the production and dissemination of cutting edge knowledge (Murray, 2001; Powell, 1990). Through knowledge transfer, actors from different institutional spheres can achieve a progressive adaptation in their procedures and goals (Bozeman, 2000), and explore scientific and technological knowledge to expand their current capabilities (Murray, 2001).

Paradoxically, and despite considerable efforts by governments, new knowledge developed in universities faces specific difficulties in its transfer to firms (Meyer et al., 2004). Scholars have found that the locus of control in scientific collaboration lies more on individuals than the institutions they represent, and that this is particularly true when academic institutions are involved (Bozeman and Corley, 2004; Liebeskind et al., 1996). The know-how and information that researchers obtain over time constitutes their own knowledge stock (McFadyen and Cannella Jr, 2004) and consequently the exchange of knowledge takes place primarily between people and within the context of personal relationships (Oliver and Liebeskind, 1997). Therefore, collaborative knowledge transfer activities are intrinsically social processes, where individuals, not institutions, are the key actors (Katz and Martin, 1997; Oliver et al., 1997; Powell, 1990). This implies a complex, and dynamic interaction between the actors involved, less guided by formal structures of authority and more dependent on the relationship among 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 about the social and relational particularities of knowledge transfer processes, there is a remarkable lack of studies that focus on individuals as the unit of analysis (Palmberg, 2008). Studies at this level of analysis would allow us to comprehend better the relational aspects underlying knowledge transfer processes. This paper contributes to addressing this gap in the literature.

Our starting point lies in some of the characteristics of the scientists' research, as they constitute the basis of their relationship with firms. We analyse whether the potential of individual researchers to transfer knowledge is linked with the characteristics of their research. Second, we analyse the impact that different types of social ties have on knowledge transfer. We want to identify which characteristics of the links between academic researchers and firms contribute to a more diverse interaction in terms of the knowledge transfer channels used within a given relationship.

The structure of the paper is as follows. Section 2 discusses the expected relation between knowledge characteristics and knowledge transfer channels. Section 3 addresses the expected relation between the features of individual ties and the use of knowledge transfer channels. After presenting our methodology and data in section 4, we turn to the analysis and the findings (section 5). Finally, section 6 offers conclusions and discusses the results.

2. Diversity of knowledge transfer channels and knowledge characteristics

Academic research usually involves novelty. To achieve new discoveries, scientists often combine multiple sources of knowledge, diverse methodologies and varied competences (Zander and Kogut, 1995). Novel research is often interdisciplinary. Further, interdisciplinary research may lead to pervasive technologies; that is, technologies characterised by multiple uses within the same and across different industrial sectors (Salerno et al., 2008). Presumably, the more interdisciplinary and pervasive the research is, the more tacit the knowledge produced and the more complex the transfer of the knowledge to the firm will be. Despite these complexities, firms will still be interested in pursuing knowledge transfer. Arguably, the more pervasive and interdisciplinary the knowledge to be acquired the greater the potential gains for the firm. This is because the higher the complexity of the knowledge incorporated by a firm, the more difficult it is for competitor to replicate it (Barney 1991). It is therefore to be expected that firms will make substantial investments in time and resources to access complex and tacit knowledge.

Further, different knowledge transfer channels are likely to have different strengths and weaknesses when it comes to transferring tacit and complex knowledge. As a result, if a firm wants to increase the chances of successfully absorbing knowledge generated elsewhere it will tend to make use of several knowledge transfer mechanisms. Consequently, the resulting interaction pattern concerning knowledge transfer will be more diverse. The discussion above leads us to the following hypotheses:

> **Hypothesis 1.1:** The more *interdisciplinary* a researchers' work, the more diverse the knowledge transfer channels between the researcher and the firm.

Hypothesis 1.2: The more *pervasive* a researchers' work, the more diverse the knowledge transfer channels between the researcher and the firm.

