Research Policy 47 (2018) 782–795

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

The innovative performance of firms in heterogeneous environments: The interplay between external knowledge and internal absorptive capacities

Riccardo Crescenzi[a,b,*], Luisa Gagliardi[c,b]

[a] Dep. of Geography and Environment, London School of Economics, Houghton Street, WC2A 2AE, UK
[b] Spatial Economics Research Centre (CEP-SERC), London School of Economics, UK
[c] Department of History, Economics and Society, School of Social Sciences (SDS), University of Geneva, Bd du Pont-d'Arve 40, 1211, Switzerland

ARTICLE INFO

Keywords:
Innovation
Geography of innovation
Absorptive capacities
Exploration and exploitation

ABSTRACT

This paper investigates the link between firm-level innovative performance and innovation prone external environments where knowledgeable individuals tend to cluster. Organizational ambidexterity and absorptive capacities (potential and realized) make it possible for firms to leverage the availability of external knowledge and boost their innovation performance. The empirical analysis focuses on England and is based on a novel combination of Community Innovation Survey (CIS) firm-level data and patent data. The results show that only firms complementing potential and realized absorptive capacities are able to take advantage of favorable external environments by actively combining internal and external sources of knowledge.

1. Introduction

The geographical mobility of skilled individuals as a channel of knowledge accumulation and diffusion has received remarkable attention in the existing literature (e.g. Feldman, 1994; Audretsch and Feldman, 2004; Carlino et al., 2007; Oettl and Agrawal, 2008; Breschi and Lissoni, 2009; Trippl and Maier, 2010; Gagliardi, 2015). Areas experiencing inflows of highly qualified individuals benefit from the development of an enabling environment for innovation and growth (Carlino et al., 2007; Glaeser et al., 2010; Kerr, 2010). Firms located in these innovation prone environments may take advantage of knowledge flows localized within the recipient spatial units (e.g. Marshall, 1920).

However, local firms have often been treated as passive recipients of local knowledge inflows rather than as active nodes that may (or may not) search for external knowledge by leveraging connections with their external environment (e.g. Feldman, 2003; Barnard and Cantwell, 2006). To overcome this limitation and investigate the conditions that allow firms to take advantage of favorable external environments and knowledge sources, this paper brings firms (and their strategies) back at the very center of the conceptualization of the link between mobility and innovation.

In order to shed new light on the response of firm-level innovative performance to the concentration of knowledgeable individuals in their external environment, we cross-fertilize the geography of innovation literature with insights from strategic management. In so doing, we aim at contributing to both strands of research that have been rarely combined to address similar questions. On the one hand, strategic management has devoted a significant attention to inter-organizational mobility of personnel as a way to achieve better innovative outcomes (e.g. Rao and Drazin, 2002;, Song et al., 2003; Rosenkopf and Almeida, 2003; Corredoira and Rosenkopf, 2010; Palomeras and Melero, 2010; Singh and Agrawal, 2011; Mawdsley and Somaya, 2016), while overlooking the complementary role of geographic mobility. On the other hand, the geography of innovation literature has traditionally focused on how contextual conditions shape firms' innovative performance (e.g. Dahl and Pedersen, 2004; Audretsch and Feldman, 2004; Boschma et al., 2008; Beugelsdijk, 2007; Crescenzi et al., 2013), but has often adopted an aggregate approach overlooking the role of firm-level heterogeneity in its interaction with the external environment.

The conceptual framework relies on the notion of organizational ambidexterity as the ability of firms to simultaneously explore and exploit (e.g. Tushman and O'Reilly, 2007; Gibson and Birkinshaw, 2004; Rothaermel and Alexandre, 2009), and applies this concept to firms' knowledge acquisition behavior. The knowledge acquisition behavior of firms is the result of the exploration and exploitation of internal and external sources; firms benefit from the combination of both. In this context absorptive capacities are the key enabling factor for the emergence of ambidexterity benefits. In particular, we rely on the distinction between potential and realized absorptive capacities (e.g. Zahra and George, 2002). The former being the actual capability of the firm to understand and process knowledge (Cohen and Levinthal, 1990) while the latter reflects differences in knowledge management

* Corresponding author at: Dep. of Geography and Environment, London School of Economics, Houghton Street, WC2A 2AE, UK.
E-mail address: r.crescenzi@lse.ac.uk (R. Crescenzi).

https://doi.org/10.1016/j.respol.2018.02.006
Received 27 June 2017; Received in revised form 8 February 2018; Accepted 9 February 2018
Available online 07 March 2018

strategies in terms of ability to "leverage the knowledge that is absorbed" (Zahra and George, 2002, p.190), and exploit it within the internal process of knowledge generation. Firms complementing potential and realized absorptive capacities are in the best position to take advantage of favorable external environments through the combination of internal and external knowledge.

This central hypothesis derived from our conceptual framework is empirically tested by means of a novel database that combines data on English firms from the United Kingdom (Community) Innovation Survey (UKIS)[1] with information on the mobility of inventors from patents records provided by the European Patents Office (EPO). We focus on firms that are sampled in two consecutive waves of the CIS – CIS4 and CIS5–thus exploiting the panel dimension of the data. In addition, we make use of information on the location behavior of multi-patenting inventors to identify those locations in England that were exposed to inflows of highly knowledgeable individuals (e.g. Song et al., 2003; Agrawal et al., 2006). While inventors' mobility offers an imprecise measure of the magnitude of the actual inflows (e.g. Ge et al., 2016), it allows a clear identification of locations that act as centers of attraction for talent. In areas that manage to develop themselves into knowledge hubs, productivity gains emerge from the clustering of talented people (Florida, 2002). Where the two datasets are merged on the basis of geographical locations we can compare the innovative performance of firms located in areas that experienced inflows of inventors in the previous period against areas which did not, testing whether – after controlling for firm-specific observable and unobservable characteristics – different contextual conditions affect innovative outcomes. In order to investigate how firms leverage realized absorptive capacities in their learning and knowledge acquisition behaviors, we distinguish between firms that make use of external resources to develop their innovations and firms that rely mainly on internal assets. We test the robustness of our results against endogeneity concerns due to reverse causality – via instrumental variable techniques – and alternative explanations for variations in firms' innovative outcomes as a consequence of their external environment.

The empirical results suggest that firms' innovative performance strongly depends on their internal assets and potential absorptive capacities. Instead, no effect is associated with their location in areas that were exposed to knowledgeable inflows in the previous period when we control for time invariant firm-specific characteristics. This result diverges from the traditional findings in the economic geography literature where the mobility of talents is associated with a boost in innovative performance via agglomeration externalities (e.g. Faggian and McCann, 2006 and Gagliardi, 2015 for the UK; Peri, 2007 and Hunt and Gauthier-Loiselle, 2010 for the US; Miguélez and Moreno, 2013 for Europe). It also supports the existence of an overestimation bias potentially affecting exiting studies that do not fully control for firm-level observable and unobservable characteristics when investigating the role of innovation prone environments. Coherently with this latter claim, we find that the innovation benefit from the location in a contextually enabling environment is highly heterogeneous and depends on the level and scope of firms' realized absorptive capacities. Only firms that successfully complement internal and external knowledge sources can take full advantage of the positive spatial externalities generated by innovation prone environments. This result links back to early innovation studies focusing on the pay-off of complementarity strategies that combine internal and external sources of knowledge (e.g. Arora and Gambardella, 1990; Cassiman and Veugelers, 2006; Love and Roper, 2009), and to more recent contributions addressing the topic in a dynamic context, by looking at the variation in innovation outcomes at the firm level as the result of the switch towards complementary strategies (e.g. Love et al., 2014). It also emphasizes – with reference to the link between mobility and innovation – that firms' outcomes can neither be fully explained by firms' internal inputs nor by their external environment in isolation, but they are rather the result of the interaction between the latter and firms' heterogeneous internal assets, technological capabilities and knowledge management strategies (e.g. Maré et al., 2014; Gagliardi, 2015).

The following section details the conceptual framework of our study. Section three describes the data used for the empirical investigation with a focus on key variables, while section four discusses the estimation and identification approach. Section five presents the main results and robustness checks and section six concludes.

2. Conceptual framework and hypothesis

The conceptual framework of this analysis aims to cross-fertilize the strategic management view on firms' knowledge acquisition behavior, and the economic geography literature, which has looked at the location behavior of individuals and firms in space in the formation of agglomeration economies.

In the Marshallian theory of agglomeration economies firms cluster in specific locations to take advantage of (i) inter-firm linkages, (ii) labor pooling effects and (iii) localized knowledge spillovers. In this context, geographical mobility (and in particular the mobility of highly skilled individuals) contributes to the creation of an enabling environment for innovation (Feldman 1994; Audretsch and Feldman, 2004; Carlino et al., 2007; Glaeser et al., 2010; Kerr, 2010). This 'enabling' environment supports the localized diffusion of knowledge and has often been evoked by both urban economists (Glaeser et al., 2010; Kerr, 2010) as well as by the more institutional approaches in the regional systems of innovation (RSI) tradition (e.g. Lundvall, 1992; Nelson, 1993; Edquist, 1997). In the former case, firms' advantages are associated to the location in places where 'knowledge is in the air' (Marshall, 1920). In the latter, benefits arise from "regionally embedded, institutionally supported, networks of actors" (Uyarra, 2011, p. 125). In these contexts, firms benefit from supportive local innovation ecosystems (Roper et al., 2017), which in turn links back to the notion of innovation prone regions as regional systems that are "capable of transforming a larger share of their own R&D into innovation and economic activity" (Rodríguez-Pose, 1999, p.82). Existing empirical studies employing this rationale have almost exclusively adopted a spatial approach (Borjas, 1999, 2006; Dustmann et al., 2005; Rodríguez-Pose and Crescenzi, 2008; Glitz, 2012) that looks at the spatial correlation between innovative outcomes and environmental attributes within self-contained, functional geographical units of analysis. They generally converge in suggesting a positive state/regional/city-level effect of geographic mobility on innovation: agglomeration dynamics taking place within recipient spatial units result in an innovation-enhancing effect.

Yet, within this framework, firms are often treated as passive recipients of knowledge with limited attention to differences in their capacity to take advantage of localized sources of knowledge. In a resource-based perspective firms are heterogeneous with respect to their resources, capabilities and organizational capacities to develop new competencies (Teece et al., 1997). This heterogeneity plays a key role in terms of (i) internal resources and capabilities that mediate the acquisition of individually embodied human and relational capital (e.g. Adler and Kwon, 2002; Hatch and Dyer, 2004; Groysberg and Lee, 2009; Mayer et al., 2012), and (ii) firms' strategic behavior in the way in which they achieve the optimal matching between alternative sets of resources for the development of their knowledge outcomes (Grigoriou and Rothaermel, 2014). In this perspective, the conditions under which firms are able to take advantage of being located in knowledge hubs are of two types. First, both financial and human resources are needed for firms to develop potential absorptive capacities and appropriate and internally recombine external knowledge from other co-located actors (e.g. Shaver and Flyer, 2000). Second, they need to actively engage

[1] UKIS data are provided under restricted access to approved researchers only by the UK Data Service (https://discover.ukdataservice.ac.uk/catalogue?sn=6699).

with virtuous local dynamics of knowledge circulation by searching for their knowledge inputs and leveraging connections with their local environment (e.g. Feldman, 2003; Barnard and Cantwell, 2006). Hence, firms' realized absorptive capacities are the result of deliberate strategies in terms of knowledge seeking behavior that reflect the ways in which different organizations balance their 'internal' (i.e. intra-firm linkages) and 'external' (geographically bounded linkages) agglomerations (Alcacer and Delgado, 2016).

