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The evolving dialogue between Innovation and Economic Geography
From physical distance to non-spatial proximities and 'integrated' frameworks

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Abstract

This paper looks at the recent economic geography literature and sets out to explore the evolution of its intersections with innovation theories. The replacement of the linear model with more sophisticated conceptualisations of the process of innovation has made it possible to account for persistent disparities in innovative performance across space and has motivated researchers to incorporate the role of space and places in the analysis of innovation processes. From the physical-metrical approach of geography as distance, to the emphasis on specialisation and diversification patterns (geography as economic place), institutional-relational factors, non-spatial proximities and 'integrated' frameworks, economic geography theory has substantially evolved in terms of its contribution to the understanding of technological dynamics with significant implications for the rationale, design and implementation of innovation policies.

1. Introduction

In an increasingly globalized world of intensified competition with ever-shorter product lifecycles, new technologies and innovation are key determinants of regional and national competitiveness. This is certainly good news for developing and emerging countries and regions: economic performance can be boosted by stronger indigenous innovative capabilities but also by better accessibility to external knowledge. New windows of opportunity are being opened by innovation and technological change for new actors to emerge in the international technological competition arena. However, a large body of empirical evidence suggests that these opportunities are far from 'universal': knowledge generation and absorption are highly localized and diffusion follows very complex (and ever changing) patterns. In both developing and developed countries, a small number of 'hotspots' are pushing the technological frontier forward, followed by a set of emerging second-tier 'imitative systems' and a large number of territories that exhibit little innovative dynamism and only marginal benefits from technological opportunities. Innovation is certainly spreading both internationally - as suggested for example by the success of China and India – and 'nationally' – with new territories gaining momentum in the 'new' member states of the EU – but only in a very circumscribed set of new suitable 'locations'. This is true in Europe and the United States where around 70% of total patenting remains concentrated in the twenty most innovative regions (Crescenzi et al., 2007) but also in China and India where these concentration patterns are even more significant (Crescenzi et al., 2012).

Rather than waning, such spatial innovation disparities are increasing in both developed and developing countries, shattering hopes that rapid progress in information and communication technologies (ICT) and the dismantling of barriers to the movement of labour and capital can automatically decouple innovative performance from previous localized patterns of technological accumulation and contextual socio-institutional and geographical conditions. Conversely, the spatial concentration of knowledge-generation in a few leading "hotspots" boosts their attractiveness for inward investment in innovative activities, further reinforcing the localisation of the key nodes of 'global' knowledge networks generated by the mobility of both capital (e.g. by multinational firms and their internal connections) and skilled labour (e.g. diasporic communities), generating a cumulative self-reinforcing process.

Technological change and innovation – with their capability to generate new economic opportunities – are features of cities, clusters and regions whose contribution towards national and global systems and networks is highly asymmetric. This, therefore, calls for appropriate frameworks of understanding able to capture the two-way nexus between geography and innovation. Coherently with this perspective, this chapter aims to critically review the existing literature on territorial innovation dynamics in order to shed light on how progressively more sophisticated conceptualisations of the role of geography in innovation dynamics have been developed, and how they can address the complexity of the 'real' world processes discussed above in a more effective manner.

When looking at how the literature has conceptualised the economic geography of innovation dynamics it is possible to identify four major streams of literature:

(i) Being based on physical-metric space, the first stream of literature has analysed the role of *geographical distance* between innovative agents in shaping their innovative capabilities;

(ii) The second stream, instead, has focused on geography as an '*economic place',* looking at how local sectoral and functional specialization patterns shape the generation of innovation;

(ii) A third set of contributions has concentrated on '*institutional-relational places'*, looking at the impact on innovation of the rules and patterns shaping the interactions between innovative agents in a given locality;

(iv) The final set of academic works has developed the idea that economic and institutional-relational processes can be de-decoupled from geographical proximity giving rise to *alternative (*'economic' and/or 'institutional-relational') *non-spatial proximities*.

Following the foregoing categorisation, this chapter starts off by reviewing the archetypical a-spatial approach: i.e. the linear model of innovation. The linear sequencing from basic into applied research and innovative products or processes leaves no conceptual room for geographical dynamics. The subsequent section looks at the literature that abandons the view of knowledge as a public good in order to explore the role of physical geographical distance in making knowledge a local quasi-public good. The fourth section places innovation 'in context' by discussing: a) the influence of economic places - local agglomeration and specialization patterns – on the innovation process, by looking at how economists and geographers have tried to identify the type of sectoral specialization that is most conducive to innovation; b) the role of local institutions is analysed in the fourth section by reviewing the literature on regional systems of innovation (RSI) where the focus is on institutional-relational places. The fifth section will review recent research based on the multi-dimensional conceptualizations of proximity that broaden the analytical focus to non-spatial proximities as determinants of local innovative performance as also integrated approaches that combine and cross-fertilise the insights of various streams of literature. The final section concludes with some directions for future research.

