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Moving People with Ideas Innovation, Inter-regional Mobility and Firm Heterogeneity

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Abstract

This paper looks at the link between inter-regional mobility, innovation and firms' behavioural heterogeneity in their reliance on localised external sources of knowledge. By linking patent data (capturing inventors' inter-regional mobility) with firm-level data (providing information on firms' innovation inputs and behaviour) a robust identification strategy makes it possible to shed new light on the geographical mobility-innovation nexus. The analysis of English firms suggests that firm-level heterogeneity – largely overlooked in previous studies - is the key to explain the innovation impact of inter-regional mobility over and above learning-by-hiring mechanisms. A causal link between inflows of new inventors into the local labour market and innovation emerges only for firms that make the use of external knowledge sources an integral part of their innovation strategies.

Keywords: Innovation, Labour Mobility, Inter-regional Migration, Spillovers

JEL Classifications: O31; O15; J61; R23

1. Introduction

Technology and innovation shape economic growth and development trajectories (Schumpeter, 1934; Abramovitz, 1956; Solow, 1957; Romer, 1986 and 1990): access to new technologies and innovation constitutes a key determinant of both national and regional competitiveness (Storper, 1997; Archibugi and Lundvall, 2001; Simmie, 2004; Crescenzi and Rodriguez-Pose, 2011). However, a large body of empirical evidence suggests that this access is far from 'universal': knowledge generation and absorption are highly localized and diffusion follows very complex (and ever changing) patterns (Döring and Schnellenbach, 2006; Carlino and Kerr, 2014).

In both developed and emerging countries, a small number of 'hotspots' are pushing the technological frontier forward, followed by a set of second-tier emerging 'imitative systems' and a large number of territories that show little or no innovative dynamism (Sun, 2003; Usai, 2008). In this context, new windows of opportunity are opening for a set of new suitable 'locations' both in Europe and in the United States where patent intensity shows signs of spatial de-concentration (Crescenzi et al., 2007; Charlot et al., 2014). In the United Kingdom the long-term innovation strength of the South-East has been accompanied by the emergence of new innovative hotspots some in already dynamic areas other outside the 'core'. Over the past fifteen years more than 1,500 information and communication technology (ICT) firms have clustered around Shoreditch in East London forming a new 'Silicon Roundabout' around Old Street (Nathan and Overman, 2013). The recent launch of three Local Digital Catapult Centres in Sunderland, Brighton and Bradford is an example of active policy attempts to nurture new digital tech clusters in the UK[1] outside the traditional 'core'.

The consolidation and expansion of existing innovation centres, as well as the emergence of new dynamic areas (and their sustainability) are the result of the

[1] http://www.digitalcatapultcentre.org.uk/three-local-catapult-centres-are-launched/

interaction between localised ‘indigenous’ factors (at the micro-firm and territorial-systemic levels) as well as ‘external’ conditions - i.e. the position of local firms and other innovative actors within knowledge networks (Santangelo, 2002; Simmie, 2003; Saxenian 2006; Mare’ et al. 2011) - generated in various ways by inward and outward flows of both capital and skilled labour.

The economic geography and urban economics literature has devoted substantial attention to the role of labour mobility in shaping the diffusion of knowledge and innovation in space (Carlino and Kerr, 2014). Some existing studies have adopted a meso-level perspective, taking regions as their unit of analysis in order to capture the systemic interactions between skill inflows and the recipient regional economy (e.g. Faggian and McCann 2006 and 2009). Other studies have taken a micro-level perspective looking at the impact of mobility on the individual performance of skilled individuals/graduates (e.g. Abreu et al. 2011) or inventors (e.g. Lenzi 2009). This paper aims to complement these separated approaches by bridging the micro and meso-level perspectives: firms are the unit of analysis (micro-level) and their performance is linked to the spatial mobility of highly-skilled highly-innovative individuals – multi-patent inventors[2] - while explicitly capturing how firms’ linkages with the external environment (meso-level) shape their capacity to benefit from these inflows. This approach makes it possible to shed new light on the territorial interactions between firms and innovative individuals and it provides new evidence on the role of firm-level heterogeneity in terms of knowledge-acquisition behavior in shaping these interactions. The analysis disentangles the spatially-mediated/agglomeration impact of inventors mobility from the traditional learning-by-hiring mechanism by focusing on mobility into self-contained local labour markets (the geographical contexts in which formal and informal knowledge exchange takes place) while controlling for the direct influence of newly hired skilled personnel at the firm-level, thus isolating the impact of inventors' mobility that passes through 'external' mechanisms[3].

In addition the paper makes original contributions to the existing literature on three further fronts. First, it focuses on inter-regional domestic mobility. Internal 'movers' are more 'homogenous' to the local environment (when compared for example to international migrants), making it easier to disentangle the impact of mobility from their contribution to local 'diversity'/'variety' (Maré et al. 2010). However, at the same time, the internal mobility of individuals by skill intensity is very hard to capture with standard data sources. This has forced the existing innovation literature – when trying to capture internal mobility - to focus almost exclusively on the mobility of recent graduates whose contribution to innovation processes is only 'potential' and possibly delayed in time. Conversely, by looking at inventors this paper can capture the internal-regional mobility of individuals who directly contribute to the innovation process. Second, this paper relies on firm-level data from the UK Community Innovation Survey (UK-CIS) that make it possible to capture both product and process innovation while, at the same time, avoiding the mechanical correlation that inevitably affects existing works that capture both mobility and innovation output by means of patent data. Third, the empirical analysis relies on a robust estimation strategy. The panel structure of the dataset makes it possible to fully control for firm-specific characteristics, accounting for both observable (such as for example intramural R&D, skilled employees[4] and market strategies) and unobservable time-invariant firm-level characteristics. In addition reverse causality – a key issue in large part of the existing literature – is dealt with by means of an Instrumental Variable (IV) strategy: we use peaks (if any) in the citations received by inventors in the twelve months immediately following the publication of their patents as a signal for inventors' quality. The immediate payoff of a highly

[3] Existing available data for the United Kingdom do not allow a direct association of CIS firms with their corresponding patents. Therefore it is impossible to directly associate inventors to individual firms.

[4] The possibility to account for the number of skilled employees in each firm, in particular, is a key advantage in CIS data since it allows identifying the overall impact of mobility on local innovation while factoring out the amount of new skills that each firm can internalize by hiring new employees.

successful (and highly cited) invention may, in fact, be associated with greater visibility and greater opportunities for mobility. In other words a highly successful invention is interpreted as an individual push factor increasing the probability of mobility (Trajtenberg et al., 2006) independently of the attractiveness and the innovative performance of any firms in any possible destination region.