2.1. Organizational ambidexterity and the moderating role of firms' absorptive capacities

The notion of organizational ambidexterity is particularly relevant to study how firms interact with their external environment. We postulate that firms benefit from the capacity to simultaneously explore and exploit different sources of knowledge (Raisch and Birkinshaw, 2008), thus achieving ambidexterity advantages associated to the development of an optimal knowledge mix. In other words, the performance of firms is intimately connected to their knowledge sourcing strategies through the combination of internal and external sources, and an excessive focus on either internal or external assets is likely to lead to obsolescence and lock in (e.g. Teece et al., 1997; Cassiman and Veugelers, 2006). Based on this premise we formulate the first conceptual proposition of this study, that is: *Ambidexterity advantages stem from the simultaneous exploration and exploitation of both internal and external sources of knowledge*.

Then, we assume firms' absorptive capacities to be a crucial condition to manage the internal-external trade off and to fully attain the ambidexterity benefits associated to exploration and exploitation. We define absorptive capacities as the set of organizational assets and processes through which firms acquire, assimilate and transform knowledge. They make it possible for firms to identify, understand and acquire knowledge originating from beyond their organizational boundaries, as well as to assimilate and integrate it with the existing internal knowledge stock (e.g. Arora and Gambardella, 1994). This observation leads to the second proposition of our conceptual framework, that is: *Absorptive capacities are crucial to leverage ambidexterity advantages*.

Finally, we add further structure to our framework of understanding by introducing a more nuanced notion of absorptive capacities as belonging to two types: potential and realized. Potential absorptive capacities are those needed to acquire and assimilate external knowledge (e.g. Lane and Lubatkin, 1998). They capture the traditional concept popularized by Cohen and Levinthal (1990) and refer to the actual capability of firms to understand and process knowledge. We assume that firms differ in their degree of potential absorptive capacities to the extent to which they possess adequate financial and human resources to build internal knowledge assets. Consequently, 'capable' firms, which are characterized by higher internal competences, are in principle more able to take advantage of favorable external conditions. Nonetheless, these potential absorptive capacities are a necessary but not sufficient condition to exploit the benefits of innovation prone local environments. Our expectation is that they are positively associated to firms' outcomes but they do not necessarily imply the actual exploitation of external knowledge to achieve better innovative performance. Conversely, realized absorptive capacities reflect the capability of firms to "leverage the knowledge that is absorbed" (Zahra and George, 2002, p.190). In other words, they signal the extent to which firms are capable (and willing) to recombine external knowledge with internal capabilities and to exploit it for the development of innovations. Hence, we make the following proposition as an additional building block to our conceptual framework: *Only firms complementing potential and realized absorptive capacities improve their innovative performance in response to innovation prone environments*.

Taken together the three conceptual propositions presented above lead to the definition of the main hypothesis tested in our empirical analysis. Overall, the extent to which firms benefit from externalities associated to the location behavior of knowledgeable individuals depends on their mix of potential and realized absorptive capacities. After controlling for the former, firms' behavior in terms of acquisition and exploitation of external sources shapes the value of their interactions with the external environment. Strategic considerations over the intensity and reliance on external assets, in turn, reflect distinctive firms' technological paradigms. Previous research has found support for this view in different contexts. For instance, Agrawal et al. (2010) suggest that large vertically integrated firms might be less prone to access locally available knowledge assets: dominant firms in 'company towns' tend to be more inward looking than other firms, while smaller firms in the same areas do not show the same myopic behavior. Crescenzi et al. (2015) find that firms' heterogeneity shapes the extent to which domestic firms are able to benefit from knowledge flows from foreign firms active in their same sector, and that differences in their external knowledge acquisition behavior contribute to determine the intensity of these flows. Existing empirical studies have so far failed to fully incorporate these insights into the analysis of knowledge flows generated by the location behavior of knowledgeable individuals. Therefore, the following testable hypothesis is formulated:

H1. Innovation prone local environments – i.e. areas experiencing inflows of knowledgeable individuals – boost the innovative performance of firms that are capable to combine external and internal knowledge sources

3. Data sources and their combination

3.1. Firm-level data

The empirical analysis is based on data on English firms from the United Kingdom (Community) Innovation Survey (UKIS).[2] The UKIS is a firm-level survey accessible to approved researchers accredited by the UK Office for National Statistics (ONS) and provides information on firms' innovative activities and performance with respect to different types of innovation outcomes (product, process and organizational innovation). The survey also offers detailed information on the internal inputs devoted to the innovative process (financial investments and skilled employees): in light of the conceptual framework developed in this paper these are essential indicators for potential absorptive capacities. The dataset also includes information on a wide range of other firm-level characteristics (such as size, sector of activity, market of reference, etc.).

The survey is constructed in order to build a balanced sample among all sectors of activity. It is characterized by a significant share of small and medium sized enterprises,[3] thus capturing a typology of innovation that is substantially underestimated by alternative sources (e.g. patents statistics commonly used in existing studies to indicate innovative performance; see e.g. Ahuja and Katila, 2001; Hagedoorn and Cloodt, 2003; Gagliardi et al., 2016).

Two consecutive waves of the UKIS have been merged to build our panel database: CIS4 (covering the 2002–2004 period) and CIS5 (covering the 2004–2006 period).[4] Previous research using CIS data has –

[2] Department for Business, Innovation and Skills and Office for National Statistics, UK Innovation Survey, 2001–2009: Secure Data Service Access [computer file]. Colchester, Essex: UK Data Archive [distributor], June 2011. SN: 6699.

[3] Almost 70% of our total sample of firms is classified as small or medium-sized enterprise.

[4] The CIS4-CIS5 merged sample makes it possible to exploit the within firm variation while keeping a reasonable number of observations. The UKIS is constructed on the basis of repeated cross-sections with a small panel dimension. Therefore the extension of the analysis to more recent waves would incur a large cost in terms of decreased observations. In addition, the robustness of the CIS4-CIS5 panel, covering the period 2002–2006, has been subject to detailed investigation from the UK Office of National Statistics (ONS), which published the following report on the dynamic changes between the two waves:

with few exceptions (e.g. Frenz and Ietto-Gillies, 2009; Gagliardi, 2015; Gagliardi and Iammarino, 2017) – almost exclusively focused on a single wave, limiting the possibility to fully control for firms' time invariant unobservable characteristics and for changes in observable features over time. Given the importance of firm-level heterogeneity for our analysis, the possibility to control for firm-level fixed effects is of paramount importance for the robustness of our results. In order to recover detailed information on the geographical location of each firm, the final CIS4–CIS5 merged sample has been merged with the Business Structural Database (BSD 2004).[5] The BSD is the census of UK enterprises that covers almost 99% of UK economic activities. This makes it possible to retrieve the 7-digit postcode location of each firm and, as a result, to attribute them to the corresponding local labor market area (also known as Travel-to-Work-Area[6] or TTWA).

The recovery of detailed geographic information at the postcode level, and the possibility to correctly locate firms within each TTWA, is of utmost importance for our analysis. TTWAs are functional local labor markets constructed in order to be self-contained areas in terms of workers' daily commuting patterns. As such, at least 75% of the individuals working in a TTWA also live in the same area. This makes it possible to look at the effect of spatially bound knowledge flows associated to the location behavior of knowledgeable individuals, while factoring out the 'noise' related to commuting patterns. In other words, by incorporating both the workplace and the residential address[7] of each individual, TTWAs are the geographical contexts in which all market mediated (via the labor market) and non-market mediated (via pure externality mechanisms) face-to-face interactions between co-located economic actors take place. Data from the UKIS are employed to construct the dependent variable (i.e. a dummy variable taking the value 1 if the firm is performing any product or process innovation, or 0 otherwise) and all other firm-level controls. Data on skilled employees and investments in R&D are used as proxies for firms' potential absorptive capacities (Kogut and Zander, 1996; Harris and Moffat, 2013). More specifically, R&D investments are measured by means of a dummy that takes the value 1 if the firm performed in a given time interval any intramural R&D investment, or 0 otherwise. Skilled employees are proxied by the share of personnel holding a degree in Science and Engineering or other subjects (see Table 1). This latter control, besides providing important information on firms' internal assets, makes it also possible to identify the effect of being located in innovation prone areas while controlling for the knowledge that is acquired by firms through learning-by-hiring. The control on firms' export orientation, instead, is constructed by exploiting information of the main market of reference (local and national vs. European and international) in order to control for the correlation between innovation and export via learning by exporting dynamics (e.g. Salomon and Shaver, 2005; Salomon and Jin, 2008, 2010).

We also exploit information on firms' knowledge seeking strategies focusing in particular on those firms that make use of external sources of knowledge, in addition to internal ones, for the generation of innovation. In this regard, we look at the relevance of different sources of information for innovation processes (our proxy for realized absorptive capacities). In fact, firms are asked in the UKIS questionnaire to rate on a scale of 0 (not important) to 3 (utmost importance) the following sources of knowledge: 'internal sources of information', 'market sources of information' − which include suppliers, clients and customers, competitors, consultants and commercial labs − and 'institutional sources of information' (including universities and Governments and public R&D institutes). We identify firms that 'external sources of information' (both market and institutional) as a 2 or 3 and construct a dummy variable that assigns them the value 1, while taking the value 0 if the rating is equal to 0 or 1. We take this as an indicator for the capacity (and willingness) of each firm to engage in valuable collaboration networks with external actors. This, in turn, signals a more outward oriented innovation strategy that reflects firms' capacity to leverage and exploit external sources, which also proxies their level of realized absorptive capacities.[8]

3.2. Identification of innovation prone areas based on knowledgeable inflows

In order to test our hypothesis on the link between firms' innovation outcomes and their external environment we need to identify areas (TTWAs as discussed above) that are prone to innovation-enhancing interactions. For this purpose, we leverage information on the spatial mobility of inventors[9] in order to capture TTWAs that experienced recent inflows of highly knowledgeable individuals. In line with previous contributions that trace mobility patterns at a very detailed geographical level, we focus on the spatial behavior of multi-patent inventors (e.g. Zucker et al., 1998a; Zucker et al., 1998b; Almeida and Kogut, 1999; Song et al., 2003; Hoisl, 2007; Breschi and Lissoni, 2009; Miguélez and Moreno, 2013; Crescenzi et al., 2016, 2017).

