Networks, proximities and inter-firm knowledge exchanges

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Topics in Economics

Motivation / 1

Knowledge, one of the most relevant intangible assets, is a crucial determinant of innovation and economic performance.
The creation and acquisition of knowledge is fundamental for economic and social enhancements.

The exchange of knowledge among agents is facilitated by their spatial proximity given its well known tacit nature, which usually bounds the spatial scope of spillovers. However, the concept of proximity has several other dimensions which may have an a-spatial nature. This is the case for technological, social, institutional and organisational proximity.

Moreover, economic agents may establish social links within different networks that may facilitate the exchanges of knowledge and moderate the adverse effects of distance.

The literature has extensively analysed the features of these networks and their effects on knowledge diffusion considering various forms of connections among agents (co-inventorship, research collaborations, patent citations)

Motivation / 2

In this paper we follow a novel route by looking at the knowledge exchanges which are due to inter-firms agreements (joint ventures and strategic alliances).

According to the management literature (Kogut 1988; Inkpen 2000; Oxley-Sampson 2004) inter-firm agreements, whatever their specific nature and motivation, create the conditions for knowledge sharing and thus represent an important channel of knowledge transmission.

Firms perform several activities before, during and after the agreements, which allow partners to access and share knowledge-based resources often embedded within the organisations (Muthusamy-White 2005; Janowicz -Noorderhaven 2008; García-Canal et al. 2008).

These flows may include access to new technologies and organizational competencies or integration, sharing and transfers of capabilities and human and organizational resources, or formal and informal inter-organizational learning processes.

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Empirics on knowledge flows / 1

Studies based on various indicators of knowledge exchanges among agents and territories:

- Participation in research programmes (Autant-Bernard et al., 2007; Maggioni et al., 2007; Balland 2012)
- Co-patenting (Cantner and Meder, 2007; Maggioni et al., 2007, Picci, 2010; Cassi and Plunket, 2012)
- Citations (Paci and Usai, 2009)
- Co-publications (Ponds et al., 2007)
- Applicant-inventors relationships (Maggioni et al., 2011)
- Human capital mobility (Miguelez-Moreno, 2011 and Breschi and Lissoni, 2009).

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Empirics on knowledge flows / 2

Studies based on inter-firm agreements / cooperation used as indicators of knowledge exchange, but limited to a single industry:

- footwear (Boschma and Ter Wal, 2007)
- nanotechnology (Autant-Bernard et al., 2007)
- aviation (Boschma and Broekel, 2009)
- biotechnology (Fornahl et al., 2011)
- global navigation satellite system (Balland, 2012)
- genomics (Cassi and Plunket, 2012)

Other studies give a global picture of the role of proximities but with aggregated regional data (Paci et al., 2014; Maggioni et al., 2012).

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Aim

Analyse how inter-firm collaborations, and the consequent knowledge exchanges among partners, are affected by the features of the networks in which firms are involved and by the proximity (measured with respect to different dimensions) among participants.

Estimate the likelihood that two organizations engage in a partnership as a function of their relative geographical, technological, social, organizational and institutional proximity and their positioning within the network (degree and closeness centrality).

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Our contribution

- We investigate announced agreements (domestic and international) with at least one firm localised in Italy over the period 2005-2012.
- Agreements covers all economic activities and this allow us to offer a wide-ranging scenario with respect to previous contributions on the role of proximity.
- We consider 631 agreements which involve 1078 firms giving rise to 887 pairs.
- We consider the concurrent effects of five proximity dimensions and two network features.
- The general traits of the agreements involving Italian firms are very similar to other national or international contexts: firms propensity to start an agreement depends much more on sectoral features rather than on country differences (Narula & Hagedoorn 1999).

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Dataset / 1

Inter-firm agreements with at least an Italian participant, 2005-2012

Announced agreements	**631**	
with 2 participants	*570*	90%
with 3 participants	*43*	7%
with 4 participants	*6*	1%
with 5 participants	*8*	1%
with 6 participants	*2*	0%
with 7 participants	*2*	0%
Participants	**1078**	
Italian	*511*	47%
foreign	*567*	53%

Participant pairs	**887**	
joint ventures	607	68%
strategic alliances	280	32%
completed	382	43%
uncompleted	505	57%
with both partners in Italy	*130*	15%
with one partner in Italy	*636*	72%
with both partners not in Italy	*121*	14%

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Dataset / 2

Participants per country of origin, 2005-2012

	Number	%
Italy	511	47.4
EU countries	141	13.1
United States	127	11.8
India	72	6.7
China	44	4.1
Russian Fed.	40	3.7
Utd Arab Em.	16	1.5
Canada	13	1.2
Turkey	13	1.2
Japan	11	1.0
Rest of the World	90	8.3
Total	1078	100.0