The empirical analysis of English firms shows that the mobility of highly skilled and innovative individuals – proxied by multi-patent inventors - does not affect firms' innovative performance in recipient areas after controlling for firms' specific characteristics. Conversely, the positive impact of inward mobility identified in previous studies only emerges when accounting for the role of firms' interactions with their external environment. When the sample is restricted to firms complementing internal with external sources of knowledge this heterogeneous effect becomes apparent. Only if firms have the capability to complement internal and external sources of knowledge they can benefit from the positive spatial externalities generated by the inflow of highly innovative individuals in their functional neighborhood. This suggests that innovative performance can be fully explained neither by firms' internal inputs (Loof and Heshmati, 2006, Van Leeuwen and Klomp, 2006) nor by their external environment in isolation but it is rather the result of the interaction between the latter and firms' heterogeneous internal assets, technological capabilities and knowledge management strategies (Alcacer and Delgado, 2013; Mare' et al, 2014; Gagliardi, 2014).

The paper is organized as follows. The next section shortly reviews the existing literature in order to frame the research questions addressed in the paper. Section 3 discusses the data focusing in particular on how mobility patterns are traced using patents and how different data sources are innovatively combined for the construction of the key variables. Section 4 presents the model of empirical analysis and discusses the key identification challenges. Section 5 illustrates the main results while Section 6 concludes with some policy considerations.

2. Geographical mobility of knowledgeable individuals and innovation: a non-obvious link

Individuals are the repositories of both skills and ideas and their location and mobility are key to knowledge accumulation and circulation (Leamer and Storper, 2001; Herrera et al., 2010). Since knowledge tends to travel along with people who master it (Breschi and Lissoni, 2001), the mobility of knowledgeable individuals leads to the circulation of knowledge across locations, shaping the structure of the networks between innovative agents (Agrawal et al., 2006) and ultimately the geography of innovation (Feldman 1994 and 2003). Following this line of reasoning, the existing literature has suggested that inflows of highly skilled individuals enrich the local knowledge base, increasing productivity and creativity of local firms (Marè et al, 2011). The expected positive effect of the inflow of skilled individuals on firms located in recipient labour markets goes beyond the local availability of new skills accessible through learning-by-hiring mechanisms (Song et al, 2003; Lewis and Yao, 2006) but it also contributes to the creation of a contextually enabling environment for innovation (Carlino et al. 2007; Glaeser et al., 2010; Kerr 2010).

Despite the increasing attention on the impact of mobility patterns on innovation performance a number of relevant questions still remain unanswered on the key mechanisms underlying this link. In particular the existing literature has taken two different – and somewhat separated – approaches to the study of the mobility-innovation nexus: a meso-level/regional approach focused on the innovative performance of recipient regions and a micro-level approach looking at the innovative performance of movers.

Meso-level analyses are based on different formulations of the regional knowledge production function (R-KPF) augmented in order to account for either the cultural/ethnic diversity of the local environment (as a result of the stratification of international migration flows) or the in-flows of highly skilled individuals. Studies focused on the impact of local diversity (e.g. Maré et al., 2010; Niebuhr, 2010; Ozgen et al., 2011) converge on the identification of a positive impact of diversity on regional innovation performance. However, often due to data limitations, these studies are unable to explore the skill composition of mobility flows (and their local stratifications) and their focus remains inherently on international (rather than inter-regional) mobility. Conversely, research aiming at identifying the direct impact of highly skilled individuals has focused on specific categories of movers: either graduates (Faggian and McCann, 2006 and 2009 in the UK; Chellaraj et al., 2008 and Hunt and Gauthier-Loiselle, 2010 in the USA) or inventors (Kerr and Lincoln 2010; Carlino et al. 2012 in the USA; Peri, 2005 and 2007; Miguelez and Moreno, 2010 in Europe). These studies all converge in suggesting a positive state/regional/city-level effect of mobility on innovation: composition effects taking place within recipient spatial units result in an innovation-enhancing effect. More recent contributions have tried to further investigate the localized conditions that shape these impacts. Conditioning factors are linked, for example, to the technological trajectory of the local economy or to local firms' heterogeneity. Kerr (2010) provides evidence on the former effect by looking at how breakthrough inventions might attract immigrant scientists and engineers leading to the emergence of urban environments able to support new innovation clusters. Conversely, Mare' et al. (2014) and Gagliardi (2014) by combining firm-level micro data with information on the skill structure of the local workforce (for New Zealand and the UK respectively) suggest that when the characteristics of local firms are fully accounted for there is no evidence of an independent link between mobility and innovation.

Given their direct relevance to the innovation process the more micro-level literature has focused on the mobility of inventors exploring two key aspects: the impact of mobility on either the performance of individual inventors or on that of the firms hiring them. The first group of studies focuses its attention on the performance of inventors following their mobility decision (Hoils 2007 and 2009 for the case of German inventors;

Lenzi 2009 for Italy) and finds a positive link between mobility and subsequent patenting productivity. However these same studies also highlight the importance of personal characteristics in shaping this outcome. The second group of studies looks into learning-by-hiring mechanisms (Song et al., 2003; Kim et al., 2006; Crespi et al., 2007; Corredoira and Rosenkopf, 2010; Singh and Agrawal, 2011) and identifies the benefits of movers' knowledge for hiring firms. However, the benefits to the hiring firms are enhanced by the complementarity between inventors' and firms' pre-existing stock of knowledge (Singh and Agrawal, 2011) and by the links established with the knowledge base of previous employers (Corredoira and Rosenkopf, 2010).

To sum up, the review of the existing literature shows that different streams of research converge on three fundamental points. First, the mobility/innovation nexus is highly heterogeneous depending on the characteristics of individual movers, of the recipient firms and of the local environment/labour markets. Second, the learning-by-hiring mechanism is only part of the explanation of the transmission of knowledge enabled by spatial mobility: there is something more that cannot be fully captured by individual micro-level outcomes and that, at the same time, remains hidden in the composition effect of R-KPF studies.

The 'enabling' environment supporting the localized diffusion of knowledge following the inflow of highly skilled/innovative individuals has been often 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 (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997; Cooke et al., 1997). The latter emphasised the importance of "regionally embedded, institutionally supported, networks of actors" (Uyarra, 2010 p. 125), implying that the impact of the inflows of knowledgeable (as well as any other increase in locally available knowledge inputs) is highly dependent upon the ways in which firms (and other innovative actors) search for their knowledge inputs, by building (or not) connections with their local environment. For example – as shown by Agrawal et al. 2010 – 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 behaviour. This behaviour reflects the different ways in which firms balance their 'internal' (i.e. intra-firm linkages) and 'external' (geographically bounded linkages) agglomerations (Alcacer and Delgado, 2013).

As a consequence, the way in which firms search for knowledge outside their organisational boundaries seems to be the result of the combination of firm-level and local-level characteristics. However, while different streams of literature agree on the relevance of these behavioural traits of local firms for their innovation performance, there is no empirical evidence on their role as key factor conditioning the innovation impact of mobility flows.