We construct a dummy variable taking the value 1 if a local labor market experienced inflows of inventors, and 0 otherwise. Our key regressor is thus aimed at selecting those spatial segments of the labor market that can be qualified as innovation prone environments in terms of attraction of talents rather than providing a measure of the magnitude of actual inflows. In so doing, we build on the consolidated rationale of the theory of agglomeration economies that focuses on geographic mobility mainly as a channel of diversity and complementarity in knowledge (e.g. Carlino, 2001). We also embrace the recent critics on the limitations associated with flow measures based on patent records (e.g. Ge et al., 2016),[10] while exploiting them exclusively as an indication for the direction of the flows.

English patents from the European Patent Office (EPO) – our main data source – include detailed geographical information (at the postcode level) on inventors, making it possible to identify their exact spatial location, and the time frame of their mobility event by looking at the priority date of the invention associated to any change in the inventor's address. As an example, if inventor Alpha patented invention #1 at time t in Cambridge and invention #2 at time t + T in London we can conclude that (s)he moved from Cambridge to London in the time window (t, t + T). In order to develop the most accurately possible

(*footnote continued*)
http://www.bis.gov.uk/assets/biscore/corporate/migratedd/publications/p/persistence_and_change_in_uk_innovation.pdf.

[5] The Business Structure Database (BSD), derived from the Inter-Governmental Department Business Register (IDBR), covers 99% of economic activity in the UK and provides geo-referenced firm-based data with 7 digit postcodes. Department for Business, Innovation and Skills and Office for National Statistics, Business Structure Database, 1997–2013: Secure Data Service Access [computer file]. Colchester, Essex: UK Data Archive [distributor], June 2011. SN: 6697.

[6] There are 228 travel to work areas (TTWAs) in the UK (as calculated using Census 2011 data): 149 TTWAs in England, 45 in Scotland, 18 in Wales, 10 in Northern Ireland and 6 cross-border TTWAs.

[7] As customary in the inventors' mobility literature we have relied on the residential address of the inventors. Conversely, the address of the applicant (the company or entity associated with the patent) does not necessarily correspond to the location where the inventive activity actually takes place. The address of the applicant often corresponds to the legal address of the company and/or to its headquarter. The best possible association between the inventors and their actual workplace is achieved by relying on Travel-To-Work areas (TTWAs) as our spatial unit of analysis.

[8] A similar proxy to signal the reliance on external sources of information and the complementary use of exploration and exploitation strategies at the firm level has been employed in existing contribution using CIS data including Criscuolo (2005), Van Leeuwen and Klomp (2006), Crespi et al. (2007) and Gagliardi and Iammarino (2017).

[9] It is worth noting that we do not exploit patent data to measure both our dependent and independent variable. This limits concerns over the existence of a mechanical correlation between innovative performance and the mobility measure, which is likely to upward bias the estimates of previous studies.

[10] By looking at patents as a means to track mobility, Ge et al. (2016) find that patent-based measures generate 12% false positives and 83% false negatives with respect to a measure of mobility created by using LinkedIn profiles.

Table 1
Variables List.
Source: UK-CIS; EPO-KITES.

Variable	Description	Source	Obs.	*TOTAL*		*2002–2004*		*2004–2006*	
				Mean	Std.	Mean	Std.	Mean	Std.
Product or Process Innovation	Dummy variable taking value 1 if the firm developed any product or process innovation	CIS	5872	0.35	0.48	0.38	0.49	0.32	0.47
Product Innovation	Dummy variable taking value 1 if the firm developed any product innovation	CIS	5872	0.29	0.45	0.31	0.46	0.28	0.45
Process Innovation	Dummy variable taking value 1 if the firm developed any process innovation	CIS	5872	0.20	0.40	0.22	0.42	0.17	0.37
R&D	Dummy variable taking value 1 if the firm is performing any intramural investment in R&D	CIS	5872	0.33	0.47	0.32	0.47	0.33	0.47
Employment with degree	Share of employees holding a degree in Science and Engineering or other subjects	CIS	5872	0.10	0.19	0.09	0.18	0.11	0.20
Export Orientation	Dummy variables taking value 1 if the firm has the European or international arena as main market of reference (local and national market as baseline)	CIS	5872	0.37	0.48	0.36	0.48	0.37	0.48
External sources of information	Dummy variable taking value 1 if the firm declares to exploit external sources of information	CIS	5872	0.67	0.47	0.68	0.46	0.66	0.47
Innovation prone area	Dummy variable taking value 1 if the firm is located in a TTWA that experienced inflows of inventors.	EPO	5872	0.17	0.38	0.22	0.42	0.12	0.32
Backward Linkages	Dummy variable taking value 1 if the firm acknowledges suppliers source of information	CIS	5872	0.51	0.50	0.53	0.50	0.49	0.50
Forward Linkages	Dummy variable taking value 1 if the firm acknowledges customers source of information	CIS	5872	0.56	0.49	0.57	0.49	0.55	0.50
Outmigration	Outflows from each TTWA over total population	ONS	5872	0.11	0.06	0.05	0.02	0.16	0.05
Patents (Spatial lag)	Spatial lag of the number of patents	EPO	5872	8.94	17.8	9.44	18.90	8.44	16.62

Note: 'Product Innovation' refers to activities bringing to the market new and improved products, including both tangible goods and the provision of services. 'Process innovation' is defined as "significant changes in the way that goods or services are produced or provided". Both variables can refer to both products and processes new to the business only or to the market and industry as well. 'R&D investments' are defined as "Creative work undertaken within your enterprise on an occasional or regular basis to increase the stock of knowledge and its use to devise new and improved goods, services and processes". 'Employment with degree' is measured with respect to people holding a degree (BA/BSc, or higher degree, e.g. MA/PhD, PGCE) in Science and Engineering or other subjects. The variable 'External sources of information' refers to firms rating 2 or 3 in a scale from 0 to 3 the importance of the following knowledge sources: "market sources of information" and "institutional sources of information". These categories include suppliers, clients, customers, competitors, other businesses in the industry, consultants, commercial labs, universities and public and private R&D institutes. The variables "Backward Linkages" and "Forward linkages" refer to firms declaring that they have a medium/high use (with respect to a low/no use) of suppliers and customers respectively as knowledge sources for the development of their innovations. Outmigration data come from mid-population estimates provided by the Office of National Statistics (ONS) and refer to all outflows from each TTWA. The spatial lag of the number of patents is constructed using a queen first order contiguity matrix.

measure we restrict the time window associated to the mobility event by focusing exclusively on recent movers. 'Movers' are considered as inventors who change their residential address in a three-year window between two inventions at different addresses, thus capturing the 'novelty' of the knowledge 'imported' by the newcomer into the destination TTWA. Hence, inventors who moved within the time span 2000–2002 have been used to identify innovation prone TTWAs to be linked to the firms in the UK-CIS4 (2002–2004) while inventors moving between 2002 and 2004 have been associated to the subsequent CIS5 wave (2004–2006) (Fig. A1 Appendix A).

It is worth noting that the nature of our data implies that we can only observe the location behavior of inter-regional movers, i.e. individuals that relocated from other local labor markets within England. As a consequence, we do not account for inventors that entered the English labor market for the first time during the period 2000–2004 from other countries.[11] This is because the identification of movers from multi-patenting inventors relies on both their origin (i.e. the place where the inventor patented the first time in the time window of interest) and destination areas (i.e. the new and different place where the inventor subsequently patents). As a matter of fact, however, we cannot observe whether an individual that patents during our time frame has already patented before in a foreign country. Yet, we believe this limitation does not substantially affect our spatial figures as we expect international movers to pay an initial cost in terms of integration process that may generate some delays in their capacity to patent. Given the restricted time window of our analysis, the number of people that patented in a foreign country, moved to the UK and patented again in an English region between 2000 and 2004 is unlikely to be significant. In addition, a potential bias would emerge only in the case in which these 'unobserved movers' exhibit a completely different location behavior with respect to inter-regional movers, which is unlikely to be the case as we expect the distribution of international migrants to closely resemble the core-periphery hierarchy of innovation centers depicted by internal mobility flows.

3.3. Preliminary descriptive statistics

The final sample of firms includes 2936 English private companies that are observed for two consecutive UKIS waves. Overall, an average of 35% of firms performed either product or process innovation over the whole period 2002–2006, 38% in the first wave (2002–2004) only, and 32% over the period 2004–2006 only. Almost 33% of the total number of firms performed investments in R&D and at least 10% of their workers had a university degree. In addition, approximately 37% of the total sample of firms is active on the international market and engaged in exports during the period under analysis. Finally, 67% of firms on average declared that they made use of external sources of information (including suppliers, clients, customers, competitors, other businesses in the industry, consultants, commercial labs, universities and public and private R&D institutes) for the development of their innovation. Table 2 shows the variation over time in the importance of different information sources. Interestingly, more than half of the sample manifested some changes in the balance between internal and external sources of information during our time frame. In particular, about 22.5% of firms declared an increase in the relevance of external sources of knowledge for the development of their innovation. This percentage rises to 29% with respect to external knowledge from suppliers, clients and customers and competitors, and is below 20% for other categories of external actors. On the other hand, for about 26% of firms in our sample there is an increase in the importance of internal sources of knowledge.

The analysis of inter-regional mobility patterns in England show

[11] Our records provide information on inventors that had patented before in Scotland or Wales, but not on those that patented in a foreign country.

Table 2
Internal and external sources of knowledge (percentage of firms).
Source: UK-CIS; EPO-KITES.

		CIS4-CIS5		
		Importance up	Importance down	Importance unchanged
Internal sources		26	27	47
External sources	Suppliers	29	29	42
	Clients and customers	29	26	45
	Competitors	29	26	45
	Consultants	19	23	58
	Universities	15	14	71
	Government and public research	14	16	70

that among the total sample of 'recent' movers changing TTWA of residence between 2000 and 2004 (the lagged time window used to attribute the status of innovation prone areas), 54.2% moved in a different NUTS3 region, 47.9% in a different NUTS2 region and 31.3% changed their NUTS1 region of residence. Inter-regional flows have been more relevant in the first rather than the second period with some differences also in their geographical distribution. Although some traditionally successful areas, such as the areas of Cambridge and Oxford, experienced inflows of inventors over the entire time span, some variation in the destinations of movers emerges when splitting our time window in the sub-periods 2000–2002 and 2002–2004. In the first period, inventors' mobility targeted mainly the South East including the surrounding areas of Greater London, such as Chelmsford, Slough and Heathrow. On the contrary, during the years 2002–2004 the attractiveness of traditional industrial cities, such as Liverpool, Greater Manchester, Sheffield and Newcastle has risen significantly. These time varying spatial patterns will serve as source of variation for the identification of differences in firms' innovative performance in response to the changes in the exposure to knowledge inflows.

Table 3 shows the number of firms in our sample by innovation status, and whether they are located in an area experiencing investors' inflows. Firms located in local labor markets qualified as innovation prone show consistently better innovative performance, with an average difference of 2 percentage points in the share of firms performing any product or process innovation. This evidence applies

Table 3
Firms' innovative performance by area.
Source: UK-CIS; EPO-KITES.