3. Diversity of knowledge 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 social actors, characterised by infrequent interactions (Granovetter, 1973) and based neither on trust nor reciprocity. According to the seminal work of Granovetter (1973), weak ties constitute conducts that are more efficient for innovation, as they are likely to provide partners with novel information. Nevertheless, when information and knowledge are considered to be of a sensitive nature and exchange partners may apply for property rights in the future, individuals may behave with considerable caution when sharing knowledge (Bouty, 2000). In this context, the hazards of opportunistic behaviours 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 the actors 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 base (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, strong relationships require considerable investments in time, energy, and resources to maintain (Boorman, 1975). For both academic researchers and firms, the resources available to allocate to relationships are limited. In order to maximize the investments already made in the relationship, agents will tend to employ such links for diverse uses. Therefore, it is expected that as the tie between a researcher and a firm becomes stronger, the channels used for the transfer of knowledge will be more diverse. Consequently, we developed the following hypotheses:

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

Previous studies stress the importance of the location of exchange partners involved in knowledge transfer. A number of such studies assert that socials actors 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 agents are located far away, it is more complicated and costly to arrange meetings, lowering the shared experiences (McFadyen et al., 2005) and the effectiveness of the knowledge transfer. Therefore, since close-distance relationships reduce the interaction costs of transfer channels and increase the shared experiences between partners, agents will tend to count more on this type of relationship than on long-distance ones. It is also widely accepted that spatial proximity helps in strengthening relationships (Bozeman et al., 2004; Katz et al., 1997). Such relationships can be particularly valuable when dealing with actors that have different goals and knowledge bases (as universities and firms do). Hussler and Ronde (2007) argue that knowledge transfer between actors who do not share similar goals and knowledge bases is more difficult than when it occurs between similar actors. Therefore, in the case of university-industry interactions, geographical proximity will ease knowledge transfer between such dissimilar actors. Further, as the transfer of complex knowledge is likely to depend, as argued above, on a variety of transfer mechanisms, we can argue that the relationships characterised by spatial proximity will show a more diverse use of knowledge transfer channels. Based on the above, we formulate the following hypothesis:

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

4. Methodology and data

To test our hypotheses, we need to analyse a group of researchers involved in an area of work where there is at least the possibility of interdisciplinary work and some degree of pervasiveness is expected. We selected scientists working in the field of nanotechnology, an area characterised by its interdisciplinarity and pervasiveness (Meyer et al., 2004; Salerno et al., 2008). We consider that given nanotechnology's interdisciplinarity, possible pervasiveness and the many policy efforts to enhance University-Industry collaboration in this area, nanotechnology offers a good test base for our hypotheses. Nevertheless, nanotechnology itself 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, electronics, robotics, metrology, instrumentation, environment, etc. It is therefore difficult to identify the population of nano-researchers. To deal with such heterogeneity

and obtain a controlled and homogeneous sample, we focus this study on the relationships maintained by firms and public scientists whose main research topics are in the area of advanced materials at nanoscale.

Data was gathered using an on-line survey, addressed at Spanish and Dutch researchers. To build our target group, we first made a selection of public research centres specialised on advanced materials, as well as research centres working on 'general' nanotechnology that had at least one group working on advanced materials. This selection was based on expert interviews and public reports. After pilot testing and several improvements, the on-line survey was sent out to 1868 researchers, 967 from Spain and 901 from The Netherlands. We received 409 responses, which constitute a 22% response rate. From this group, we deleted incomplete cases and selected only those respondents who reported at least one link with a firm. Respondents who did not meet these criteria were dropped from the data set. Furthermore, 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'. After these filtering stages, the final data set comprised 71 individuals, 52 Spanish and 19 Dutch, who reported a total of 124 ties with firms.

Table 1: Knowledge transfer channels

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

Table 2: Descriptive statistics of the 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 institutions	17.8	9.969
Independent			
Interdisciplinarity	Total number of different disciplines the respondents considered that best characterise 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 firm with whom they interact most often. 6-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 firm, 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 firm.	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 firm).	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 firm 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 asks this question the other way around (whether the contact person asks the researcher for advice), and then average the results.	3.01	0.971