3. Combination of data sources and measurement problems

3.1 Tracing inventors' mobility using patent data

Patent data have been extensively used in the literature in order to analyze the mobility of star scientists and its impacts (Zucker, Darby and Armstrong, 1998a; Zucker, Darby and Brewer, 1998b; Almeida and Kogut, 1999; Stolpe, 2001; Singh, 2003; Song et al, 2003; Zucker and Darby, 2006, 2007; Hoisl, 2007; Breschi and Lissoni, 2009; Miguelez and Moreno, 2010; Miguelez et al., 2010). They make it possible to exploit information at the level of the individual inventors and to trace their mobility at a very detailed geographical level. This makes patent data particularly suitable for the analysis of inter-regional mobility given that "micro-data on interregional labour mobility is [otherwise] very difficult to find" (Faggian and McCann 2009, p. 320), in particular for specific segments of the skill distribution.

The analysis of mobility patterns by means of patent data exploits information on multi-patent inventors (i.e. inventors of more than one patent) by comparing their residential addresses in each patent record: where a change is detected over time the inventor moved from one location to another. If the old and the new addresses are sufficiently distant in geographical space (or they belong to different regions or countries) the inventor is classified as a 'mover'.

This procedure, while customary in the literature, calls for a special attention in the exact identification of each inventor in the patent database ('*Who's who problem').* Inventors' names are sometimes misspelled or misreported in patent documents, making it difficult to associate different patents to the same individual in the case of multi-patent inventors (Trajtenberg et al., 2006). In order to deal with this potential problem we rely on the KEINS database (Lissoni et al., 2006) that includes all applications to the European Patent Office (EPO) after – among other procedures - a careful and systematic treatment of misreporting/misspelling of inventors' names[5].

Once multi-patent inventors are clearly and univocally identified the precise identification of movers is also non-straightforward. Patent records report detailed geographical information (at the postcode level) on patenting inventors, making it possible to identify their exact spatial location. Postcode information can be re-aggregated at the Travel to Work Area (TTWA) level, in order to capture mobility across functional local labour markets in Britain[6]. Patent records make it also possible to identify the time-frame for the mobility event by looking at the priority date of the invention associated to the new inventor's address[7]: if inventor Alpha patented invention 1 at time t in Cambridge and invention 2 at time t+T in London we can

[5] See Lissoni et al, 2006 for further information on the data-cleaning procedure

[6] Mobility is defined with respect to changes in the place of residence of individual inventors, not their place of work. Whereas changes in inventors' residence are likely to explain non market-mediated externalities (e.g. those associated with informal face-to-face contacts) they may – in principle - underestimate the externalities mediated by the labour market. However, in our analysis, this potential bias is minimized by the use of 'functional labour markets' (i.e. Travel to Work Areas - TTWAs) to identify the residential movers. TTWAs are defined as self-containing labour markets based on commuting flows with at least 75% of people living and working in the same area. This implies that changes in the TTWA of residence are very likely to correspond to simultaneous changes in the TTWA of work.

[7] Information on the time of the invention refers to the priority data, which is considered by OECD the closest to the invention process.

conclude that (s)he moved from Cambridge to London in the time-window (t,t+T). In order to develop the most accurate mobility measure possible – for the purposes of this paper it is best to under-estimate mobility rather than to over-estimate it – we restrict the time window associated to the mobility event by focusing exclusively on recent movers: we consider as 'movers' inventors changing their residential address in a three-year time window between two inventions at different addresses, minimising any influence due to alternative confounding factors that can affect the relation between mobility and innovation over a longer time interval and capture the 'novelty' of the knowledge 'imported' by the newcomer into the destination TTWA. The focus on multi-patent inventors and the 'conservative' rule adopted in order to identify 'recent' movers reduces significantly the number of available observations making it impossible to develop a measure of actual flows. Flows measures are likely to be affected by significant measurement issues that may generate a severe attenuation bias in our estimates. For this reason our preferred measure of mobility has been constructed as a dummy variable taking value 1 in case of positive inflows of inventors in a certain locations and zero otherwise. Our key regressor is thus aimed at providing a representative proxy for the spatial patterns of inventors' mobility across England as a 'shock' indicator for the local knowledge stock (rather than a measure of actual inflows).

The descriptive analysis of inter-regional mobility patterns in England shows that among the total sample of 'recent' movers changing TTWA of residence between 2000 and 2005 (the lagged time window used in our estimations), 54.2% moved in a different NUTS3 region, 47.9% in a different NUTS2 region and 31.3% changed NUTS1 region of residence. Although some traditionally successful areas, such as for example London or 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 2003-2005. Inter-regional mobility patterns have been more relevant in the first rather than the second period with some differences also in their geographical distribution.

3.2 Firm-level data

Data on inventors' mobility are complemented by information on firms' innovative performance from the UK Community Innovation Survey (UK-CIS)[8].

The UK-CIS is a firm-level survey providing information on firms' innovative performance with respect to different types of innovation outcomes (product, process and organizational innovation). The survey offers detailed data also on the internal inputs devoted to the innovative process (financial investments and employees) and a large range of other firm-level characteristics (such as size, sector of activity, market of reference, etc.).

The CIS is the best possible data source for this analysis for several reasons. First, it is constructed in order to build a balanced sample among all sectors of activity reducing the traditional bias of patent data toward high-tech sectors. Second, the sample is characterised by a significant share of small and medium sized enterprises[9] thus capturing a typology of innovation that is substantially different from that captured by patents. Finally, it provides detailed information on skilled employees in each firm, allowing us to disentangle the impact of mobility into local labour markets from learning-by-hiring mechanisms (i.e. the new knowledge that firms can access by hiring new personnel).

Two consecutive waves of the UK-CIS have been merged to build our database: CIS4 (covering the 2002-2004 period) and CIS2007 (covering the 2005-2007 period). Previous research using CIS data focused on a single wave thus limiting the possibility to fully control for firms' specific characteristics: 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 merged CIS4 – CIS2007

[8] 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.

[9] Almost the 70% of our total sample of firms is classified as small or medium enterprise.

sample has been, in its turn, merged with the Business Structural Database (BSD 2004) database[10]. This has allowed the retrieval of the 7-digits postcode of each firm and, as result, their attribution to the corresponding TTWAs. Data from the UK-CIS have been used to construct the dependent variable (dummy variable taking value 1 if the firm is performing any product or process innovation and 0 otherwise) and all other firm-level regressors.

CIS data have been matched with our measure of inventors' mobility based on the combination of both space and time criteria[11]. Inventors who moved within the time span 2000-2002 have been linked to the UK-CIS4 (2002-2004) while inventors moving between 2003 and 2005 have been associated to the subsequent CIS2007 wave (2005-2007). The geographical criterion matches firms and inventors via their TTWA of operation and destination respectively. Table 1 shows the number of firms in our sample by innovation status and whether they are located in an area experiencing investors' inflows.