Period	Innovative Performance	Innovation prone area			
		NO		*YES*	
		Obs.	*Share*	*Obs.*	*Share*
TOTAL	*Product Innovation*	4868	0.29	1004	0.31
	Process Innovation	4868	0.20	1004	0.20
	Product or Process Innovation	4868	0.35	1004	0.37
2002–2004	*Product Innovation*	2284	0.30	652	0.32
	Process Innovation	2284	0.23	652	0.21
	Product or Process Innovation	2284	0.37	652	0.39
2004–2006	*Product Innovation*	2584	0.27	352	0.30
	Process Innovation	2584	0.17	352	0.18
	Product or Process Innovation	2584	0.32	352	0.34

Note: Product Innovation refers to "activities bringing to the market or into use by business, new and improved products, including both tangible goods and the provision of services". Process innovation is defined as "significant changes in the way that goods or services are produced or provided". Both variables can refer to both products and processes new to the business only or also new to the industry.

mainly to the category of product innovation, while no significant differences in process innovation emerge. This preliminary unconditional correlation resonates with earlier studies that attributed a positive innovation impact to the mobility of knowledgeable individuals (e.g. Faggian and McCann, 2006; Chellaraj et al., 2008; Hunt and Gauthier-Loiselle, 2009).

Finally, Fig. 1 provides a preliminary attempt to link the firm and geographical dimensions alongside the conceptual rationale of this analysis. In this regard, we construct a matrix that reports the share of innovation active firms by typology of region (defined as innovation prone, if they experience any inflows of knowledgeable individuals, and innovation adverse otherwise), and by the nature of their knowledge seeking behavior (distinguishing between firms exploiting internal sources only and those complementing internal with external sources). The pairwise comparison between the upper and the lower quadrants (quadrant 1 with quadrant 3 and quadrant 2 with quadrant 4) shows that, given a certain knowledge seeking behavior, the share of innovative firms is higher in innovation prone areas. Nonetheless, much of the variation comes from the horizontal dimension, i.e. when we compare firms that, given their actual geographical location, differ in terms of knowledge seeking behavior (comparison of quadrant 1 with quadrant 2 and quadrant 3 with quadrant 4). The largest observable difference in the share of innovative firms is manifested alongside the diagonals, in particular when comparing quadrant 1 (which refers to inward looking firms located in innovation adverse regions) with quadrant 4 (outward oriented firms in innovation prone regions). Two main preliminary considerations, which are consistent with our conceptual framework, emerge from the evidence above. First, unintended positive spillovers on firms' innovation due to location specific characteristics are positive but of limited relevance. Firms' heterogeneity in terms of knowledge seeking behavior and strategic approach to the complementarity between internal and external sources plays a major role. That is, firms' attitude and capacity to engage actively with their external environment shape the impact of context-specific characteristics on their performance. Second, best performing firms are those that leverage the benefits from being located in innovation prone areas by making external knowledge an actual component of their innovation process.

4. Estimation strategy and identification approach

Our estimation is based on the Knowledge Production Function (KPF) approach popularized by Griliches (1986) and Jaffe (1986) where firms' innovative performance can be explained by the amount of internal inputs (mainly capital and labor) devoted to the innovative process. The standard specification is augmented by our regressor of interest, the dummy that signals the attractiveness of each local labor market in terms of knowledgeable inflows, following existing contributions that adapt the knowledge production framework to extended input specifications (e.g. Zucker et al., 2007; Ramani et al., 2008; Czarnitzki et al., 2009; Crescenzi et al., 2015).

The estimation equation takes the following form:

$$P(Product\ or\ Process\ Innovation^{i}_{c,t}) = \beta_0 + \beta_1 K^{i}_{c,t} + \beta_2 L^{i}_{c,t} + \beta_3\ Innovation\ Prone\ Area_{c,t-T} + \delta_i + \delta_t + \varepsilon^{i}_{c,t} \quad (1)$$

Where $P(Product\ or\ Process\ Innovation)^{i}_{c,t}$ is the probability of performing any product or process innovation for firm *i* located in TTWA *c* at time *t*; K and L are respectively the amount of intramural R&D expenditure that each firm i located in TTWA *c* within the period *t* devoted to the innovative process, and the share of high skilled workers[12]

[12] Data on skilled employees come from the section 'General Economic Information' of the CIS questionnaire. It refers to the share of employees that hold a degree (BA/BSc, or

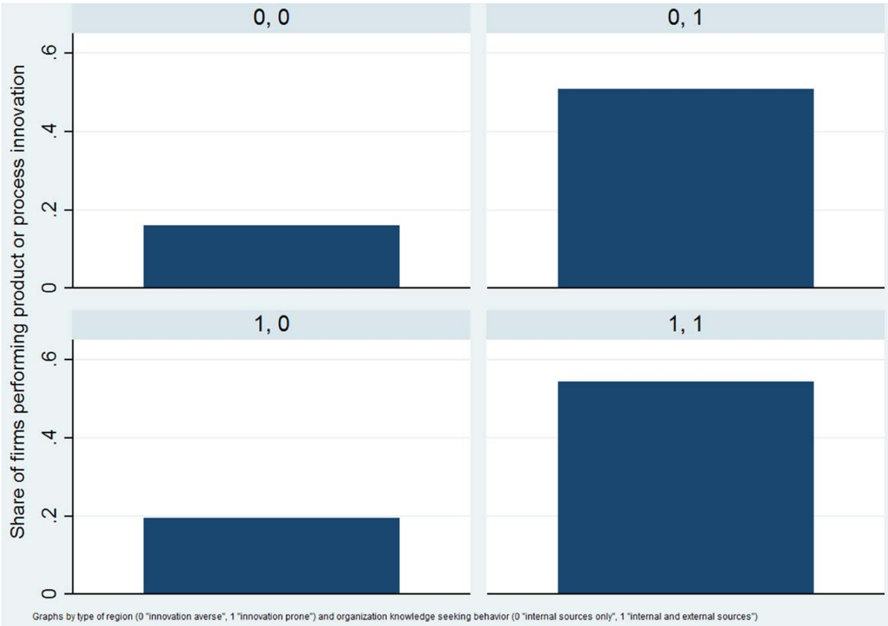

Fig. 1. Share of innovation active firms by typology of region and knowledge seeking behavior.
Note: The graph reports the share of firms performing product or process innovation according to whether they are in an innovation prone area or not (0: innovation adverse areas; 1: innovation prone areas) and whether they make use of external sources of knowledge or not (0: internal sources only; 1: internal and external sources).
Source: UK-CIS

employed by the firm. Innovation Prone Area, the regressor of interest, is a dummy that takes the value 1 if TTWA *c* experience inventors' inflows at time t-T and 0 otherwise.

Our specification controls for both firm and wave fixed effects. This is a highly valuable feature since firm fixed effects make it possible to account for the role of time invariant unobservable characteristics at the firm level, including the possibility that they systematically differ with respect to their capability to understand, process and absorb knowledge. Eq. (1) is estimated by means of a Linear Probability Model (LPM). Several considerations justify this methodological choice. First, estimating Eq. (1) through binary response models – such as probit models – is subject to separation problems (Zorn, 2005), which arise when one or more covariates perfectly predict the outcome of interest and is intuitive when both the dependent and independent variables of interest are binary.[13] The conventional response to separation problems is dropping from the analysis the observations that generate the problem (Long and Freese, 2006). However, this is a highly problematic choice when the separation reflects a genuine causal process–as potentially in our case – since we are looking at the impact of a rare event (recent mobility) upon a specific sub-group of firms (e.g. those performing product or process innovation). Second, while unobserved firm-level fixed effects can be efficiently controlled for by means of a within transformation in a linear context (see for example Miguel et al., 2004), the same approach is not applicable to non-linear estimation techniques. The inclusion of firm level dummies when the time dimension is small − as in the case of this analysis − would result in the incidental parameters problem leading to inconsistent estimates. Finally, endogeneity concerns, especially for panel data, cannot be applied in a straightforward manner in the context of Maximum Likelihood (ML) or Control Function (CF) approaches. For instance, the application of instrumental variable techniques (2SLS estimation) would be particularly concerning in our case as any misspecification of the first stage in the 2SLS approach would just impact on efficiency, while the ML or control function estimators would become inconsistent (Lewbel et al., 2012). While the first concern discussed above could be potentially addressed by means of a Penalized Maximum Likelihood estimation approach and, in principle, it also remains applicable to an ordinary least squares (OLS) framework, the second and third considerations persist. The concurrence of these features has therefore driven our choice in favor of the LPM as the most suitable estimation strategy. The choice of the LPM under similar conditions is now customary in the empirical literature and it has proved to deliver, where direct comparisons with nonlinear techniques are made possible by the data, qualitatively similar results (Miguel et al., 2004; Gagliardi, 2015; Crescenzi et al., 2015, 2016).

The model specified in Eq. (1) makes a clear assumption on the direction of the causality between our dependent and independent variables. We postulate that being located in a knowledge hub makes firms more innovative as they have the possibility to take advantage of the creation of a contextually enabling environment for innovativeness. Causality may, however, also run in the opposite direction. Spatial contexts in which highly innovative firms are located may be able to develop as knowledge hubs by attracting knowledgeable individuals due, for example, to better job opportunities. In the first instance, the adoption of a 'lagged' measure of mobility to qualify our innovation prone status substantially limits this concern. Moreover, apart from the cases where a few very large firms dominate their respective local markets, individual firms can rarely act as a primary pull factor for labor inflows into their entire labor market area. In order to further minimize any potential reverse causality bias, we adopt a novel *instrumental variables (IV) approach*. We draw from the economic literature on migration and exploit supply push factors in the TTWAs of origin as an instrument for the likelihood of inflows in each TTWA (e.g. Ortega and Peri, 2009; Bianchi et al., 2012). In other words, we instrument the likelihood of inflows in TTWA *c* by means of the outflows from all other TTWAs $j \neq c$, taking advantage of the fact that 'push-factors' of mobility do not depend on the characteristic of the area of destination but only on conditions in the area of origin.

More specifically, we exploit as a push factor the signaling effect linked to the quality of a highly successful invention that increases inventors' visibility, making them more attractive for potential

(*footnote continued*)
higher degree, e.g. MA/Phd, PGCE) in science and engineering or in other fields.