2. The linear model of innovation: the a-spatial benchmark

The linear model of innovation has for a long time been the most influential theoretical framework for the understanding of the economic impact of science and technology. It postulates that all innovations result from basic science (Godin 2006): conducted in the research laboratories of universities and government research institutions, basic science produces new knowledge that is passed on to the applied science laboratories of private companies, where it is prepared for the translation into commercial products. The linear or "assembly-line model" (Ruttan 2001) conceives the innovation process as a one-way path:

Basic science → Applied science → Development → Commercialization and Diffusion

This view also implies that basic science creates positive externalities in the form of public knowledge: underinvestment in basic research must be expected in the absence of government intervention. The allocation of public resources to basic science is expected to maximize externalities that allow for the universal diffusion of knowledge as a public good.

Empirically, the reasoning behind the linear model lies at the core of econometric studies examining the link between R&D and patents, in the first instance, followed by that between patents and economic growth. These analyses are based on knowledge production functions (KPF) proposed by Griliches (1979), which allows for an investigation of the causal relation between productivity growth, unobservable knowledge capital, and its observable input (R&D) as well as output (typically patents), and further factors. Based on firm-level data, these studies are mostly conducted by "mainstream economists".

The linear model of innovation has been particularly influential in the post-war when it shaped the US science and technology policies (Ruttan 2001) and remains popular with policy makers in the 21st century, as evidenced by targets in terms of R&D spending to GDP ratios set in the EU's Lisbon Agenda or by the contemporary policy focus on centres of excellence that still survives in the innovation policies of several countries. Two major reasons explain the lasting influence of the linear model. Firstly, the model conveys an unequivocal normative message: policy-makers should invest in basic research to maximize innovative potential. Second, national statistical offices and international organizations have reified "basic science", "applied science", and "development" into standard categories for the collection of data on innovative efforts, hardening the model as a concrete reference for policy discussions and transformed the linear model into a "social fact" (Godin, 2006).

According to Freeman (1996 p.27), there is no other model of innovation processes that "has been more frequently attacked and demolished" than the linear model. The most fundamental critique to this approach aims at the core of the model, i.e. its linear character. The latter has been criticized for failing to reflect the complexity of innovation processes and the heterogeneity of its dynamics. Kline and Rosenberg (1986 p.285) argue that "innovation is neither smooth nor linear, nor often well behaved." These critics consider the production of new technological knowledge an interactive process between multiple agents. Since this process is assumed to involve continuous feedback, the advocates of this view reject the linear model's conceptualization of innovation processes as a one-way sequence of steps. The creation of new knowledge is a socially embedded, interactive process. It is shaped by the interactions between innovative agents, that, in their turn are fundamentally influenced by physical space (that can facilitate or hamper their contacts) and by the places in which they are embedded being part of local industrial specialization processes, technological trajectories and institutional modes of innovation.

3. Physical 'distance' between innovative agents and knowledge flows.

Once the view of knowledge as a pure public good – at the basis of the linear model – is replaced by a more realistic appreciation of its actual scope, geography as physical distance immediately becomes a fundamental component for the understanding of innovation processes. Knowledge has only a few of a public good's characteristics: it is non-rivalrous and only to a limited extent excludable. In this regard, the literature on the role of geographical distance in innovation processes shares some common ground with the a-spatial linear model which assumes that knowledge production gives rise to external economies in the form of public knowledge. However, while in the linear model the location of innovative agents' location is irrelevant to their capability to benefit from these externalities, the geographical literature considers knowledge as a spatially bounded quasi-public good whose circulation is largely restricted within the functional borders of the area where it is generated.

When looking at the spatial diffusion of knowledge flows a crucial distinction is made between codified and tacit knowledge (Leamer and Storper, 2001). The former is assumed to be relatively cheap to transfer since it can be expressed in a set of codes or instructions and distributed via communication channels (such as the Internet) and accessed by anybody familiar with the respective symbol system (e.g. language). Conversely, tacit knowledge is more expensive to transfer over long distances because – due to its higher complexity and context-dependency – it is not codifiable (Leamer and Storper 2001). The relatively high cost of transferring tacit knowledge across space renders this type of knowledge geographically "sticky" , making face-to-face (F2F) contact an economically efficient means for its transmission. Encompassing verbal, physical, non-intentional and intentional as well as contextual elements, F2F contacts allow for the communication of complex, contextual messages and minimizes free rider problems by promoting the development of trust (Storper and Venables, 2004).