Interestingly, firms located in areas experiencing inventors' inflows show consistently better innovative performance. This preliminary evidence correlates with early studies in the field that attributed a positive innovation impact to the mobility of knowledgeable individuals. The full list of variables used in the empirical analysis and standard descriptive statistics are reported in table 2.

[10] The Business Structure Database (BSD), derived from the Inter-Governmental Department Business Register (IDBR), covers the 99% of economic activity in UK and provides geo- referenced firm- based data with 7 digits postcode. 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.

[11] Sectoral characteristics cannot be used in order to merge the two datasets. Patents are classified in terms of technological classes (not industrial sectors) and this classification remains a patent-specific rather than inventor-specific characteristic. Multi-patent inventors may patent in multiple technological classes that are relevant to a variety of industrial sectors. As a consequence we assume that the impact of the mobility of knowledgeable individuals on firms' innovation is not constrained within a single technological class or industrial sector.

4. Estimation strategy

The analysis of the effect of mobility on firms' innovation is based on the Knowledge Production Function (KPF) approach popularized by Griliches (1979, 1986) and Jaffe (1986) where firms' innovative performance can be explained by the amount of internal inputs (mainly capital and labour) devoted to the innovative process.

The standard specification is augmented by our regressor of interest in order to account for the role of geographical mobility as additional determinant of innovation. From the methodological point of view this implies adopting a spatial correlation approach (*Borjas, 1999*) assuming that firms located in areas 'shocked' by a recent inflow of knowledgeable individuals/multi-patent inventors will benefit from an additional extra-firm source of (novel, non-redundant) knowledge. By focusing on self-contained local labour market areas (TTWAs) and factoring out the direct impact of mobility on firms' innovation by controlling for the share of skilled employees in each firm (which includes the possible hiring of new inventors), our specification captures the contribution of mobility to the creation of a contextually enabling environment for firm-level innovation. By looking at how mobility impacts upon the level of creativity and productivity of local interactions, over and beyond those explicitly mediated by the labour market, the analysis provides fresh evidence on the role of human capital externalities in the emergence of innovative outcomes.

The estimation equation takes the following form:

$$P\left(Innovation_{c,t}^{i}\right) = \beta_0 + \beta_1 K_{c,t}^{i} + \beta_2 L_{c,t}^{i} + \beta_3 Inventors'Inflows_{c,t-T} + \delta_i + \delta_t + \varepsilon_{c,t}^{i} \quad (1)$$

Where:

- $P(Innovation_{c,t}^{i})$ is the probability of performing any product or process innovation for firm *i* located in TTWA *c* at time *t*;

- $K_{c,t}^{i}$ is the amount of intramural R&D expenditure that each firm *i* located in TTWA *c* within the period *t* devoted to the innovative process;
- $L_{c,t}^{i}$ is the share of high skilled workers[12] employed by firm *i* located in TTWA *c* within the period *t*
- $Inventors\_flows_{c,t-T}$, the regressor of interest, is a dummy that takes value 1 if TTWA *c* experience inventors inflows at time *t-T* and 0 otherwise;
- δ^{i}, δ_{t} and are firm and time fixed effect respectively;
- $\varepsilon_{c,t}^{i}$ is the error term.

The above specification benefits from the panel dimension of our data, accounting for firm and time-specific characteristics. This is a highly valuable feature since the majority of previous contributions, notwithstanding the increasing evidence on the relevance of firms' heterogeneity in mediating the impact between mobility and innovation, cannot fully account for firm fixed effects[13]. The relation of interest is estimated by means of a Linear Probability Model (LPM). Several considerations justify this methodological choice. First, estimating equation (1) through a 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 dependent and independent variables of interest are binary[14]. The conventional response to separation problems is to drop from the analysis the observations that generate the problem (Long and Freese, 2006). However, this is a highly problematic

[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 higher degree, e.g. MA/Phd, PGCE) in science and engineering or in other fields.

[13] The structure of our data does make it possible to control for area-level trends that, in principle, might be a relevant explanation for firms' innovative performance. However, the analysis covers a limited time-span in which changes in local conditions cannot produce any substantial impact on firms' innovative performance.

[14] In our case the dependent variable $P(Innovation_{c,t}^{i})$ is perfectly predicted by $Inventors\_flows_{c,t-T}$ 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 equation (1) using probit/logit techniques.

choice when the separation may reflect a genuine causal process - as potentially in our case - and the problem is further worsened by the fact that 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 dealt with by means of two-stage techniques – as in the case of this analysis – cannot be applied in a straightforward manner in the context of Maximum Likelihood (ML) or Control Function (CF) approaches. In case of any misspecification of the first stage the 2SLS approach would lose 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 remains applicable also to an ordinary least squares (OLS) estimation approach, the second and third considerations represent a key feature of this empirical framework which aims at identifying causal predictions for the impact of inter-regional mobility on innovation. The concurrence of all the above-mentioned features of the empirical framework under analysis has driven our choice in favour of the LPM as the most suitable estimation strategy. The choice of the LPM under similar conditions is now customary in the empirical literature, delivering (where direct comparisons are made possible by the data) qualitatively similar results (Miguel et al., 2004; Gagliardi, 2014; Crescenzi et al, 2015)

4.1 Identification strategy

The model specified above aims to test the hypothesis that inflows of knowledgeable individuals in a specific geographical context may affect the innovative performance of local firms through their influence on the degree of creativity and productivity of local interactions (Mare' et al, 2010).

Causality may, however, also run in the opposite direction. Spatial contexts in which highly innovative firms are located may be able to attract a larger number of knowledgeable individuals due, for example, to better job opportunities.

The possibility to control for firm and time specific characteristics and the adoption of a 'lagged' measure of mobility limit substantially 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 labour inflows into their entire labour market area. However, in order to minimise any potential reverse causality bias, we adopt a novel instrumental variables (IV) approach. Previous studies have accounted for endogeneity by means of a number of different instruments. Hoisl (2007) looked at whether the invention was made in a large city or in a rural area assuming that inventions made in large urban areas have a greater signalling effect, leading to a higher probability for their inventor(s) to receive a job offer by a competitor of their current employer. Miguelez and Moreno (2010) adopted spatial econometrics techniques, using the spatial lag of the additional regressors to instrument mobility. Gagliardi (2014) employed a shift-share approach to attribute actual flows on the basis of patterns of historical settlements.

Conversely, the IV adopted in this paper assumes that inflows in each TTWA c may be instrumented by push factors operating in all other TTWAs $j \neq c$. As push factors we exploit the signalling effect linked to the quality of a highly successful invention that increases inventors' visibility making them more attractive for potential employers located in other labour markets different from c.

For each TTWA *j* we calculate the index $Cit^{j}_{t-T,t-T+1}$ as the number of citations received by all patents published the year before our mobility time window[15] (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.

$$Cit^{j}_{t-T,t-T+1} = \frac{Number\ of\ Citations^{j}_{t-T,t-T+1}}{Number\ of\ Patents^{j}_{t-T,t-T+1}} \tag{2}$$

The IV is then constructed comparing for each TTWA *j* the $Cit^{j}_{t-T,t-T+1}$ index with the average number of citations per patent in the 12 months after publication at the national level during the time span 1995-2007.