[13] In our case the dependent variable $P(Innovation^{i}_{c,t})$ is perfectly predicted by $InventorsFlows_{c,t-T}$ for the cases in which both variables are equal to 0 (when firm *i*, which does not perform any innovation activity, is located in a TTWA *c* that does not experience inventors inflows) or both are equal to 1 (when firm *i*, which does perform any innovation activity, is located in a TTWA *c* that experiences inventors inflows). Together with cases in which our dependent variable is equal to 1 and the regressor of interest is equal to 0 (firm *i*, which performs some innovation activity, is located in a TTWA c that does not experience inventors inflows) the three occurrences cover 90% of our sample giving rise to a quasi-separation problem when estimating Eq. (1) using probit/logit techniques.

employers located in other labor markets. The immediate payoff of a highly successful (and highly cited) invention may, in fact, be associated with greater visibility and opportunities of mobility and job offers.[14] We interpret a peak in the number of citations received in the 12 months after the patent's publication at TTWA level as an indication for the development of highly successful patents by local inventors,[15] which increases the probability of individual mobility − and thus the likelihood of the local labor market to be a "net donor of talents" − independent of the degree of attractiveness of the potential areas of destination. Then, we use this supply push factor in all TTWAs $j \neq c$ to instrument for our regressor of interest. To attribute the push factors in all TTWAs j of origin to the destination TTWAs c, we employ a distance based weighting matrix. This assumes that the exposure of each TTWA c to the relocation of inventors from other local labor markets is proportional to the bilateral distance between c and each j. Computationally, the instrument takes the following form:

$$IV^{c}_{t-T} = \sum_{j \neq c}^{n} Citations^{j \neq c}_{t-T,t-(T+1)} {}^{*} W_{cj} \quad (2)$$

We expect our instrument to be positively correlated to the instrumented variable. This rationale is supported by previous related research showing that inventors characterized by more valuable patents (i.e. most cited patents) are those with the highest probability of mobility (Trajtenberg et al., 2006). A more detailed description of the technical aspects related to the construction of the instrument, and its robustness against exclusion restrictions' concerns, is available in Appendix B.

5. Empirical results and robustness checks

5.1. Baseline estimates: the role of firms' heterogeneity

Results for the estimation of Eq. (1) are reported in Table 4. In Column 1 we estimate the standard firm-level KPF (adopted as the baseline model) where innovation is a function of intramural investments in R&D and the proportion of employment with degree or above, which are our main proxies for potential absorptive capacities. We also control for export orientation at the firm level to account for learning by exporting mechanisms. The estimates confirm the relevance of R&D investment, which turn out to be a positive and significant determinant of innovation as expected. The regressor for human capital inputs into the KPF shows the expected sign and is significant at the 1% level. In Column 2 we include TTWA dummies to account for time invariant characteristics at the local labor market level. Results remain robust with the dummy for being located in innovation hubs being significantly correlated with firm innovation at the 1% level: being located in places that can attract knowledge inflows increases the likelihood of innovation by about 4%. We make a step forward and control for firm fixed effects in Eq. (1). This makes it possible to fully control for both observable and unobservable characteristics at the firm level (e.g. size, age, industry, location, etc.). Accounting for firms' observable and unobservable heterogeneity significantly affects our results. In the specification reported in Column 3 the regressor of interest, the dummy for innovation prone areas, maintains its positive sign – suggesting a positive association between the location in an environment that is conducive of positive knowledge externalities and the innovative performance of local firms – but is not statistically significant. These results recommend greater caution in the analysis of the impact of mobility on firms' innovation in line with recent research in the field (e.g. Maré et al., 2014; Gagliardi, 2015). When firms' specific characteristics are fully accounted for there is no evidence of an independent link between the external environmental conditions and innovation, implying that firms' heterogeneity remains the key missing link in 'aggregate' studies based on regional knowledge production functions approaches.[16]

Table 4
Main results.

	(1)	(2)	(3)
Dep.Var. Product or Process Innovation	FE	FE	FE
R&D	0.4085***	0.4006***	0.2541***
	(0.0136)	(0.0138)	(0.0233)
Employment with degree	0.1478***	0.1430***	0.0864*
	(0.0299)	(0.0300)	(0.0462)
Innovation prone area	0.0309**	0.0452**	0.0226
	(0.0150)	(0.0228)	(0.0190)
Export Orientation	0.1234***	0.1168***	0.0075
	(0.0128)	(0.0130)	(0.0267)
TTWA FE	NO	YES	NO
Firm FE	NO	NO	YES
Wave FE	NO	NO	YES
Observations	5872	5872	5872
R2	0.2170	0.2455	0.0688

Clustered-Robust standard errors in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Results also remain consistent when endogeneity concerns are accounted for by means of the instrumental variable approach presented in Section 4. Our regressor of interest remains positively associated to innovation but not statistically significant (Table 5, Column 1). As expected our instrument is positively correlated with the instrumented variable: indeed, the immediate payoff of the development of a highly successful invention is reflected in a higher probability of inventors moving out of their current region of residence. The first stage supports the strength of the IV approach (Column 2) showing an F-statistic that is well above the value of ten from the 'rule of thumb' proposed by Staiger and Stock (1997).

5.2. Heterogeneous effects: the importance of firms' realized absorptive capacities

Results from Table 4 suggest that firms' heterogeneity plays a crucial role in channeling the benefits from the location in contextually enabling environments. By means of firm fixed effects we factor out a significant portion of this variation due to unobservable characteristics. However, time variant heterogeneity may still play a significant role in explaining firms' knowledge acquisition and exploitation behavior. Our hypothesis is that much of this time variant firm heterogeneity has to do with realized absorptive capacities, which encompass all firms' characteristics, attitudes and strategic behaviors that allow them to successful exploit − rather than just understand and assimilate – external sources of knowledge within their innovation processes. The aim of this section is to dig further into this rationale and to explicitly test this hypothesis in our data. Accordingly, we exploit information, available in the UKIS, on firms' heterogeneity in learning behavior. In order to account for the role of realized absorptive capacities we restrict the analysis to those firms declaring that they significantly exploit external

[14] This rationale is also employed by Hoisl (2007) who proposes an instrument based on whether an invention was made in a large city or in a rural area. The assumption is that inventions made in large urban areas have a greater signaling effect, thus leading to a higher probability for their inventor(s) to receive a job offer by a competitor of their current employer.

[15] By citation peak we refer to a steady increase in the number of citations by TTWA with respect to the national average. We measure it by the average number of citations per patent by TTWA in the 12 months after the patent's publication date normalized with respect to the average number of citations per patent in the 12 months after publication at the national level during the time span 1995–2007. Further details are reported in Appendix B.

[16] We also re-run our baseline specification on product and process innovation separately (Table A1, Appendix A, Columns 1 and 2). The coefficient remains not statistically different from zero in both specifications.

Table 5
Instrumental variable (2SLS) estimation (full and restricted sample).

	(1)	(2)	(1)	(2)
Dep.Var.	Product or Process Innovation	Inventors' Inflows	Product or Process Innovation	Inventors' Inflows
	Full sample		Restricted sample	
Innovation prone area	0.0752		0.2055**	
	(0.0605)		(0.1002)	
R&D	0.2537***	0.0077	0.1609***	0.0108
	(0.0233)	(0.0173)	(0.0302)	(0.0231)
Employment with degree	0.0889*	−0.0475	0.0836	−0.0627
	(0.0469)	(0.0455)	(0.0717)	(0.0689)
Export Orientation	0.0058	0.031	−0.0044	0.0406
	(0.0268)	(0.0215)	(0.0382)	(0.0299)
Peak Citations		0.3381***		0.3457***
		(0.0585)		(0.083)
Firm FE	YES	YES	YES	YES
Wave FE	YES	YES	YES	YES
Observations	5872	5872	3084	3084
R2	0.0664	0.1581	0.0166	0.1518
F		33.45		17.36

Clustered-Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Note: The restricted sample is constructed drawing from the section "Context for Innovation" restricting the analysis to firms rating 2 or 3 (in a scale from 0 to 3) the category "market sources of information and institutional sources of information" that includes suppliers, clients, customers, competitors, other businesses in the industry, consultants, commercial labs, universities and public and private R&D institutes.

sources of knowledge in their innovation process. This same sub-sample has been used in related studies addressing the role of external sources of information for firms' economic performance (Criscuolo, 2005; Van Leeuwen and Klomp, 2006; Crespi et al., 2007). Then, we re-estimate our preferred specification (the one reported Column 1, Table 5) on this new sample.

Interestingly, when we focus on those firms that exploit external knowledge as an innovation input, the effect of being located in an innovation prone area becomes positive and significant at the 5% level (Table 5, Column 3). The estimated coefficient suggests that firms located in areas experiencing inflows of knowledgeable individuals are on average 20% more likely to develop product or process innovation. The coefficient for other internal inputs – such as R&D investments – is sensibly lower than in the full sample, supporting the view that – after reaching a minimum threshold that ensures that the necessary potential absorptive capacities are in place – external sources of knowledge can partially substitute for internal resources in outward oriented firms. In other words, firms that manage successfully the internal-external trade-off are also those developing an optimal knowledge mix.

The magnitude of the effect, despite not being directly comparable with other studies, is generally in line with previous findings. In particular, Hunt and Gauthier-Loiselle (2010) find that immigrants generate positive spillovers in the USA, resulting in a 15% increase in patents per capita in response to a 1 percentage point increase in immigrant college graduates. Gagliardi (2015) – using CIS data for Britain – suggests that a 1% increase in skilled immigrant generates a 19% increase in the probability of firms performing any product or process innovation at the regional level.

It is important to highlight that our IV strategy is also highly robust on the restricted sample. First stage results reported in Column 4 (Table 5) confirm that the instrument remains significantly correlated with our regressor of interest and highly significant. Additionally, the F-statistics suggest that the IV does not suffer from weak instrument bias.

5.3. Robustness checks

We perform a number of checks on the robustness of our main findings. In particular, the reliability of our estimates is tested with respect to alternative channels of knowledge diffusion and additional sources of potential biases. The exclusion restrictions of our preferred IV specification relies on the assumption that citations' peaks at the TTWA level signal the recent development of highly successful inventions and affect innovation only through the mobility of inventors. However, alternative explanations may turn out to be equally reasonable.

First, the development of highly successful patents − leading to the observed citations' peak – may also generate knowledge spillovers across TTWAs via demonstration effects and/or backward and forward linkages. The first mechanism is, in fact, ruled out by the restrictive time window selected for the identification of the citation peak. It is highly unlikely that firms can imitate highly visible inventions from other regions by developing related inventions in just 12 months. The use of patents to legally protect these inventions implies an ownership advantage that is unlikely to be eroded by imitation in such a short time-span (Bloom and Van Reenen, 2002). Conversely, spillovers through backward and forward linkages may still be a relevant concern. In order to test the significance of this potential alternative transmission channel, the IV model is re-estimated for both the full and the restricted sample by including controls for backward (towards upstream industries) and forward (towards downstream industries) linkages. Results reported in Table 6 (Column 1 and 2) show that our findings remain robust (although the coefficient for being located in an innovation prone area is slightly lower on the full sample with respect to the estimates reported in Table 4). Overall, spillovers through backward and forward linkages play a much more significant role on the full sample than on the restricted sample of firms, showing an attitude towards the exploitation of external sources of knowledge.