The importance of F2F contacts can be interpreted as a pivotal factor underlying the spatial clustering of innovative activities (Leamer and Storper, 2001): The complexity and context-dependency of knowledge flows associated with innovative activities make the latter dependent on F2F – "an intrinsically spatial communication technology" (Rodríguez-Pose and Crescenzi, 2008a p.379). The dependency on F2F contacts may thus induce innovative actors to locate close to each other, which in turn leads to the emergence of geographical clusters of highly innovative agents.

In line with this conceptualisation, geographical distance plays a major role in innovation processes: geographical proximity is deemed to facilitate the transmission of imperfectly appropriable but spatially sticky knowledge (Malecki 2010a). Empirically, a large body of research on localized knowledge spillover (LKS) examines the importance of geographical proximity for the dissemination of knowledge (for a review see Doering and Schellenbach, 2006; and Breschi, 2011): shifting from firm-based KPFs to regions as units of observation, this stream of literature finds empirical support for the relevance of geographically mediated knowledge spillovers and identifies evidence of geographically bounded spillovers measuring their spatial extent (Doering and Schellenbach, 2006). As second stream of empirical literature has used patent citations to track the spatial diffusion of patented inventions (Sonn and Storper, 2008), suggesting that patent citations display a high degree of spatial autocorrelation: inventors refer to previous patents originating in the same city more frequently than to a control group.

When it comes to the design of regional innovation policies, the consideration that geographical distance acts as a barrier for the diffusion of knowledge flows leads to the acknowledgment of geographical peripherality as a source of structural disadvantage (Rodríguez-Pose and Crescenzi, 2008a). The emphasis on the spatial boundedness of knowledge flows may also be interpreted as warranting interventions aimed at minimizing the geographical distance between innovative actors in the public and private sector. Incubators and science parks are two examples of policy measures reflecting the idea that public policies can actively maximize spillovers promoting regional innovative output by providing infrastructure that allows for a spatial concentration of regional innovative activities .

However, 'classic' studies on LKS are often based on indicators that capture the potential for spatially bound knowledge spillovers rather than actual flows/contacts between agents. The mechanisms underlying the transmission of knowledge spillovers remains underdeveloped, meaning that the concept of LKS is still largely a "black box" (Doering and Schellenbach, 2006): while some authors suggest that market transactions rather than externalities may explain local knowledge flows, others point out that members of epistemic communities may be connected by ties that transcend geographical proximity. The insufficient understanding of how knowledge is actually transferred between individuals located in the same geographical area impedes the formulation of a clear normative message to policy-makers.

In response to these criticisms recent empirical work has focused more closely on the role of individuals as knowledge carriers (Singh and Agrawal, 2011) and in particular on the mobility of knowledge-carrying workers and researchers (Miguelez and Moreno, 2010). In addition the literature has explicitly acknowledged that **i**nnovative agents cannot rely exclusively on local knowledge assets. Highly innovative actors benefit from a combination of "local buzz" (Storper and Venables 2004) – i.e. the innovation-enhancing local environment based on frequent F2F contacts of individuals who are co-located in a confined, typically urban place – and "global pipelines" i.e. communication channels formed by a differentiated set of 'global' actors (different streams of literature have looked at Multinational Firms, Diasporic Communities, Universities and 'star' scientists) that increasingly tap into pools of external knowledge bearing the associated communication cost/effort (Cantwell, 2009; Crescenzi et al. 2013a; Saxenian 2006; Malecki, 2010a and b).

Only the most recent developments in economic geography theory (reviewed in section 5) will overcome this dichotomous (local vs. global) conceptualisation of knowledge transmission mechanisms developing more sophisticated frameworks of understanding.

4. Innovative agents 'in context': local specialization patterns and institutions

Economic places – Industrial specialization

Geographical distance between innovative agents is an important predictor of knowledge exchange costs. The communication of economically valuable (potentially not codifiable\codified knowledge) across large distances is possible but at increasing costs. However, a number of other characteristics of the local environment generate incentives for knowledge exchange and shape the synergies for innovation generation. In this context, a vast amount of literature has dwelt on the role played by specialization patterns by contrasting the innovation performance of both highly specialised and diversified economic environments that often coexist in both developing and developed countries.

A high degree of specialization facilitates the exchange of specialized, industry-specific knowledge. Occurring between firms active in the same industry, these Marshall-Arrow-Romer (MAR) knowledge spillovers are deemed to spur innovation. MAR spillovers are a typical feature of ‘classic’ industrial districts. (Amin, 2003). Conversely, ‘Jacobian spillovers’ are associated with a diversified economic fabric, which is often found in big cities. Jacobs (1969) argues that the most valuable sources of knowledge that a firm may benefit from lie outside its own industry. This view suggests that a diverse industrial structure allows for cross-industry knowledge flows that induce recombinant innovation.