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Dataset / 3

Agreements and participants per SIC division, 2005-2012

	Agreements		Participants	
	Num.	%	Num.	%
A Agriculture	1	0.2	2	0.2
B Mining	20	3.2	34	3.2
C Construction	12	1.6	17	1.9
D Manufacturing	213	46.8	504	33.8
E Transp., Comm., Energy, Sanitary Serv.	91	14.8	160	14.4
F Wholesale Trade	58	2.4	26	9.2
G Retail Trade	30	2.4	26	4.8
H Finance, Insurance, Real Estate	90	15.1	163	14.3
I Services (personal and business)	114	12.6	136	18.1
J Public Administration	2	0.9	10	0.3
Total	631	100.0	1078	100.0

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Empirical model / 1

Prob **(agreement$_{ij}$) = *f* (proximities$_{ij}$, network$_i$, network$_j$, controls$_i$, controls$_j$)**

The observational units are pairs of firms (ij)

The dependent variable is a binary variable:
= 1 for firm pairs (887) which actually established a link
= 0 for firm pairs that could have set up an agreement but did not.

The zero observations are "potential" pairs.
They are computed by pairing all the firms (1078) included in our sample (580,503) and subtracting the actual pairs (887). The potential pairs are 579,616.

Setting up a cooperative agreement is a rare event (0.15% of realizations).

In this case the logit model estimated on the total number of firm pairs severely underestimate the probability of occurrences. Therefore the analysis is performed within a logistic framework for rare events (King and Zeng, 2001, 2002).

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Empirical model / 2

Prob **(agreement$_{ij}$) = *f* (proximities$_{ij}$, network$_i$, network$_j$, controls$_i$, controls$_j$)**

Explanatory variables

Proximity dimensions between any two firms
- Geographical
- Technological
- Organizational
- Institutional
- Social

Network structure of each firm
- degree centrality
- closeness centrality

Firm controls

status (listed, private), organization (independent, in a group), ownership nationality, geographical location (North-Centre-South of Italy, EU), main sector of activity (10 SIC divisions)

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Geographical proximity

- The diffusion and absorption of external knowledge, especially in its tacit component, is facilitated when agents are physically proximate (Von Hippel, 1994).
- Consequently, spatial proximity has been the most thoroughly investigated dimension within the wide literature on localised knowledge spillovers and flows (Jaffe et al., 1993; Jaffe, 1995; Anselin et al., 1997).
- As a measure of geographical proximity we use the inverse of the distance in kilometers between the location of the partners.
- Alternative measure: dummy variable which takes value 1 when both partners are located in the same Italian region.

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Technological proximity

- Knowledge transfer require a homogenous cognitive base to understand, process and absorb the external available knowledge (Cohen and Levinthal, 1990). Firms that share a similar knowledge base can exchange knowledge more easily and efficiently.
- We compute a set of five mutually exclusive technological interaction dummies, ordered by decreasing technological similarity (Ellwanger and Boschma, 2012) and based on the *Standard Industrial Classification*:
  - I*D_intra_SIC4* = 1 when the partners operate in the same 4-digit SIC Industry and 0 otherwise;
  - *ID_intra_SIC3* = 1 when the lowest degree of industrial relatedness is the 3-digit SIC Industry Group; 0 otherwise (i.e. they operate in different Industry group or are related at a lower industrial disaggregation);
  - with the same methodology we compute the dummies *ID_intra_SIC2* for the 2-digit SIC Major group and *ID_intra_SIC1* for the 1-digit SIC Division;
  - *ID_inter_SIC1* = 1 when the partners operate in different divisions (conglomerate agreements); this set of firms is the reference group.

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Organizational proximity

- The exchange of information and knowledge can be influenced by the membership of individuals to the same club, group or organisation. The common membership implies the sharing of a set of rules and practices, based on organizational arrangements, which are crucial in reducing uncertainty and opportunistic behaviour (Kirat and Lung, 1999).
- Such arrangements can be either within or among firms and may take different forms along a range which goes from informal relations among companies to formally organized firms.
- We measure organizational proximity with a dummy (ID_intra_group) equal to 1 if the two organizations involved in a partnership belong to the same corporate group (i.e. they have the same ultimate parent company), as in Balland et al. (2013).

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Institutional proximity

- The exchange of knowledge among economic agents is facilitated if they share the same institutional framework (such as laws and norms) since it provides them a set of common procedures and routines.
- This common background may be crucial in reducing uncertainty, lowering transaction costs, favouring a pro-cooperative attitude, which enhances the possibility of agreements and the knowledge exchanges (Maskell and Malmberg, 1999; Gertler, 2003).
- We measure institutional proximity with a dummy (ID_status), which takes value 1 if the two firms share the same status (both listed or private, or government).
- Alternative measure: dummy (ID_indep), which takes value 1 if the partners are both independent entities.