To collect the data on our dependent variable (*diversity of knowledge transfer channels used within a given relationship between a researcher and a firm*), we asked our respondents to indicate, for each relationship, the knowledge transfer channels used. Table 1 shows the channels included in

the question and how often the various channels were mentioned. We created an ordinal dummy variable with three categories: the value is 1 if the researcher is engaged with the firm through just one type of channel; 2 if the researcher and the firm use two channels; and 3 if they are linked through 3 or more channels. The analysis includes two control variables. Earlier studies have shown that dissimilar social contexts lead to different ways of interaction between agents (Mollenhorst et al., 2008). In order to address this issue, we control for *country* differences in the interactions patterns of Dutch and Spanish researchers. We also control for academic *seniority*. Table 2 summarises the independent variables used in our study. Note that we have used several indicators in order to measure tie strength (see below).

5. Analysis and findings

We employed ordered logit regressions to test our hypotheses. We used the Huber-White sandwich estimator for estimating standard errors. Working with dyadic data can imply the violation of the assumption that the observations are independent. Since a single researcher can have relations with different industrial partners, our respondents can report multiple relationships. 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 big 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 tie strength. In the second model, we have replaced tie strength measurement by its five underlying indicators: communication frequency, years in contact, friendship, trust and reciprocity.

Table 3: Ordered LOGIT regression analysis. Dependent variable: interaction pattern between the researcher and the firm 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**	
	Coef.	Std. Err.	P-value	Std. Err.	P-value	Coef.	Std. Err.	P-value	Std. Err.	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 obs. (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.

Both models confirm that there is a positive and significant relationship between pervasiveness and the diversity of knowledge transfer channels. So **hypothesis 1.2** can be accepted. However, we found no significant relationship for interdisciplinarity, so **hypothesis 1.1** must be rejected. The result in our first model also supports **hypothesis 2.1**. The strength of the link between the firm and the researcher has a significant and positive effect on the diversity of knowledge transfer channels used by both agents in each relationship. In contrast, we reject **hypothesis 2.2** about the impact that the geographical distance has on the diversity of channels. Instead, we observe 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 but opposite effect.

In the second model, we have used the five different indicators of tie strength. Not all the indicators of tie strength are significant. We find that three out of five indicators have a significant and positive relation with knowledge channel diversity (communications frequency, 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 also add the correlation matrix of the individual indicators (Table 4). Based on Granovetter's tie strength definition, we would expect all these indicators to be highly correlated. Instead, we observe that the frequency of communication it is not correlated with *any* other indicator. The remaining indicators all correlate with each other, but only friendship, trust and reciprocity are highly correlated.

Table 4: Correlation matrix of tie strength indicators

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

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

6. Conclusions and discussion

We have selected for our analysis a pervasive field of knowledge with applications across industry. In line with our initial hypothesis we confirmed that, in the case we examined, researchers and firms tended to use a variety of simultaneous knowledge transfer channels. As the establishment of strong links through parallel channels is costly, their presence suggests that firms were sufficiently attracted to the knowledge base potentially offered by the academics as to invest a considerable amount of resources to build strong links based on different interaction mechanisms. We also found, however, that no significant relationship existed between interdisciplinarity and the use of diverse knowledge transfer channels. This result contradicts our initial hypothesis. While firms seemed interested in making investments to access pervasive technologies, they did not make the additional investments needed to develop strong links to access complex interdisciplinary knowledge basis.

Importantly, and again contrary to expectations, we have found that diverse knowledge transfer channels occur more often if the distance between the partners is *higher*. One possible explanation is that for novel research, a good match between academic researcher and firm is relatively rare. It seems that once the appropriate partner is found, the investments to establish the link are done regardless of the geographical distance separating the partners, and the higher transaction costs associated with such distance. Instead, it can be argued that distant partners increment their degree of commitment through the formalization of their common activities by using multiple knowledge transfer channels.

We found that the common set of indicators used to measure tie strength in the spirit of Granovetter's work, does not result in a robust scale in our context. We recommend that studies in this area do not only use 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 these two countries. The results we have identified seem to emerge independently from the institutional context within which research is conducted. This result further supports the use of analytical methodologies that focus on the individual as research subject. Naturally, results may change across disciplines and research fields, but this study shows that the insights to be obtained from this methodological approach can contribute to theoretical development.

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