The empirical literature suggests that both Jacobian and MAR externalities play an important part in enhancing innovation. Possibly due to differences regarding methodology and level of aggregation, analyses come to mixed, often conflicting results (for extensive reviews see Beaudry and Schiffauerova, 2009 and De Groot et al., 2009). Although part of the literature suggests that only specialisation can be conducive to innovation, it must be stressed that MAR and Jacobian spillovers are not mutually exclusive (Beaudry and Schiffauerova, 2009). Indeed, large cities can be simultaneously specialised in one or more sectors and simultaneously display a diverse range of further industries.

Specialisation and diversification patterns have been harmonically combined into ‘economic places’ by two sub-streams of literature. The first stream has combined specialization patterns with a product life cycle perspective (Duranton and Puga 2001). Moving from a static to a dynamic view of the role of specialization patterns in the creation of new technological knowledge, innovation processes at different stages of the product life cycle rely on different types of knowledge spillovers. Firms develop new products in diversified urban contexts – termed “nursery cities” – benefiting from access to a greater variety of knowledge sources so that they can test new combinations until they identify the ideal production technology. Once production technology is standardized, firms re-locate to specialized places as the focus shifts from radical to incremental innovations, and the ability to exchange knowledge with other firms from the same industry becomes more beneficial than having access to knowledge from a wide range of sectors. In the nursery-city approach, both types of specialization patterns should coexist in a balanced system of cities, as they play different roles at different product life cycle stages (Duranton and Puga, 2001).

The second view that goes beyond the classic MAR versus Jacobian dichotomy proposes a more sophisticated understanding of sectoral diversity. The “related variety” approach (Frenken et al., 2007; Boschma et al., 2009a) concentrates on cognitive proximity between sectors. Drawing on the notion of absorptive capacity, in a related variety framework knowledge will necessarily 'spill over' between any pair of industries: the identification and absorption of new knowledge requires a pre-existing complementary knowledge. Related-variety industries share complementary competences (Boschma et al. 2009). Intermediate levels of cognitive proximity between related industries facilitate intersectoral knowledge flows conducive to innovation. Accordingly, neither specialization nor diversity per se enhances innovation: the former may lead to a too narrow knowledge base, whereas the latter might involve a lack of complementary knowledge across sectors (Iammarino 2011). Instead, the composition of sectors in a region should ideally display an intermediate level of cognitive proximity between the different industries. Hence, the perspective of related variety suggests that it is "diversity 'in what' that matters" (Iammarino, 2011 p.148).

Relational-institutional places

While the specialization literature unquestionably abandons the a-spatial perspective of the linear model, it heavily concentrates on economic processes, essentially disregarding the institutional-relational dimension of territorial innovation processes. The concept of related variety does, however, share common roots with (regional) systems of innovation (Lundvall, 1992) - the key components of institutional-relational places - and both streams are influenced by ideas from evolutionary economics and economic geography.

The Systems of Innovation (SI) perspective considers knowledge production as a non-linear, interactive, and socially embedded process (Freeman, 1987; Lundvall, 1992; Edquist, 1997). SI literature adopts a systemic perspective and considers the creation of new knowledge as the result of evolutionary processes in complex systems (Chaminade and Edquist, 2006). Its emphasis on multiple feedback between innovative agents sharply contrasts with the linear model's conceptualization of innovation as a one-way process. While in the linear model there are only three major types of innovative actors (corresponding to the categories of basic research, applied research, and product development), the SI approach allows for a great variety of participants in the innovative process. The organisations with which firms interact "to gain, develop and exchange various kinds of knowledge" (Edquist, 1997 p.1) include other enterprises but also government bodies, research institutes, universities, banks, etc. (Edquist, 1997). By embedding innovation in its social environment, this approach puts culture and institutions at the core of the analysis: habits, norms, and laws shape the relations between the innovative agents.

The literature has deployed the SI perspective in three major analytical perspectives: the sectoral, national and regional levels. The sectoral systems of innovation (Malerba 2006) highlight sector-specific patterns of knowledge production and suggest that the relative importance of different types of knowledge spillovers and learning varies across sectors. At the national level different institutional settings and governance structures shape the synergies between innovative agents and their evolutionary trajectory (Lundvall, 1992). Combining the SI literature with concepts from economic geography that emphasize the local roots of innovation and learning (Storper, 1997), economic geographers and regional economists have extended the SI perspective to the regional level (Edquist, 1997). The Regional Systems of Innovation (RSI) literature puts geography in the sense of institutional-relational places at the centre of the analysis of spatial disparities in innovative performance. Iammarino (2005 p. 499) defines an RSI as “the localized network of actors and institutions in the public and private sectors whose activities and interactions generate, import, modify and diffuse new technologies with and outside the region”. From an RSI perspective, regionally specific modes of learning, technological trajectories and knowledge bases constitute important reasons for regional disparities in innovative output (Asheim and Gertler, 2006).