Computationally the instrument takes the following form:

$$PeakCitations^{c}_{t-T} = \sum_{j\neq c}^{n} \frac{\left(Cit^{j}_{t-T,t-T+1} - \frac{NationalNumber\ of\ Citations_{1995,2007}}{NationalNumber\ of\ Patents_{1995,2007}}\right)}{\frac{NationalNumber\ of\ Citations_{1995,2007}}{NationalNumber\ of\ Patents_{1995,2007}}} * W_{cj}$$

(3)

Where $W_{c,j}$ is an inverse linear distance matrix between each TTWA *c* and all the other TTWAs *j.*

In other words, the in-flows of inventors in each TTWAs c is instrumented by the spatially weighted average of the peaks in citations of inventions patented in all other TTWAs j.

[15] 1999 and 2002 respectively

A disproportionate increase in the number of recent citations with respect to the national average is interpreted as a signal for the recent development of a highly successful invention. The immediate payoff of a highly successful invention may be associated with greater visibility and opportunities of mobility and job offers. In this view a highly successful invention may be interpreted as an individual push factor increasing the probability of mobility independently of the degree of attractiveness of the potential areas of destination. As a consequence we expect our instrument to be positively correlated to the instrumented (inter-regional mobility) variable. This rationale is supported by previous related research showing that the inventors characterized by more valuable patents (i.e. most cited patents) are those with the highest probability of mobility (*Trajtenberg et al., 2006*). In this context the exclusion restriction relies on the assumption that the IV, based on a peak in the number of recent citations in area c, has no direct effect on firms' innovation in recipient areas other than via mobility. However, 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 citation peak: it is unlikely that firms can take advance of highly visible inventions in other regions through imitative dynamics by developing related inventions in just 12 months. The use of patents to legally protect these inventions implies an ownership advantage that is unkely to be eroded by imitation in such a short time-span (Van Reenen and Bloom, 2002). Conversely, spillovers though backward and forward linkages may still be a relevant concern and we will explicitly check for the robustness of our IV estimates against these alternative channels of knowledge diffusion.

From the methodological point of view the focus on the forward citations received in the 12 months after patent publication is consistent with our interest in the potential signalling 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 inventions receiving relevant attention outside each individual local area ('national champions'). Finally the selection of a time interval spanning from 1995 to 2007 to construct 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.

5. Empirical Results and robustness checks

Results for the estimation of the effect of inventors' mobility on the innovative performance of English firms 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 investment in R&D and the proportion of employment with tertiary degrees or above. Our baseline specification also controls for firm and time fixed effects.

The estimates confirm the relevance of R&D investment, which turns out to be a positive and significant determinant of innovation as expected. The regressor for human capital input into the KPF shows the expected sign and is significant at 10%. In the interpretation of this coefficient it is important to consider the specific features of the CIS sample, which is skewed towards small and medium enterprises with a relatively limited variation in their hiring capacity over time (*UK Data Archive Studies, 2008*).

Column 2 introduces our key variable of interest (Inventors' inflows) constructed in order to take value 1 if the firm is located in a TTWA that experienced inflows of inventors before the time span under analysis. The positive sign of the estimated coefficient confirms the preliminary insights from the descriptive statistics suggesting a positive association between inflows of inventors in the local labour market and the innovative performance of the corresponding firms. The regressor is, however, not statistically significant. This evidence is also confirmed after controlling for differences in market strategies by including a regressor for firms' export orientation. This additional control is customary in the literature based on the CIS and makes it possible to control for changes in firms' growth and/or general performance in a time-varying fashion (size, structure etc. are all captured by the FE already) (Column 3).

Our results seem to be in line with other recent studies recommending greater caution in the analysis of the impact of mobility on firms' innovation. When firms' specific characteristics are fully accounted for there is no evidence of an independent link between mobility and innovation, implying that firms' heterogeneity is the key missing link in previous studies (in particular in 'aggregate' studies based on regional knowledge production functions).

This conclusion is reinforced when the baseline specification is re-estimated by neglecting the panel structure of the data and employing a pooled OLS approach. When we fail to fully control for firms' time invariant (observable and unobservable) characteristics the regressor of interest turns positive and statistically significant at 5% (Table 4, Panel I, Column 1). This result holds also when area-specific characteristics are fully controlled for by means of TTWA dummies (Panel I, Column 2), suggesting that it is firm-level heterogeneity that drives the positive impact of mobility flows rather than local/geographical heterogeneity.

Besides the role played in explaining the heterogeneity in the degree of attractiveness across geographical areas, locational attributes do not fully account for the heterogeneity across firms in their capability to benefit from new available sources of localized knowledge. This further suggests that the effect of mobility on firms' innovation is primarily mediated by firm-specific characteristics in terms of absorptive capacity, learning behavior (inward looking/myopic) and/or capabilities to form 'systemic' bridges with other local actors.

Our baseline specification is re-run also on product and process innovation separately (Table 4, Panel II, Columns 3 and 4). The intrinsic nature of the knowledge flows associate to our mobility measure – that is focused on the 'producers' of patentable innovations - is more directly linked with product rather than process innovation. Despite some evidence of variation in the magnitude of the coefficient in the expected direction (larger coefficient for product innovation), no evidence of systematic changes in the statistical significance is found.

Overall, the results discussed so far – in line with part of the existing micro-level literature - do not find empirical support for a link between inflows of inter-regionally mobile inventors and firms' innovative performance in recipient areas. This lack of statistical significance seems to be mainly explained by firm-level heterogeneity. These results remain consistent also when further endogeneity concerns are accounted for by means of the instrumental variable approach presented in section 4.1. Inventors' inflows remain positively associated to innovation but not statistically significant (Table 5, Panel I, 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 validity of our IV approach (Panel I, Column 2) showing a F-statistics that is well above the value of ten from the 'rule of thumb' proposed Staiger and Stock (1997) and the thresholds values developed by Stock and Yogo (2005).
The IV framework makes it also possible to further investigate the role played by firms' heterogeneity in accounting for the emergence of heterogeneous effects associated to the attitude of firms towards the exploitation of external sources of information.

Both urban economists and the regional systems of innovation literature suggest that mobility is a powerful channel of knowledge diffusion potentially generating valuable positive externalities in recipient locations (over and above the learning-by-hiring mechanisms taking place within the organizational boundaries of individual firms). However, as discussed in the literature review, the existing literature has often overlooked the bidirectional nature of knowledge flows, paying limited attention to firms' learning behavior as a key building block of localized systemic interactions (Crescenzi et al., 2015). Although knowledge originates elsewhere or is carried by external actors, the receiving node has to play an active role to decode, animate and recreate that knowledge in the new context (Barnard and Cantwell, 2006; Storper and Venables, 2004). This implies that deliberate strategies pursued by local firms may substantially shape their capability to absorb and exploit the external knowledge injected by the 'newcomer' inventors in an effective way.