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Social proximity

- Direct and indirect relationships in the past provide a facilitating environment for sharing knowledge in the future.
- Thus the degree of social proximity decreases with the geodesic distance measured by the shortest path between two nodes (i.e. firms) (Autant-Bernard et al., 2007; Balland, 2012).
- As indicator of social proximity we use the inverse of the geodesic distance, which ranges from zero (when two nodes have infinite distance, they have never met in the past, nor any of their direct and indirect partners) to one (when two nodes are directly linked).
- In order to retrieve as much information as possible from our data we compute the inverse of the recursive measure of geodesic distance (*geod_dist_rec*) between firm *i* and firm *j* in all previous years available.
- Alternative measure: the inverse of the geodesic distance only in previous five years (*geod_dist_5y*).

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Network characteristics

Knowledge flows across a-spatial networks, where agents exchange ideas on a voluntary base (Cowan and Jonard, 2004) according to the characteristics of the network:

- the preferential attachment hypothesis predicts that actors' tend to link to the most connected individuals: agents with a large number of relations are more attractive because they are supposed to be more productive or more trustworthy (Barabasi and Albert, 1999).
- the transitivity (reachability) hypothesis predicts that some agents are more easy to reach than others due to their relative position in the network: some nodes are relatively closer to all other nodes and therefore they are a more effective way to potentially connect to all other nodes in order to acquire knowledge.

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Network characteristics - indicators

- Preferential attachment hypothesis: propensity to link to the most connected individuals.

  Indicator: degree of centrality : number of links (relations) of each firm in the previous period 2000-2004.

- Transitivity hypothesis: some agents are more reachable than others due to their relative position in the network.

  Indicator: closeness centrality : inverse of the sum of the distances of a node to all other nodes in the previous period 2000-2004.
  (i.e how long it will take to spread information from one node to all other nodes sequentially).

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Estimation method / 1

The analysis is performed within a logistic framework for rare events (King and Zeng 2001, 2002), the standard logistic approach would underestimate the probability of occurrences because of the large number of zeros.

We apply the endogenous stratified sampling approach which requires selecting all the observations for which Y=1 (the "cases") and randomly selecting the observations for which Y=0 ("controls").

We sequentially consider several samples sizes by increasing the number of zero observations. We stop when we get no further improvements in terms of estimates accuracy.

We select the 0.1 proportion (1/10: each actual pair matched with 10 other randomly drawn potential pairs)

Number of observations: 887+8870 = 9757

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Estimation method / 2

Estimation is based on the prior correction method, which corrects for the bias induced by selecting with respect to the response variable.
The correction is based on the population proportion of "one" observations (0.0015 that is 0,15%).

Similar results when we apply the alternative correction method, based on weighting.

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Estimation strategy

The starting point is that the random probability of an agreement is 0.15% (out of all potential pairs).

1. Estimate the benchmark model with just geographical proximity, network characteristics of each partner and firm controls.
2. Estimate the baseline model with all additional proximity dimensions: technological, organisational, institutional and social.
3. Test for robustness with respect to alternative proximity measures and subsamples.
4. Post-estimation stage: measure the increase in the estimated conditional probability for a given change in each variable in turn to assess the effects of proximity or network features on the likelihood that any two firms exchange knowledge.

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Logit models - prior correction for rare events

	standard	baseline
Spatial proximity		
geographic distance (inverse)	0.254 ***	0.256 ***
same region		
Technological proximity		
same division (SIC1)		0.939 ***
same major group (SIC2)		2.733 ***
same industry group (SIC3)		3.174 ***
same industry (SIC4)		3.972 ***
Organisational proximity		
same group		3.073 ***
Institutional proximity		
same status		0.199 **
both partners independent		
Social proximity		
geodesic distance (inverse)		0.175 ***
geodesic distance (inverse, 5 years)		
Network effects		
degree centrality - partner 1	0.076 ***	0.068 ***
degree centrality - partner 2	0.065 ***	0.063 ***
closeness centrality - partner 1	9.117	13.453 **
closeness centrality - partner 2	12.705 *	17.127 **
Estimated prob. at median values	**0.027**	**0.038**

Obs: 9757
All firms controls included
Random probability of an agreement = 0.15%

Preferred model with five proximity measures, network effects and individual controls:
all dimensions of proximity exhibit a positive and significant effect.
They are complementary and not substitute.

Inter firm agreements are mostly facilitated by a common cognitive base

Preferential attachment and transitivity are both network features which positively affect the probability of a knowledge exchange.