The consideration of both ‘economic’ and ‘institutional-relational’ places has profound implications for innovation policies that depart from the ‘one-size-fits-all’ approach supported by the ‘linear model’. The design of any innovation policy should reflect region-specific modes of knowledge production and industrial specialisation patterns, making the in-depth understanding of the technological trajectory and existing knowledge base of each region the starting point for any innovation policy (Iammarino, 2005; Asheim et al., 2011a).

The RSI’s emphasis on interactive learning in “regionally embedded, institutionally supported, networks of actors” (Uyarra, 2010 p. 125), implies that by simply increasing innovation inputs policy makers are unlikely to maximise a place’s innovative potential. The shift from individual actors to a systemic view calls for policy-makers to address the institutionally shaped relations between the components of the system. The rationale for public intervention comes from some kind of systemic failure, which calls for corrective measures aimed at improving the local institutional set-up of a place. Cross-fertilizing the RSI perspective with the notion of related variety, Asheim et al. (2011a) urge policy-makers to enhance innovation via “platform policies” facilitating knowledge flows between related sectors.

In comparison with the clear-cut normative message of the linear model, just how policy-makers should translate the RSI approach into practice is less straightforward. The approach has been criticised because it provides little guidance on instruments and measures appropriate for tackling systemic failures. The approach’s interpretative flexibility or “fuzziness” (Markusen, 2003) renders its use more difficult for policy-makers. Equally, there are divergent views regarding the exact components and borders of an RSI (Asheim et al., 2011b; Uyarra, 2011). On the empirical side, a bias towards high-performing clusters has been also criticised (Asheim et al., 2011b; Uyarra, 2010). A further weakness of empirical RSI studies stems from the lack of indicators appropriate to truly measure the performance of a system in terms of the quality of knowledge flows and interactive processes, rather than in terms of absolute innovative output (Iammarino, 2005; Asheim et al., 2011b).

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5. Bringing different approaches together: non-spatial proximities and 'integrated' frameworks

As discussed in the previous sections, knowledge spillovers do not spread uniformly across space but exhibit strong distance-decay effects. While geographical proximity (*geography as physical distance)* facilitates the transmission of imperfectly appropriable but spatially sticky knowledge, the creation of new knowledge remains a socially embedded, interactive process. However, despite its potentially supportive role for the exchange of knowledge, geographical proximity constitutes “neither a necessary nor a sufficient condition” for learning processes (Boschma 2005 p.62). Learning processes and communication are shaped by industrial specialization, technological trajectory and institutional modes of innovation that are characteristic of specific *economic and/or relational places.* Consequently, the analysis of the geography of innovative processes calls for the joint analysis of the full set of physical, economic and institutional conditions that make innovation possible. Economic geography theory has responded to this challenge in two ways. On the one hand it has explicitly conceptualised the differential (and potentially independent) role of spatial and non-spatial conditions and, on the other, has fully explored the full set of their interactions.

In the first stream, Boschma (2005) has proposed a framework that introduces four non-spatial types of proximity, conceptually independent from physical distance: (i) cognitive proximity, referring to the degree to which agents share a common knowledge base; (ii) organizational proximity, defined as "the extent to which relations are shared in an organizational arrangement" (Boschma 2005, p.65); (iii) social proximity, measuring social embeddedness based on friendship, experience and kinship of relations between agents, and (iv) institutional proximity, which is based on agents sharing the same institutional rules and cultural habits. In this framework cognitive proximity is considered as the only form of proximity that is a permanent prerequisite for interactive learning and innovation: without overlapping knowledge bases, learning is impossible – even if there is high geographical proximity between the agents. In this context co-location and physical proximity may still play an important role on a temporary basis to establish contacts that are then maintained through the continuous presence of organizational, social, or institutional proximity. The positive effect of geographical proximity (geography as distance in our framework) might be more indirect and subtle than frequently assumed: it may help innovative actors to find the 'optimal' balance between different a-spatial forms of proximity shaping 'economic' and 'institutional' places conducive to innovation.

Acknowledging that proximity can be defined independently of physical-metric considerations prepares the stage for an integrated view of the forces influencing regional innovation processes. The introduction of alternative proximities makes it possible to adopt a new perspective on the role of *geography as distance*. Non-spatial proximities provide the justification for knowledge flows in networks as described by Breschi and Lissoni (2005). Regions may thus use alternative proximities to overcome geographical distance and tap into remote knowledge pools via global pipelines. Although this relativizes the significance of co-location, it is important to emphasize that Boschma's (2005) framework is nonetheless compatible with the concept of local buzz (Storper and Venables, 2004): we may conceive local buzz as "cognitive, organizational, social and institutional proximity brought together in a reduced geographical environment" (Rodriguez-Pose and Crescenzi, 2008b p.383). From this point of view, alternative proximities influence both inter-regional and intra-regional knowledge flows. With respect, instead, to *economic places*, the notion of cognitive proximity is particularly fruitful for analyses of opportunities of learning across industries. As stressed in the related variety perspective, cross-sectoral knowledge flows hinge upon the right level of cognitive proximity. As far as *institutional-relational places* are concerned, the idea that place-specific innovation systems display idiosyncratic modes of learning suggests that a lack of local institutional proximity may impede successful learning.