The UK-CIS survey makes it possible to test these mechanisms by means of information on firms' heterogeneity in learning behaviour: the CIS questionnaire devotes an entire section to the nature of knowledge sources used by each firm to develop innovation. The questionnaire distinguishes between knowledge coming from external sources covering a wide range of economic actors (suppliers, clients, customers, competitors, other businesses in the industry, consultants, commercial labs, universities and private R&D institutes) and sources that are internal to the firm itself.

In order to identify this heterogeneous effect we restrict the analysis to those firms declaring that they significantly exploit 'external sources[16] 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 firm's economic performance (Criscuolo et al, 2005, Loof and Heshmati, 2006, Van Leeuwen and Klomp, 2006, Crespi et al., 2007*)*.

[16] With reference to the question regarding the importance of different sources of information in the development of innovation we selected those firms rating 2 or 3 in a scale from 0 to 3 the category 'market sources of information' and 'institutional sources of information' that include suppliers, clients, customers, competitors, other businesses in the industry, consultants, commercial labs, universities and public and private R&D institutes.

Interestingly when we focus on those firms that are more likely to consider external knowledge as an innovation input the effect of mobility on innovation becomes positive and significant at 5% level (Table 5, Panel II, Column 1). The estimated coefficient suggests that firms located in areas experiencing inventors' inflows are on average 20% more likely to develop process or product innovation. Interestingly the coefficient for other traditional internal inputs - such as R&D investments - is sensibly lower than in the full sample, supporting the view that external sources of knowledge can partially substitute for internal resources in outward oriented firms.

The magnitude of the effect, despite being not 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 one percentage point increase in immigrant college graduates. Gagliardi (2015) – using CIS data for the 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 highly robust also on the restricted sample. First stage results reported in Column 2 (Panel II, Table 5) confirm that the instrument remains significantly correlated with our regressor of interest and highly significant. Also in this case the F-statistics suggest that the IV does not suffer from weak instrument bias.

The robustness of these IV estimates is also tested with respect to alternative channels of knowledge diffusion. The exclusion restriction relies on the assumption that recent citations's peaks at the TTWA level signal the recent development of highly successful inventions and affect innovation only though the mobility of inventors. As discussed in section 4.1, demonstration effects are unlikely to represent an alternative channel for the diffusion of these highly successful inventions. Conversely, buyer-supplier linkages may still play a relevant role. 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[17]. Results reported in table 6 (Column 1 and 2) show that our findings are robust to the inclusion of these additional controls (although the coefficient for inventors' inflows is slightly lower on the full sample with respect to estimates reported in table 5 - Panel I). Overall spillovers through backward and forward linkages play a much more significant role on the full sample rather than on the restricted sample of firms showing an attitude towards the exploitation of external sources of knowledge.

These results suggest that firms' heterogeneity plays a key role in explaining the mobility-innovation nexus. The reasons behind the emergence of a positive and significant impact when the analysis is restricted to firms more prone to the exploitation of external sources of knowledge may refer to both quantitative and qualitative factors. The benefits from inflows of knowledgeable (highly skilled, highly creative) individuals, such as multi-patent inventors, are difficult to be fully internalized by the firms hiring them. Especially small and medium enterprises (largely represented in the CIS sample and systematically under-represented in studies based exclusively on patent data) are likely to find learning-by-hiring mechanism is too costly (due to sunk costs and lack of scale), making external search relatively more convenient. External search makes the scanning of available sources more flexible, facilitating the acquisition of complementary non-redundant knowledge and/or the innovative re-combination of otherwise dispersed knowledge bits. Conversely, inward-looking firms - focused mainly or exclusively on internal sources of knowledge - might miss relevant innovation opportunities, suffering from the cognitive myopia discussed by Agrawal et al. (2010). If inward-looking firms cannot access sufficiently diversified sources of knowledge within

[17] The variables for backward and forward linkages are constructed as dummy variables. They take value 1 if the firm makes medium/high use (vs. low/no use) of suppliers (backward linkages) and clients (forward linkages) respectively as a source of information for the development of their innovations.

their organisational boundaries – this is the case of Multinational Firms for example (Crescenzi et al. 2015) – the risk of cognitive lock-in is higher (Kerr et al. 2014) and the inflow of knowledgeable individuals into the local economy of no help to avoid this.

6. **Conclusions**

The way in which knowledge is organised in space is crucially important for innovation and, ultimately, economic growth. The inter-regional mobility of highly skilled, highly creative individuals – such as multi-patent inventors – is key to knowledge circulation and to the geographical adjustment of innovation drivers in response to technological change and new market opportunities. Knowledgeable individuals make the circulation of valuable, individual embodied, tacit knowledge possible. However, mobility does not happen in a vacuum and the way in which movers match, connect to and interact with firms in their host environment is an important, although significantly under-explored, part of this picture.

This paper has looked at the link between inter-regional mobility, innovation and firms' behavioural heterogeneity in their reliance on localised external sources of knowledge. By linking patent data – that offer a unique measure of inventors' inter-regional mobility – with firm-level data – providing unique information on firms' innovation inputs and behaviour – a robust and innovative identification has made it possible to shed new light on the mobility-innovation nexus. Firms located in local labour markets that receive inflows of inventors tend to be more innovative. However, this effect identified in previous regional-level analyses, is not robust after controlling for firm-level observable and unobservable time-invariant characteristics. Firm-level heterogeneity – largely overlooked in previous studies - is the key to explain the innovation impact of mobility over and above learning-by-hiring mechanisms. A causal link between inflows of inventors and innovation clearly emerges for firms that make the exploitation of external knowledge sources an integral part of their innovation strategies. Conversely, the mobility of knowledgeable individuals is of limited or no benefit to cognitively inward looking firms. Firms not benefiting from inter-regional mobility belong to two categories. The first category is likely to include large multi-establishment (often multi-national) firms that can rely on a sufficiently diversified internal knowledge-base that can be accessed with relatively low transaction costs thanks to the organisational proximity between various knowledge-holders. Conversely, the second category includes firms, for which the costs of accessing external knowledge remain – notwithstanding geographical proximity - prohibitively high due to internal routines or knowledge-management failures, leading to a higher chance of cognitive lock-in with limited benefits from the external environment.

What can we learn from these results? The empirical analysis presented in the paper should be interpreted bearing in mind some key limitations. First we focused our attention on the mobility of inventors, a very specific typology of skilled and innovative individuals. 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). Third, 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, some tentative policy considerations are certainly justified by our results. The mobility of knowledgeable individuals occurs naturally due to the push factors generated by technological change and market forces. The knowledge made possible by this mobility supports innovation performance (at least in some firms). Active policies should be designed in order to remove existing barriers to internal labour mobility: from restrictions to the development of the housing market that reduce housing affordability to obstacles to spatial wage flexibility and institutional/regulatory barriers.