Second, it may be possible that our instrument captures broader spatial spillovers operating across contiguous areas. For instance, if highly innovative locations are close to each other the instrument – which attributes to each TTWA the effect of a peak in the number of citations in other TTWAs through an inverse distance matrix − may partially reflect the effect of this clustering phenomenon. If this is the case part of the positive effect attributed to the exposure to inventors' inflows just reflects the agglomeration of highly innovative locations. We report in Columns 3 and 4 (Table 6) our main results on the full and restricted sample respectively further controlling for the spatial lag in the number of patents. In the case in which our instrument mainly captures spatial spillovers we should expect its significance to be substantially lower in the first stage. However, estimates suggest that the instrument remains significantly and positively correlated with the instrumented variable. Results also remain comparable with those reported in Table 5.

Finally, the robustness of our results needs to be tested against the role of outflows from each TTWA. The literature on migration has traditionally found a significant correlation between inflows and outflows within the same spatial contexts despite the lack of consensus on its sign and magnitude (e.g. Card, 2005). Inventors' inflows can either generate a displacement effect due to increasing competition within the labor market or induce a positive impact in the case where agglomeration effects prevail. Consequently, we include in Table 6 (Column 5 and 6) a control for outmigration. Once again, results on the full and restricted samples reported in Columns 5 and 6 respectively do not support this concern and remain consistent with our main estimates.

5.4. A sketched profile of best performing firms

The main result of this analysis is that firms' heterogeneity in terms of knowledge seeking and acquisition behavior plays a crucial role in channeling the benefits from the location in contextually enabling

Table 6
Instrumental Variables Estimation – Robustness Checks.

	(1)	(2)	(3)	(4)	(5)	(6)
Dep.Var. Product or Process Innovation	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
	Panel I		Panel II		Panel III	
R&D	0.2122***	0.1596***	0.2537***	0.1610***	0.2538***	0.1600***
	(0.0232)	(0.0301)	(0.0233)	(0.0302)	(0.0233)	(0.0303)
Employment with degree	0.0830*	0.0882	0.0889*	0.0841	0.0891*	0.0832
	(0.0458)	(0.0715)	(0.0469)	(0.0717)	(0.0469)	(0.0722)
Innovation prone area	0.0551	0.2042**	0.0763	0.2067**	0.0726	0.2194**
	(0.0630)	(0.1001)	(0.0605)	(0.1006)	(0.0613)	(0.1016)
Export Orientation	0.0019	−0.0036	0.0059	−0.0047	0.0059	−0.0055
	(0.0263)	(0.0383)	(0.0268)	(0.0382)	(0.0268)	(0.0384)
Backward Linkages	0.1060***	0.0548**				
	(0.0188)	(0.0266)				
Forward Linkages	0.0864***	0.0305				
	(0.0192)	(0.0335)				
Patents (spatial lag)			0.0110	0.0141		
			(0.0183)	(0.0260)		
Outmigration					−0.0462	0.2685
					(0.2514)	(0.3820)
Firm FE	YES	YES	YES	YES	YES	YES
Wave FE	YES	YES	YES	YES	YES	YES
Observations	5872	3084	5872	3084	5872	3084
R2	0.1004	0.0202	0.0664	0.0165	0.0667	0.0133
F	33.31	17.33	33.72	17.37	31.79	16.85

Clustered-Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ Column 2, 4 and 6 refer to the sub-sample of firms exploiting external sources of information to develop their innovative activities.

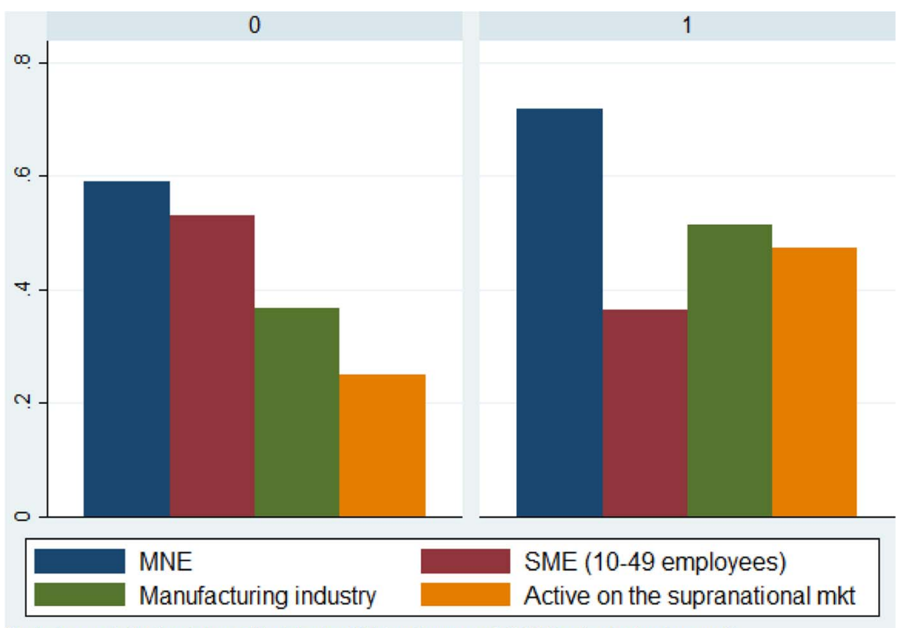

Fig. 2. Firm profile by knowledge seeking behavior.
Source: UK-CIS. Note: Y-axes reporting the share of firms of each category in the legend

environments. This section digs deeper into the main characteristics of the best performing firms (i.e. firms complementing internal and external sources of knowledge) by drawing a sketched profile alongside four important dimensions: ownership, size, industry and market behavior. Fig. 2 identifies four organizational types: firms that are part of an MNE group, small enterprises (10–49 employees), firms active in the manufacturing industry and firms that report the supranational market (European and/or international) as their main reference market. It reports the share of firms of each kind by knowledge behavior comparing firms that exploit internal knowledge sources only (left panel) with those complementing internal and external sources (right panel). MNEs exhibit a more pronounced attitude to the exploitation of both internal and external sources of knowledge. This is in line with previous findings in the international business literature on the behavior of MNEs in the UK. Cantwell and Iammarino (2000) find that the location patterns of MNEs in the country follows the hierarchy of knowledge centers and that this reflects their distinctive knowledge seeking behavior in terms of attitude to exploit localized sources of knowledge. Small firms are instead under-represented in the sample of firms that complement internal with external knowledge sources. This reasonably reflects the lower absorptive capacities, both potential and realized, of smaller firms for which the cost of accessing external knowledge remains –

notwithstanding geographical proximity – prohibitively high due to internal routines or knowledge-management failures. Finally, outward oriented firms, which use external sources of knowledge extensively, are more likely to operate in the manufacturing industry rather than in the service sector and they are also characterized by a stronger presence on the supranational market, meaning that they tend to send their products outside their regional or national boundaries.

6. Conclusions and implications

This paper investigates how the innovative performance of firms changes in response to innovation prone local environments that offer exposure to the inflows of knowledgeable individuals. The paper integrates insights from economic geography on the circulation of knowledge across and within functional regions with a more careful conceptualization of firms' knowledge acquisition and exploitation behavior from the management literature.

The empirical analysis suggests that firms located in local labor markets exposed to inflows of knowledgeable individuals tend to be more innovative. However, this effect, also identified in previous regional-level analyses, is not robust after controlling for firm observable and unobservable characteristics. Firm-level heterogeneity in terms of resources and capabilities is of paramount importance to explain the impact of external conditions on innovation. Contextually enabling environments boost innovation only in firms that make the exploitation of external knowledge sources an essential part of their strategies, actively combining potential and realized absorptive capacities. Conversely, exposure to an innovation prone external environment is of limited or no benefit to cognitively inward looking firms.

What can be learned from these results? The empirical analysis presented in the paper should be interpreted while bearing in mind some key limitations. First, our measure of exposure to knowledgeable inflows is based on a very specific typology of skilled and innovative individuals, namely inventors. Second, our analysis shares the strengths as well as the limitations of other studies based on CIS data: the sample might systematically under-estimate certain forms of innovation (e.g. innovation in services).[17] Third, though we control for the variation over time in qualified personnel at the firm level – thus disentangling the innovation effect associated to the learning by hiring mechanism from the pure externality dynamic – we cannot directly identify the firms actually hiring the inventors: data limitations make this impossible, preventing us from exploring the concurrent effect of job-to-job mobility.

Having acknowledged these limitations, this paper fills two relevant gaps at the intersection between different streams of research. The strategic management literature has devoted substantial attention to the organizational mobility of personnel as a way to achieve better innovative outcomes, but it has traditionally under-investigated the complementary role of geographic mobility. Conversely, economic geography has extensively investigated the impact of contextual conditions on firms' innovative performance, but has often under-estimated the role of firm-level heterogeneity in the interaction with external environments. This paper develops a testable framework that places the interaction between firm strategies and innovation prone external environments at the very center of the innovation performance of firms. Robust quantitative results show that knowledge management strategies are central in order to leverage knowledge-rich contextual conditions.

Second, by cross-fertilizing the management and economic geography perspectives we gather important implications for both managerial practices and policy making. On the one hand, our results suggest that managerial strategies should carefully account for the local environment in which firms operate. Private returns can be generated from the adoption of open innovation strategies that pro-actively build on the complementarity between internal and external assets. Large firms are increasingly aware of these opportunities and these types of initiatives have flourished in recent years – e.g. the *Ecoimagination* program launched by General Electrics – as a means to manage innovation strategies in a fast growing and ever changing global competitive environment. Our results support the adoption of these open strategies in firms of all sizes including SMEs (that are also represented in the UKIS sample used in the analysis).

On the other hand, this research stresses the importance of accounting for the complex bilateral relationship between organizational and contextual conditions when designing public policies targeting innovation. It uncovers the potential drawbacks of 'traditional' innovation policies that look at firms as passive recipients of knowledge, failing to develop 360° diagnoses of knowledge-absorption and knowledge-exploitation behaviors at the firm level. Typical examples of this approach are 'traditional' top-down innovation policies inspired by the Lisbon Agenda of the European Union and implemented in virtually all EU countries and regions in the 2000s. This generation of innovation policies relied extensively on public and private R&D incentives in order to foster the innovative performance of countries, regions and firms. Since 2014 a new approach to innovation policies has been embraced by the European Union. This new generation of innovation policies is inspired by a 'Smart Specialisation' approach that places the process of 'entrepreneurial discovery' – led by (existing and new) entrepreneurs – at the very center of all innovation strategies (Foray et al., 2011). The policy's support to the process of 'entrepreneurial discovery' aims at reinforcing the capacity of firms to search outside their organizational boundaries and "discover the domains of R&D and innovation in which a region is likely to excel given its existing capabilities and productive assets" (Foray et al., 2011, p. 7). Innovation policies inspired by the Smart Specialisation approach and financed across the entire EU by Cohesion and Innovation funds constitute a fertile experimentation field for concrete policy tools simultaneously targeting firm-level capacities and their connections with the surrounding innovation eco-systems in line with the evidence produced in this paper. However, robust counterfactual evidence on what works (and what does not) in order to achieve the intended objectives in terms of wider collaboration patterns and firm-level innovation is still at an infant stage (e.g. Crescenzi et al., 2018). The identification of the most effective tools to practically trigger the mechanisms highlighted by our analysis remains a key challenge for scholarly and policy debates in Europe (and beyond). Further insights on these issues remain part of our agenda for future research.