The second stream of literature focused more directly on the interaction between geography as economic places, institutional-relational places, and physical-metrical distance – while simultaneously acknowledging the importance of alternative, non-spatial proximities. Following an 'integrated approach', any analysis of a region's innovative performance has to take five keystones into account: (i) the link between local innovative efforts and knowledge generation as typically emphasized by a-spatial approaches, (ii) the geographical diffusion of knowledge spillovers and the region's industrial specialization (representing geography as distance and geography as an economic place), (iii) the presence of networks based on alternative, non-spatial proximities, and (iv) the genesis and structure of local and regional policies as well as (v) the existence and efficiency of regional innovation systems, with the last two keystones reflecting geography as institutional-relational places (Crescenzi and Rodriguez-Pose, 2011). The interaction of these five pillars shapes the creation of new knowledge in a region. In accordance with recent changes in economic geography theory, the importance of a-spatial networks and mobile capital with respect to global knowledge flows is underlined in this framework: the ability of local actors to establish external relations based on alternative proximities is assumed to determine the position of the region in global networks (for example where MNEs "pump" global knowledge into the local economy and "channel" the results of local innovative activities into global knowledge pipelines).

A number of subsequent empirical studies have built upon such an integrated perspectives, aiming to shed light on the relevance of two or more of their elements. These contributions can be grouped according to their treatment of space/place on the basis of the categories developed in this chapter: space as physical distance, economic places, institutional-relational places and above.

[INSERT TABLE 1 HERE]

Table 1 provides an overview of the factors taken into account by recent contributions that in different ways contrast, compare and/or interact with alternative conceptualisations of 'geography and space'. The columns of the table correspond to the four categories developed in this chapter: geographical distance (covered by studies that examine distance-based aspects such as LKS and agglomeration economies), 'economic places' (regional sectoral specialization patterns), 'institutional-relational places' (regional systems of innovation and other local socio-institutional conditions) and 'alternative non-spatial proximities'.

The first two rows of the table highlight the conceptual basis of the proposed classification in relation to the two conceptual papers reviewed above: Boschma (2005) for the conceptualisation of non-spatial proximities and Crescenzi and Rodriguez-Pose (2011) for the 'integrated framework' and the interaction between various geographical innovation dimensions. The second section of the table refers to 'representative' empirical works that explicitly test the differential role of the various geographical aspects. The key 'benchmark' and point of departure of all these papers is 'geographical distance' whose impact on innovative performance is compared and contrasted with other relevant dimensions\factors. Autant-Bernard and LeSage (2011) look at 'geographical distance' and 'economic places' (in a sectoral perspective) by examining the impact of Marshallian and Jacobian spillovers both within and between regions by means of a Knowledge Production Function approach. Their results shed light on the differential spatial extent of different typologies of knowledge flows suggesting that Jacobian externalities tend to decay more rapidly with geographical distance. In their comparison of the territorial dynamics of innovation in the U.S. and in Europe, Crescenzi et al. (2007) assess the influence of physical-metric, economic and institutional-relational dimensions of geography**.** They use a modified KPF framework to account for intraregional and interregional knowledge spillovers, sectoral specialization, and regional innovation systems conditions. Their study finds that the geographical processes governing knowledge production differ between Europe and the U.S. While institutional-relational factors (in the form of social filters) are fundamental in both continents, the role of spatial distance differs substantially. In the U.S. innovation is generated in relatively self-contained and more specialised geographical areas while European region's rely heavily on the capacity to assimilate inter-regional knowledge spillovers. The importance of a-spatial networks and proximities is also acknowledged, in particular as far as the US are concerned, although this perspective is not directly tested in the paper.

The influence of non-spatial proximities is directly examined by Maggioni et al. (2007) who compare the role of geographical distance against the influence of social proximity between research staff by looking at co-patenting data and EU-funded research collaborations by means of KPF and gravity models. They find that spatial proximity is of greater relevance to knowledge production than social proximity. Additional empirical work examining the relation between geographical distance and non-spatial proximities comes from the literature on university-industry collaboration. Again in a KPF framework, Ponds et al. (2010) examine the relative importance of geographical and social proximity (proxied by co-publication patterns), for the impact of academic research on regional innovation: social proximity makes it possible for knowledge spillovers to diffuse over large distances, suggesting that geographical proximity is of limited relevance for spillovers resulting from research collaboration. Opting for a different methodology, D'Este et al. (2011) employ a case-control approach for the examination of the role of geographical and organizational proximity in the formation of university-industry partnerships. They suggest that British companies in spatially dense clusters of technology-intensive industries establish connections with universities largely independently of the university's location, whereas firms outside dense clusters seem to place more weight on geographical proximity when establishing their links with universities.