As discussed above mobility is not equally important for all firms. Firms with more limited access to an internally diversified knowledge-base are those with the highest potential to benefit from the inflows of knowledge-carriers in their local labour markets. A careful diagnosis of the knowledge-seeking behaviour of firms in different locations should be a pre-requisite for innovation policies targeting the mobility of high-skilled individuals (for example in disadvantaged areas or in emerging innovation clusters). The attraction of highly skilled knowledgeable individuals can boost local innovation (or support the emergence of a new innovation cluster) only where this is part of a systemic approach to regional innovation that facilitate the inclusion of these inflows into the network structure of the local economy supporting – where necessary – the correction of myopic knowledge search patterns of local firms.

References

Abramovitz, M. (1956) “Resources and output trends in the United States since 1870”. *American Economic Review*, 46 (2). 5-23.

Abreu M., Faggian A. & McCann P., (2011), "Migration and inter-industry mobility of UK graduates: Effect on earnings and career satisfaction," ERSA conference papers ersa11p118, European Regional Science Association.

Agrawal A., Cockburn I. and McHale J. (2006), “Gone but not forgotten: labour flows, knowledge spillovers, and enduring social capital”, *Journal of Economic Geography* 6: 571-91.

Agrawal A., Cockburn I., Rosell C. (2010) “Not invented here: creative myopia and company towns” *Journal of Urban Economics*, 67 (1) (2010), 78–89

Alcacer, J., Delgado, M. (2013). “Spatial organization of firms and location choices through the value chain.” HBS Working Paper 13-025.

Almeida P. and Kogut B. (1999), “Localisation of knowledge and the mobility of engineers in regional networks”, *Management Science* 45, 905-17.

Carlino G. and Kerr W. R. (2014), “Agglomeration and Innovation”, Working Paper 14/26, Federal Reserve Bank of Philadelphia, Philadelphia, PA

Carlino, G., Chatterjee, S., Hunt, R. (2007), “Urban density and the rate of invention.” *Journal of Urban Economics*, 61 (3), 389-419.

Archibugi, D. and Lundvall, B.-A. (2001). *The globalizing learning economy.* Oxford: Oxford University Press.

Barnard, H. and 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”', *Journal of Management & Governance,* 10 (1), 21-27

Borjas, G.J., (1999) “The Economic Analysis of Immigration” *Handbook of Labour Economics,* Elsevier.

Breschi S. and Lissoni, F. (2001) “Knowledge Spillovers and Local Innovation Systems: A Critical Survey”, *Industrial and Corporate Change*, 10, 975-1005.

Breschi, S and Lissoni, F (2009), “Mobility of skilled workers and co-invention networks: an anatomy of localized knowledge flows”, *Journal of Economic Geography* 9: 439-468.

Buzard K., Hunt R.M., Carlino J, Carr J.k., Smith T.E, (2015) “Localized Knowledge Spillovers: Evidence from the Agglomeration of American R&D Labs and Patent Data” Working Paper 15-03, Federal Reserve Bank of Philadelphia, Philadelphia, PA

Bloom, N., and J. Van Reenen. (2002). Patents, real options and firm performance, *Economic Journal* 112 (478):C97-C116.

Card D (2005) Is the new immigration really so bad? *The Economic Journal* 115: 300–323

Card D (2007) How immigration affects US cities. In: Inman RP (ed) *Making cities work: Prospects and policies for urban America*. Princeton University Press, Princeton, NJ

Charlot S., Crescenzi R. & Musolesi A. (2014) "Econometric Modelling of the Regional Knowledge Production Function in Europe", Journal of Economic Geography, in press, doi: 10.1093/jeg/lbu035

Chellaraj, G., Maskus, K. and Mattoo A. (2008), "The Contribution of Skilled Immigrations and International Graduate Students to U.S. Innovation", *Review of International Economics*, 16(3):444-462.

Cooke, P., Gomez Uraga, M. and Etxebarria, G. (1997). Regional innovation systems: institutional and organisational dimensions, *Research Policy*, 26 (4/5). 475–491.

Corredoira R. A. and Rosenkopf L. (2010) Should auld acquaintance be forgot? the reverse transfer of knowledge through mobility ties, *Strategic Management Journal* 31, 159–181.

Crescenzi, R., Rodriguez-Pose, A. And Storper, M. (2007). The Territorial Dynamics of Innovation: A Europe-United States Comparative Analysis. *Journal of Economic Geography*, 7 (6). 673-709.

Crescenzi, R. and Rodriguez-Pose, A. (2011). I*nnovation and Regional Growth in the European Union*. Berlin: Springer Verlag.

Crescenzi, R., Gagliardi, L., Iammarino, S. (2015) "Foreign Multinationals and domestic innovation: intra-industry effects and firm heterogeneity", *Research Policy*, 44, 596–609.

Criscuolo, P., & Verspagen, B. (2008). Does it matter where patent citations come from? Inventor vs. examiner citations in European patents. *Research Policy*, *37*(10), 1892-1908.

Crespi G., Geuna A. and Nesta L. (2007), "The mobility of university inventors in Europe", *Journal of Technology Transfer* 32: 195-215.

Döring T. and Schnellenbach J. (2006) What do we know about geographical knowledge spillovers and regional growth?: a survey of the literature, *Regional Studies* 40, 375–395.

Duranton G (2007) Human capital externalities in cities: Identification and policy issues. In: Arnett RJ, McMillen DP(eds) *A companion to urban economics*. Blackwell Publishing, Oxford.

Edquist, C. (1997). Introduction. Edquist, C. (ed.): *Systems of innovation: technologies, institutions, and organizations.* London: Pinter. 1-35.

Faggian A. and McCann, P.(2006) "Human Capital Flows and Regional Knowledge Assets: A Simultaneous Equation Approach", *Oxford Economic Papers,* 52: 475-500

Faggian, A. and McCann, P (2009), "Human Capital, Graduate Migration and Innovation in British Regions", *Cambridge Journal of Economics* 33: 317-333.

Feldman, M. P. (1994). The Geography of Innovation, Kluwer Academic Publishers, Boston

Feldman, M., Audretsch, D.B., 1999. Innovation in cities: science-based diversity, specialization, and localized competition. European Economic Review 43, 409–429.

Feldman, M.P., 2003. The locational dynamics of the US Biotech Industry: knowledge externalities and the anchor hypothesis. Industry and Innovation 10, 311–328.

Florida, R. (2002), "The Economic Geography of Talent", *Annals of the Association of American Geographers* 92: 743–755.

Freeman, C. (1987). *Technology Policy and Economic Performance: Lessons from Japan*. London: Pinter.

Gagliardi, L. (2014), "Does skilled migration foster innovative performance? Evidence from British local areas", Papers in Regional Science (forthcoming).