The concurrent effect of 5 proximities and 2 network features makes the probability of inter firm agreements increase up to 3.8%, which is 25 time higher than the basic random probability (0.15%)

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Logit models - robustness

	standard	baseline	robustness			
Spatial proximity						
geographic distance (inverse)	0.254 ***	0.256 ***		0.257 ***	0.254 ***	
same region			1.495 ***			
Technological proximity						
same division (SIC1)		0.939 ***	0.931 ***	0.939 ***	0.945 ***	
same major group (SIC2)		2.733 ***	2.720 ***	2.732 ***	2.731 ***	
same industry group (SIC3)		3.174 ***	3.123 ***	3.167 ***	3.209 ***	
same industry (SIC4)		3.972 ***	3.984 ***	3.969 ***	3.966 ***	
Organisational proximity						
same group		3.073 ***	3.279 ***	3.128 ***	3.046 ***	
Institutional proximity						
same status		0.199 **	0.208 **		0.223 **	
both partners independent				0.205		
Social proximity						
geodesic distance (inverse)		0.175 ***	0.169 ***	0.178 ***		
geodesic distance (inverse, 5 years)					0.120 *	
Network effects						
degree centrality - partner 1	0.076 ***	0.068 ***	0.069 ***	0.068 ***	0.069 ***	
degree centrality - partner 2	0.065 ***	0.063 ***	0.064 ***	0.063 ***	0.065 ***	
closeness centrality - partner 1	9.117	13.453 **	14.362 **	13.330 **	13.661 **	
closeness centrality - partner 2	12.705 *	17.127 **	17.695 **	16.928 **	17.732 **	
Estimated prob. at median values	**0.027**	**0.038**	**0.028**	**0.031**	**0.039**	

Obs: 9757

All firms controls included

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Estimates for sub-samples

We have carried out a sub-sample analysis to investigate whether relevant differences emerged when splitting the sample according to some features of the knowledge flows:

- completed vs. uncompleted agreements
- joint ventures vs. strategic alliances
- manufacturing vs. service sectors

This analysis is rather preliminary since the limited number of actual agreements prevents us from estimating all the sub-samples and thus further research is required.

In any case, no significant differences were found across subsamples, thus confirming the main findings discussed above for the whole estimation sample.

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Effects of Proximities and Networks on the probability of Inter-Firms Agreements

From Model 2 Table 4: Prob (Y=1|X)=0.03765	Standard deviation	Absolute difference	Percentage Increase
Spatial proximity			
geographic distance (inverse)	3321.71	0.00870	23.11
Technological proximity			
same division (SIC1)	0.424	0.01730	45.95
same major group (SIC2)	0.168	0.02036	54.08
same industry group (SIC3)	0.122	0.01670	44.36
same industry (SIC4)	0.184	0.03706	98.43
Organisational proximity			
same group	0.039	0.00459	12.19
Institutional proximity			
same status	0.470	0.00351	9.32
Social proximity			
geodesic distance (inverse)	0.036	0.00032	0.85
Network effects			
degree centrality (partners average)	4.353	0.01172	31.12
closeness centrality (partners average)	0.005	0.00306	8.13

All changes are equal to one standard deviation and are measured with respect to the median

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Main results and conclusions

- The results of our preferred model – with five proximity measures, network effects and individual controls – show that all dimensions of proximity exhibit a positive and significant effect. They are complementary and not substitute.
- Knowledge exchanges are facilitated not only by spatial proximity, but most importantly by a common cognitive base (impact is five times higher).
- Preferential attachment and transitivity are both network features which positively affect the probability of a knowledge exchange.
- The concurrent effect of the five proximity dimensions and of the two network features makes the probability of knowledge exchanges increase up to 3.8%, which is 25 time higher than the basic random probability (0.15%).

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Policy implications /1

- The existence of several channels of firms knowledge exchange calls for a coordinated strategy able to achieve different targets with diverse instruments.
- More policies should aim directly to knowledge diffusion and absorption taking into account the diverse institutional and industrial contexts: no "one size fits all" policies (Todling and Trippl, 2005; Asheim et al, 2011).
- Practically, policies should support and encourage the formation of dense networks among firms which go beyond geographical clusters and which may exploit very diverse channels for knowledge flows.

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Policy implication /2

- Technological proximity matter much more than the geographical one in influencing inter-firm agreements and thus knowledge exchanges. This suggests the implementation of specific industrial policies to support the formation and the functioning of a-spatial industrial clusters characterized by proximate technology.

- Finally, the presence of externalities which exploit social interregional relations requires policies designed specifically to provide a balanced set of incentives to motivate economic agents towards cooperation without deterring competitiveness.

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Future research

- Check with other more complex measures of technological relatedness
- Robustness test with other countries
- Robustness test with other forms of agreements and cooperation
- Robustness test with respect to other forms of internationalisation: M&A or greenfield investment
- Post-deal performance analysis with a more inter-temporal perspective.

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