The work by Breschi and Lenzi (2012) points in a similar direction. They look at the internal and external network structures of U.S. cities by linking the interactions of innovative agents at the micro-level with innovative output at the city-level. They include social network indicators in a KPF in order to compare the innovation impact of the internal city-level co-invention network with the embeddedness of local inventors in global co-invention networks after controlling for the role of specialization patterns. The empirical results suggest that external linkages are only likely to improve regional innovative performance if they are combined with an appropriate intra-regional network structure that facilitates knowledge diffusion.

In a comprehensive attempt to disentangle the role of different forms of proximity, Marrocu et al. (2011) use an augmented KPF to investigate the relevance of the five a-spatial proximities proposed by Boschma (2005) and interregional spillovers. Co-inventorship serves as a proxy for social proximity, while a similarity index based on the sectoral distribution of patenting activity in each pair of regions defines cognitive proximity. Organizational proximity is measured by the affiliation of applicant and inventors to the same organization, whereas country dummies are used to account for institutional proximity. The authors thus succeed in linking a-spatial networks based on alternative proximities at the individual level with innovative performance at the regional level. Their results suggest that cognitive proximity is always relevant, while geographical proximity is not the most important type of proximity for innovation processes, while the role of social and organisational proximity appears to be marginal.

Crescenzi et al. (2013b) pursue the same objective as Marrocu et al. (2011) in trying to disentangle the relative importance of various proximities but with a focus on the determinants and incidence of collaborative knowledge creation – both areas under-explored in the field to date (Boschma and Frenken, 2009b). The analysis is based on inventor pairs and relies on a novel case-control-type identification strategy, looking at both single and multiple inventors, across all technology fields and controlling for a range of individual, institutional, and macro factors to identify causal effects. Overall, the results highlight important differences between the proximities that help inventors collaborate for the first time, the factors shaping repeat interactions, and the behaviour of serial inventors. Physical proximity is critical to break the ice; once a relationship has been established, however, other forms of proximity become more important. Conversely for serial inventors (the most innovative individuals), geography disappears almost completely as an influence.

This highly dynamic but still embryonic stream of literature, which explicitly aims at disentangling the innovative impact of various spatial and non-spatial factors, has not yet reached a consensus on the relative importance of different forms of proximity. The heterogeneity of the results is likely to stem from both methodological and operational differences. The estimation of Knowledge Production Functions 'augmented' in order to account for the impact of various proximities, although now customary in this literature, remains problematic due to the strong collinearity among the various proximities (and whose impact the foregoing functions set out to isolate and compare) and the potential simultaneity between innovative performance and the evolution of non-spatial proximity relations. In addition the use of patent data to measure both 'proximities' and performance might generate additional measurement problems. Thus, in order to further advance our understanding of the transmission mechanisms underlying the geography of innovation the KPF approach should be supplemented by other techniques able to directly model the formation of links and networks and their spatiality before assessing their impact on 'aggregate' performance.

6. Conclusions

The conceptualisation of geography in innovation literature has changed substantially since the heydays of the linear model. Persistent disparities in innovative performance across space have motivated researchers to develop progressively a more sophisticated analysis of the role of space and places in innovation processes. From the physical-metrical approach of *geography as distance,* to the emphasis on specialisation and diversification patterns (*geography as economic place) and institutional-relational factors,* economic geography theory has substantially evolved in terms of its contribution to the understanding of technological dynamics.

While the abandonment of the linear model has always been at the very centre of the geographical analysis of innovation processes, the most recent developments in the discipline have questioned the excessive emphasis on spatially localised processes that has long dominated the geographical approach. Geographical proximity has progressively lost its role as the single most important type of proximity to influence innovation processes. Cognitive proximity has emerged as a permanent requirement for interactive learning while social, organizational, and institutional proximity may act as temporary substitutes for geographical proximity. Geographical proximity remains to strengthen non-spatial proximities and help innovative actors to find the right balance of non-spatial forms of proximity. The analysis of the systematic interactions among these different dimensions calls for progressively more 'integrated frameworks' in order to understand territorial innovation dynamics.