Disclaimer

Acknowledgements

The research leading to these results has received funding from the European Union Seventh Framework ProgrammeFP7/2007-2013 under grant agreement No SSH−CT-2010-266959; Project PICK-ME. The authors would like to thank the participants to the DRUID Conference

[17] Almost 32% of our sample of firms operates in the manufacturing industry, about 35% of which performed any product or process innovation, compared to 24% in the service industry. Despite this, the possible overrepresentation of innovation in manufacturing is unlikely to be a major concern in our context. In fact, by focusing on the geographical mobility of patenting inventors the focus of the paper is a priori oriented towards a type of technological knowledge that is inherently more likely to be associated to innovation in manufacturing.

2017 in New York, the Spatial Economics Research Centre (SERC)–LSE seminars, the Eurolio Conference in Saint Etienne (France), the OECD − Regional Development Programme Internal Seminars in Paris, the Barcelona Workshop on Regional and Urban Economics, the ONS Secure Data Service Workshop in London, the IC10 2014 Workshop in Paris, the Seminars in Economics of Science and Engineering at the Harvard Business School and the joint World Bank/Inter-American Development Bank Brown Bag Lunch (BBL) series for comments and suggestions. The authors are solely responsible for any errors contained in the article.

Appendix A

Table A1
Product and Process Innovation.

	(1)	(2)
Dep.Var.	Product Innovation	Process Innovation
R&D	0.1986***	0.1714***
	(0.0222)	(0.0203)
Employment with degree	0.1636***	−0.0259
	(0.0460)	(0.0428)
Innovation prone area	0.0251	−0.0120
	(0.0174)	(0.0172)
Export Orientation	0.0158	0.0151
	(0.0260)	(0.0242)
Firm FE	YES	YES
Wave FE	YES	YES
Observations	5872	5872
R2	0.0495	0.0449

Clustered-Robust standard errors in parentheses, ***p < 0.01,**p < 0.05, *p < 0.1.

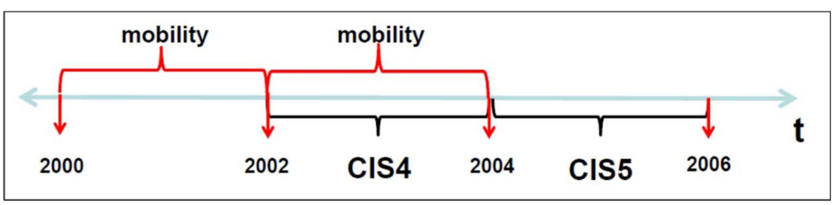

Fig. A1. Attribution of mobility flows.

Appendix B. Construction of the instrument

For each TTWA *j* we calculate the index $Citt - T, t - T + 1j$ as the number of citations received by all patents published the year before our mobility time window[18] (t-T) over the 12 months following their publication (t-T + 1) as a share of the total number of patents published in that same period in each TTWA. This measure offers an indication for the average number of citations per patent in each local labor market during the year after their actual publication.

$$Cit^{j}_{t-T,t-T+1} = \frac{NumberofCitations^{j}_{t-T,t-T+1}}{NumberofPatents^{j}_{t-T,t-T+1}} \tag{2}$$

The IV is then constructed comparing the $Cit^{j}_{t-T,t-T+1}$ index for each TTWA *j* with the average number of citations per patent in the 12 months after publication at the national level during the time span 1995–2007. The number of citations per patent in the year after their publication for the whole UK over a 12 year time span provides a measure of the national average trend in citations. By comparing it with the average number of citations per patent in each TTWA at a specific point in time we can detect any deviations from the national average for each local labor market. We interpret this deviation from the national average as a signal for the development of a highly cited (and highly visible) invention by individual inventors located in specific geographical segments of the labor market. Computationally the instrument takes the following form:

$$IV^{c}_{t-T} = \sum_{j\neq c}^{n} \frac{\left(Cit^{j}_{t-T,t-T+1} - \frac{\text{National Number of Citations}_{1995,2007}}{\text{National Number of Patents}_{1995,2007}}\right)}{\frac{\text{National Number of Citations}_{1995,2007}}{\text{National Number of Patents}_{1995,2007}}} {}^{*}W_{cj} = \sum_{j\neq c}^{n} \text{Citations}^{j\neq c}_{t-T,t-(T-1)} {}^{*}W_{cj} \tag{3}$$

Where $W_{c,j}$ is an inverse linear distance matrix between each TTWA *c* and all the other TTWAs *j*. We therefore instrument the capability of each TTWA *c* to attract knowledgeable individuals by the spatially weighted average of the peaks in citations of inventions patented in all other TTWAs *j* measured as the deviation from the national average in the number citations per patent.

From the methodological point of view the focus on forward citations received in the 12 months after the patent's publication is consistent with our interest in the potential signaling effect associated to the recent development of a valuable invention. The choice of the national level as a benchmark, apart from being justified by its exogenous nature with respect to any local path-dependency pattern, makes it possible to focus on

[18] 1999 and 2002 respectively.

inventions receiving relevant attention outside each individual local area ('national champions'). Finally, the selection of a time interval spanning from 1995 to 2007 for the construction of the national average supports our claim that the peak in the number of citations experienced by a certain area represents a unique phenomenon in time (reasonably connected to the development of a highly successful invention) rather than a consolidated local trend.