These shifts in economic geography theory have important implications for innovation policies. The conceptualisation of innovation as an interactive process occurring within complex innovation systems requires that policy-makers tackle linkages between actors, rather merely making investments in basic research. Innovation policy starts from a profound understanding of a region's idiosyncratic institutional set-up, technological trajectory, and knowledge base. However, the identification of the potential barriers to innovative performance cannot be limited to the local dimension: understanding the region as a "localised interface where global and local flows of knowledge intersect" (Kroll, 2009 p.1) implies that cooperation and networking should also be encouraged with remote partners in other regions and countries (Miguelez and Moreno, 2010). At the same time, results indicating that academic spillovers can be mediated over longer distances via non-spatial proximities suggest that policy measures aimed at stimulating knowledge flows should not merely concentrate on the local level but rather adopt a national or even international perspective (Ponds et al., 2010). In addition, the acknowledgement of the crucial role of people as carriers of knowledge also implies that the generation and attraction of highly-skilled individuals should be part of regional innovation policy (Trippl and Maier, 2011; Marrocu et al., 2011).

Influential reports by the World Bank (World Bank 2009), the European Commission (Barca 2009), the OECD (2009a, 2009b) and the Corporación Andina de Fomento (2010) in different ways reflect recent theoretical changes in economic geography. While the World Development Report 2009 has the important merit of fully incorporating geography as distance and economic places into the formulation of development policies, the policy conclusions formulated by the OECD, the Barca Report and the Corporación Andina de Fomento fully endorse an integrated territorial approach to innovation which takes full account of the role played by institutional-relational factors and non-spatial proximities.

The development of the economic geography theory of innovation has contributed towards a progressive shift in the policy paradigm from a purely 'science and technology' approach to the emphasis on agglomeration and spatial proximity that has characterized innovation policies targeting cluster development and firm incubators. However, the most recent evolution in the territorial theory of innovation opens the way to more balanced integrated policies that systematically account for the multifaceted influence of geography on innovation processes.

If the effectiveness of innovation policies can substantially benefit from the evolution of economic geography theory, a number of relevant aspects remain to be further explored both conceptually and empirically. From the conceptual point of view, further research is needed on the linkages between the micro-level of the individual innovative actors, the meso-level of their territorial interactions and the diffusion channels of 'macro' global flows of skills and knowledge. A sound theory for this complex set of processes is a necessary condition to open the 'black box' of knowledge generation and diffusion. If the (increasing) importance of non spatial proximities is now fully acknowledged further work is needed on the reasons and the mechanisms that govern the development and the evolution of such proximities. In the same way as location theory aims to explain the co-location decisions on economic agents in physical space, it is necessary to explore the fundamental mechanisms that drive the development of non-spatial proximities between innovative agents in the cognitive space.

Conversely, the empirical analyses of the geography of innovation need to substantially broaden their scope both in terms of methodologies and use of available data in order to cope with increasing theoretical sophistication and new policy challenges (in both developed and emerging countries). If regional 'aggregate' Knowledge Production Functions have greatly contributed to the development of this field of research it is crucial to reinforce micro-level analyses that can clearly target relevant actors and their behaviour. Substantial progress is needed for a more detailed identification of the role of spatial and non-spatial networks in this context. In addition, the reliance on patent data has also led to the under-examination of non-patented forms of innovation including process and organizational innovation. The integrated use of different data sources (including firm-level innovation surveys such as the Community Innovation Survey) is certainly an important development in this direction but the emergence of new and more sophisticated research questions calls for the collection of more sophisticated micro-data on the innovation and relational behaviour of firms, individuals and institutions.

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Table 1 – Classification of recent developments in Economic Geography Theory and their contribution to the understanding of territorial innovation dynamics

<table>
<tr><th></th><th>geographical distance</th><th>economic places</th><th>institutional-relational places</th><th colspan="4">alternative non-spatial proximities</th></tr>
<tr><th>Authors (Year)</th><th>Localised Knowledge Flows</th><th>Specialization</th><th>Regional Systems of Innovation</th><th>Institutional</th><th>Cognitive</th><th>Organizational</th><th>Social</th></tr>
<tr><td colspan="8">Conceptualization</td></tr>
<tr><td>Boschma (2005)</td><td>X</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Crescenzi and Rodriguez-Pose (2011)</td><td>X</td><td>X</td><td>X</td><td colspan="4">X</td></tr>
<tr><td colspan="8">Empirical testing</td></tr>
<tr><td>Autant-Bernard and LeSage (2011)</td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Crescenzi et al. (2007)</td><td>X</td><td>X</td><td>X</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Maggioni et al. (2007)</td><td>X</td><td></td><td></td><td></td><td>X</td><td></td><td>X</td></tr>
<tr><td>Ponds et al. (2010)</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>D'Este et al. (2011)</td><td>X</td><td></td><td></td><td></td><td></td><td>X</td><td></td></tr>
<tr><td>Breschi and Lenzi (2012)</td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>Marrocu et al. (2011)</td><td>X</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Crescenzi et al. (2013b)</td><td>X</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
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