References

Adler, P.S., Kwon, S.W., 2002. Social capital: prospects for a new concept. Acad. Manage. Rev. 27 (1), 17–40.
Agrawal, A., Cockburn, I., McHale, J., 2006. Gone but not forgotten: knowledge flows, labor mobility, and enduring social relationships. J. Econ. Geogr. 6 (5), 571–591.
Agrawal, A., Cockburn, I., Rosell, C., 2010. Not invented here: creative myopia and company towns. J. Urban Econ. 67 (1), 78–89.
Ahuja, G., Katila, R., 2001. Technological acquisitions and the innovation performance of acquiring firms: a longitudinal study. Strateg. Manage. J. 22 (3), 197–220.
Alcacer, J., Delgado, M., 2016. Spatial organization of firms and location choices through the value chain. Manage. Sci. 62 (11), 3213–3234.
Almeida, P., Kogut, B., 1999. Localisation of knowledge and the mobility of engineers in regional networks. Manage. Sci. 45, 905–917.
Arora, A., Gambardella, A., 1990. Complementarity and external linkages: the strategies of the large firms in biotechnology. J. Ind. Econ. 361–379.
Arora, A., Gambardella, A., 1994. The changing technology of technological change: general and abstract knowledge and the division of innovative labour. Res. Policy 23 (5), 523–532.
Audretsch, D.B., Feldman, M.P., 2004. Knowledge spillovers and the geography of innovation. Handbook of Regional and Urban Economics 4. pp. 2713–2739.
Barnard, H., Cantwell, J., 2006. Knowledge in the theory of the firm and MNC: asset or action? A commentary on foss N. knowledge and organisation in the theory of the MNC. J. Manage. Govern. 10 (1), 21–27.
Beugelsdijk, S., 2007. The regional environment and a firm's innovative performance: a plea for a multilevel interactionist approach. Econ. Geogr. 83 (2), 181–199.
Bianchi, M., Buonanno, P., Pinotti, P., 2012. Do immigrants cause crime? J. Eur. Econ. Assoc. 10 (6), 1318–1347.
Bloom, N., Van Reenen, J., 2002. Patents, real options and firm performance. Econ. J. 112 (478), C97–C116.
Borjas, G.J., 1999. The economic analysis of immigration (Chapter 3). In: Card, D., Ashenfelter, O. (Eds.), Handbook of Labour Economics. Elsevier.
Borjas, G.J., 2006. Native internal migration and the labor market impact of immigration. J. Hum. Resour. 41 (2), 221–258.
Boschma, R., Eriksson, R., Lindgren, U., 2008. How does labour mobility affect the performance of plants? The importance of relatedness and geographical proximity. J. Econ. Geogr. 9 (2), 169–190.
Breschi, S., Lissoni, F., 2009. Mobility of skilled workers and co-invention networks: an anatomy of localized knowledge flows. J. Econ. Geogr. 9, 439–468.
Card, D., 2005. Is the new immigration really so bad? Econ. J. 115, 300–323.
Carlino, G., Chatterjee, S., Hunt, R., 2007. Urban density and the rate of invention. J. Urban Econ. 61 (3), 389–419.
Carlino, G.A., 2001. Knowledge spillovers: cities' role in the new economy. Bus. Rev. Q 4, 17–24.
Cassiman, B., Veugelers, R., 2006. In search of complementarity in innovation strategy: internal R&D and external knowledge acquisition. Manage. Sci. 52 (1), 68–82.
Chellaraj, G., Maskus, K.E., Mattoo, A., 2008. The contribution of skilled immigration and international graduate students to US innovation. Rev. Int. Econ. 16, 444–462.
Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: a new perspective on learning and innovation. Adm. Sci. Q. 128–152.
Corredoira, R.A., Rosenkopf, L., 2010. Should auld acquaintance be forgot? The reverse transfer of knowledge through mobility ties. Strateg. Manage. J. 31, 159–181.
Crescenzi, R., Gagliardi, L., Percoco, M., 2013. Social capital and the innovative performance of Italian provinces. Environ. Plan. A 45 (4), 908–929.
Crescenzi, R., Gagliardi, L., Iammarino, S., 2015. Foreign Multinationals and domestic innovation: intra-industry effects and firm heterogeneity. Res. Policy 44, 596–609.
Crescenzi, R., Nathan, M., Rodríguez-Pose, A., 2016. Do inventors talk to strangers? On proximity and collaborative knowledge creation. Res. Policy 45 (1), 177–194.
Crescenzi, R., Filippetti, A., Iammarino, S., 2017. Academic inventors: collaboration and proximity with industry. J. Technol. Transf. 42 (4), 730–762.
Crescenzi, R., Blasio, G. De, Giua, M., 2018. Cohesion policy incentives for collaborative industrial research. the evaluation of a smart specialisation forerunner programme LSE/SERC Discussion Paper #231/2018, 2018 available at: http://www.spatialeconomics.ac.uk/textonly/SERC/publications/download/sercdp0231.pdf.
Crespi, G., Geuna, A., Nesta, L., 2007. The mobility of university inventors in Europe. J. Technol. Transf. 32, 195–215.
Criscuolo, P., 2005. On the road again: researcher mobility inside the R&D network. Res. Policy 34 (9), 1350–1365.
Czarnitzki, D., Kraft, K., Thorwarth, S., 2009. The knowledge production of 'R' and 'D'. Econ. Lett. 105 (1), 141–143.
Dahl, M.S., Pedersen, C.Ø., 2004. Knowledge flows through informal contacts in industrial clusters: myth or reality? Res. Policy 33 (10), 1673–1686.
Dustmann, C., Fabbri, F., Preston, I., 2005. The impact of immigration on the British labour market. Econ. J. 115 (507).
Introduction. In: Edquist, C. (Ed.), Systems of Innovation: Technologies, Institutions, and Organizations. London Pinter, pp. 1–35.
Faggian, A., McCann, P., 2006. Human capital flows and regional knowledge assets: a simultaneous equation approach. Oxford Econ. Pap. 52, 475–500.
The Geography of Innovation. In: Feldman, M.P. (Ed.), Kluwer Academic Publishers, Boston.
Feldman, M.P., 2003. The locational dynamics of the US Biotech Industry: knowledge externalities and the anchor hypothesis. Ind. Innov. 10, 311–328.
Florida, R., 2002. The economic geography of talent. Ann. Assoc. Am. Geogr. 92, 743–755.
Foray, D., David, P.A., Hall, B., 2011. Smart Specialization. From Academic Idea to Political Instrument, the Surprising Career of a Concept and the Difficulties Involved in Its Implementation, MTEI Working Paper.
Frenz, M., Ietto-Gillies, G., 2009. The impact on innovation performance of different sources of knowledge: evidence from the UK Community Innovation Survey. Res. Policy 38 (7), 1125–1135.
Gagliardi, L., Iammarino, S., 2017. Innovation in Risky Markets. Multinational and Domestic Firms in the UK Regions. CIMR Research Working Paper Series, Working Paper No. 37.
Gagliardi, L., Marin, G., Miriello, C., 2016. The greener the better? Job creation effects of environmentally-friendly technological change. Ind. Corp. Change 25 (5), 779–807.
Gagliardi, L., 2015. Does skilled migration foster innovative performance? Evidence from British local areas. Pap. Reg. Sci. 94 (4), 773–794.
Ge, C., Huang, K.W., Png, I.P., 2016. Engineer/Scientist careers: patents, online profiles, and misclassification bias. Strateg. Manage. J. 37 (1), 232–253.
Gibson, C.B., Birkinshaw, J., 2004. The antecedents, consequences, and mediating role of organizational ambidexterity. Acad. Manage. J. 47 (2), 209–226.
Glaeser, E.L., Rosenthal, S.S., Strange, W.C., 2010. Urban economics and entrepreneurship. J. Urban Econ. 67 (1), 1–14.
Glitz, A., 2012. The labor market impact of immigration: a quasi-experiment exploiting immigrant location rules in Germany. J. Labor Econ. 30 (1), 175–213.
Grigoriou, K., Rothaermel, F.T., 2014. Structural microfoundations of innovation the role of relational stars. J. Manage. 40 (2), 586–615.
Griliches, Z., 1986. Productivity, R&D, and the basic research at the firm level in the 1970's. Am. Econ. Rev. 76, 141–154.
Groysberg, B., Lee, L.E., 2009. Hiring stars and their colleagues: exploration and exploitation in professional service firms. Organ. Sci. 20 (4), 740–758.
Hagedoorn, J., Cloodt, M., 2003. Measuring innovative performance: is there an advantage in using multiple indicators? Res. Policy 32 (8), 1365–1379.
Harris, R., Moffat, J., 2013. Intangible assets, absorbing knowledge and its impact on firm performance: theory: measurement and policy implications. Contemp. Social Sci. 8, 346–361.
Hatch, N.W., Dyer, J.H., 2004. Human capital and learning as a source of sustainable competitive advantage. Strateg. Manage. J. 25 (12), 1155–1178.
Hoisl, K., 2007. Does mobility increase the productivity of inventors? J. Technol. Transf. 34, 212–225.
Hunt, J., Gauthier-Loiselle, M., 2010. How much does immigration boost innovation? Am. Econ. J. Macroecon. 2 (2), 31–56.
Jaffe, A.B., 1986. Technological opportunity and spillovers of R&D: evidence from firms' patents profits, and market value. Am. Econ. Rev. 76 (5), 984–1001.
Kerr, W.R., 2010. Breakthrough inventions and migrating clusters of innovations. J. Urban Econ. 67, 46–60.
Kogut, B., Zander, U., 1996. What do firms do? Coordination, identity, and learning. Organ. Sci. 7, 502–523.
Lane, P.J., Lubatkin, M., 1998. Relative absorptive capacity and interorganizational learning. Strateg. Manage. J. 19 (5), 461–477.
Lewbel, A., Dong, Y., Yang, T.T., 2012. Comparing features of convenient estimators for binary choice models with endogenous regressors. Can. J. Econ./Revue canadienne d'économique 45 (3), 809–829.
Long, J.S., Freese, J., 2006. Regression Models for Categorical Dependent Variables Using Stata. Stata Press, College Station, Texas.
Love, J.H., Roper, S., 2009. Organizing the innovation process: complementarities in innovation networking. Ind. Innovation 16 (3), 273–290.
Love, J.H., Roper, S., Vahter, P., 2014. Dynamic complementarities in innovation strategies. Res. policy 43 (10), 1774–1784.
Lundvall, B.A. (Ed.), 1992. National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. London Pinter.
Maré, D.C., Fabling, R., Stillman, S., 2014. Innovation and the local workforce. Pap. Reg. Sci. 93 (1), 183–201.
Marshall, A., 1920. Principles of Economics: an Introductory Volume, 8th ed. Macmillan, London.
Mawdsley, J.K., Somaya, D., 2016. Employee mobility and organizational outcomes: an integrative conceptual framework and research agenda. J. Manage. 42 (1), 85–113.
Mayer, K.J., Somaya, D., Williamson, I.O., 2012. Firm-specific, industry-specific, and occupational human capital and the sourcing of knowledge work. Organ. Sci. 23 (5), 1311–1329.
Miguélez, E., Moreno, R., 2013. Research networks and inventors' mobility as drivers of innovation: evidence from Europe. Reg. Stud. 47 (10), 1668–1685.
Miguel, E., Satyanath, S., Sergenti, E., 2004. Economic shocks and civil conflict: an instrumental variables approach. J. Political Econ. 112 (4), 725–753.
Nelson, R.R. (Ed.), 1993. National Innovation Systems: A Comparative Analysis. Oxford

University Press, New York.
Oettl, A., Agrawal, A., 2008. International labor mobility and knowledge flow externalities. J. Int. Bus. Stud. 39 (8), 1242–1260.
Ortega, F., Peri, G., 2009. The Causes and Effects of International Migrations: Evidence from OECD Countries 1980–2005 (No. w14833). National Bureau of Economic Research.
Palomeras, N., Melero, E., 2010. Markets for inventors: learning-by-hiring as a driver of mobility. Manage. Sci. 56 (5), 881–895.
Peri, G., 2007. Higher education, innovation and growth. In: Brunello, G., Garibaldi, P., Etienne, W. (Eds.), Education and Training in Europe. Oxford University Press.
Raisch, S., Birkinshaw, J., 2008. Organizational ambidexterity: antecedents, outcomes, and moderators. J. Manage.
Ramani, S.V., El-Aroui Carrére, M.A., Carrére, M., 2008. On estimating a knowledge-production function at the firm and sector level using patent statistics. Res. Policy 37 (9), 1568–1570.
Rao, H., Drazin, R., 2002. Overcoming resource constraints on product innovation by recruiting talent from rivals: a study of the mutual fund industry, 1986–1994. Acad. Manage. J. 45 (3), 491–507.
Rodríguez-Pose, A., 1999. Innovation prone and innovation averse societies: economic performance in Europe. Growth Change 30 (1), 75–105.
Rodríguez-Pose, A., Crescenzi, R., 2008. R&D, spillovers, innovation systems and the genesis of regional growth in Europe. Reg. Stud. 42 (1), 51–67.
Roper, S., Love, J.H., Bonner, K., 2017. Firms' knowledge search and local knowledge externalities in innovation performance. Res. Policy 46 (1), 43–56.
Rosenkopf, L., Almeida, P., 2003. Overcoming local search through alliances and mobility. Manage. Sci. 49 (6), 751–766.
Rothaermel, F.T., Alexandre, M.T., 2009. Ambidexterity in technology sourcing: the moderating role of absorptive capacity. Organ. Sci. 20 (4), 759–780.
Salomon, R., Jin, B., 2008. Does knowledge spill to leaders or laggards? Exploring industry heterogeneity in learning by exporting. J. Int. Bus. Stud. 39 (1), 132–150.
Salomon, R., Jin, B., 2010. Do leading or lagging firms learn more from exporting? Strateg. Manage. J. 31 (10), 1088–1113.
Salomon, R.M., Shaver, J.M., 2005. Learning by exporting: new insights from examining firm innovation. J. Econ. Manage. Strateg. 14 (2), 431–460.
Shaver, J.M., Flyer, F., 2000. Agglomeration economies, firm heterogeneity, and foreign direct investment in the United States. Strateg. Manage. J. 21 (12), 1175–1194.
Singh, J., Agrawal, A.K., 2011. Recruiting for ideas: how firms exploit the prior inventions of new hires. Manage. Sci. 57, 129–150.
Song, J., Almeida, P., Wu, G., 2003. Learning by Hiring: when is mobility more likely to facilitate interfirm knowledge transfer? Manage. Sci. 49, 351–365.
Staiger, D., Stock, J.H., 1997. Instrumental variables regression with weak instruments. Econometrica 65, 557–586.
Teece, D.J., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. Strateg. Manage. J. 509–533.
Trajtenberg, M., Shiff, G., Melamed, R., 2006. The Names Games: Harnessing Inventors' Patents Data for Economic Research, NBER WP 12479.
Trippl, M., Maier, G., 2010. Knowledge spillover agents and regional development. Pap. Reg. Sci. 89 (2), 229–233.
Tushman, M., O'Reilly, C., 2007. Research and relevance: implications of Pasteur's quadrant for doctoral programs and faculty development. Acad. Manage. J. 50 (4), 769–774.
Uyarra, E., 2011. Regional innovation systems revisited: networks, institutions, policy and complexity. In: Herrschelt, T., Tallberg, P. (Eds.), The Role of Regions? Network, Scale, Territory. Region Skane, Gothenburg.
Van Leeuwen, G., Klomp, L., 2006. On the contribution of innovation to multi-factor productivity growth. Econ. Innov. New Technol. 15 (4–5), 367–390.
Zahra, S.A., George, G., 2002. Absorptive capacity: a review, reconceptualization, and extension. Acad. Manage. Rev. 27 (2), 185–203.
Zorn, C., 2005. A solution to separation in binary response models. Political Anal. 13, 157–170.
Zucker, L.G., Darby, R.M., Armstrong, J., 1998a. Geographically localized knowledge: spillovers or markets? Econ. Inq. 36 (1), 65–86.
Zucker, L.G., Darby, M.R., Brewer, M.B., 1998b. Intellectual human capital and the birth of U.S. biotechnology enterprises. Am. Econ. Rev. 88, 290–306.
Zucker, L.G., Darby, M.R., Furner, J., Liu, R.C., Ma, H., 2007. Minerva unbound: knowledge stocks, knowledge flows and new knowledge production. Res. Policy 36 (6), 850–863.