Glaeser E, Kallal H, Scheinkman J, Shleifer A (1992) Growth of cities. *Journal of Political Economy* 100: 1126–1152.

Glaeser, E.L., Rosenthal, S.S. and Strange, W.C. (2010), "Urban Economics and Entrepreneurship", *Journal of Urban Economics*, 67(1): 1-14.

Griliches, Z. (1979) "The Search for R&D Spillovers", *Bell Journal of Economics* 10: 92-116.

Griliches, Z., (1986) "Productivity, R & D, and the Basic Research at the Firm Level in the 1970's", *American Economic Review*, 76: 141-54.

Jaffe, A.B. (1986), "Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value," *American Economic Review* 76(5): 984-1001.

Herrera, L., Muñoz-Doyague, M.F. and Nieto, M. (2010), "Mobility of public researchers, scientific knowledge transfer, and the firm's innovation process", *Journal of Business Research* 63: 510-518

Hoisl K. (2007) Does mobility increase the productivity of inventors?, Journal of Technology Transfer 34, 212–225.

Hoisl, K. (2009), "Tracing Mobile Inventors – The causality between Inventors Mobility and Inventors Productivity", *Research Policy*, 36(5): 619‐636.

Hunt, J. and Gauthier-Loiselle, M. (2008), "How Much Does Immigration Boost Innovation?", *NBER WP 14312.*

Kerr, W.R. (2010), Breakthrough Inventions and Migrating Clusters of Innovations. *Journal of Urban Economics*, 67: 46-60.

Kerr, W.R. and Lincoln, W. (2010), The Supply Side of Innovation: H1-B Visa Reform and US Ethnic Invention. *NBER Working Paper 15768*, National Bureau of Economic Research, Cambridge Mass.

Kerr, W., Lerner, J., Schoar, A. (2014). "The consequences of entrepreneurial finance: evidence from angel financings." Review of Financial Studies, 27 (1), 20-55.

Kim J., Lee S. J. and Marschke G. (2006), "International Knowledge Flows: Evidence from an Inventor-Firm Matched Data Set", *NBER WP* No. 12692.

Leamer E, Storper M (2001) The economic geography of the internet age. *Journal of International Business Studies* 32: 641–665

Lewbel, A., Dong, Y., & Yang, T. T. (2012). Comparing features of convenient estimators for binary choice models with endogenous regressors. *Canadian Journal of Economics/Revue canadienne d'économique*, *45*(3), 809-829.

Lenzi C. (2009) Patterns and determinants of skilled workers' mobility: evidence from a survey of Italian inventors, *Economics of Innovation and New Technology* 18, 161–179.

Lettl, C., Rost, K., von Wartburg, I., (2009), Why are some independent inventors 'heroes' and others 'hobbyists'? The moderating role of technological diversity and specialization. *Research Policy* 38(2), 243–254.

Lewis, T. R. and Yao, D (2006), "Innovation, Knowledge flow, and Worker Mobility," Mimeo, Wharton School, University of Pennsylvania.

Lissoni, F, Sanditov, B. and Tarasconi, G. (2006), "The Keins database on Academic Inventors: Methodology and Contents", CESPRI WP 181.

Lööf, H., & Heshmati, A. (2002). Knowledge capital and performance heterogeneity:: A firm-level innovation study. International Journal of Production Economics, 76(1), 61-85.

Long, J. S. and J. Freese (2006), *Regression models for categorical dependent variables using Stata,* College Station, Texas, Stata Press.

Lucas, R. (1988), "On the Mechanics of Economic Development", *Journal of Monetary Economics,* 22: 3-42.

Lundvall, B.-A. (ed.) (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter.

Maré, D.C., Fabling, R. and Stillman, S. (2011), "Immigration and Innovation", *IZA DP* 5686.

Maré, D. C., Fabling, R., & Stillman, S. (2014). Innovation and the local workforce. *Papers in Regional Science*, *93*(1), 183-201.

Miguel, E., Satyanath, S., & Sergenti, E. (2004). "Economic shocks and civil conflict: An instrumental variables approach". *Journal of Political Economy*, *112*(4), 725-753.

Miguelez, E. and Moreno, R. (2010), “Research Networks and Inventors’ Mobility as Drivers of Innovation: Evidence from Europe”, *IREA WP*.

Miguélez, E., Moreno, R., & Suriñach, J. (2010), “Inventors on the move: Tracing inventors' mobility and its spatial distribution”. *Papers in Regional Science*, *89*(2), 251-274.

Moretti, E., (2004) "Human capital externalities in cities" in: J. V. Henderson and Thisse J.F. (ed.), *Handbook of Regional and Urban Economics*, edition 1, volume 4, chapter 51, pages 2243-2291 Elsevier.

Nathan, M. and Overman, H. (2013) “Agglomeration, clusters, and industrial Policy”, *Oxford Review of Economic Policy*, 29(2), 383–404

Nelson, R. R. (ed.) (1993). *National Innovation Systems: A Comparative Analysis*. New York: Oxford University Press.

Niebuhr, A. (2010). “Migration and Innovation: Does Cultural Diversity Matter for Regional R&D

Activity?” *Papers in Regional Science*, 89: 563–585.

Ottaviano G, Peri G (2006). “The economic value of cultural diversity: Evidence from US cities”. *Journal of Economic Geography* 6: 9–44

Ozgen, C., Nijkamp, P. and Poot, J. (2011), “Immigration and Innovation in European regions” *IZA DP* 5676.

Peri, G. (2005), “Determinants of Knowledge Flows and Their Effect on Innovation”, *Review of Economics and Statistics* 87:2, 308-322.

Peri, G. (2007), "Higher Education, Innovation and Growth", in Brunello, G., Garibaldi, P. and Etienne W. (eds.) *Education and Training in Europe*, Oxford University Press.

Romer, P. (1986). “Increasing returns and long-run growth”. *Journal of Political Economy*, 94 (5). 1002-1037.

Romer, P. (1987). “Growth based on increasing returns due to specialization”. *American Economic Review,* 77 (2). 56-62.

Santangelo, G. D. (2002). “The Regional Geography of Corporate Patenting in Information and Communications Technology (ICT): Domestic and Foreign Dimensions”. *Regional Studies*, 36 (5), 495-514.

Saxenian, A. (2006). *The New Argonauts: Regional Advantage in a Global Economy*. Cambridge, Massachusetts: Harvard University Press.

Schumpeter, J. (1934). *The Theory of Economic Development*, Cambridge, Mass.: Harvard University Press.

Simmie, J. (2003). “Innovation and Urban Regions as National and International Nodes for the Transfer and Sharing of Knowledge”. *Regional Studies,* 37 (6/7). 607-620.

Simmie, J. (2004). Innovation and Clustering in the Globalised International Economy. *Urban Studies*, 41(5/6). 1095–1112.

Singh, J. (2003) "Inventor Mobility and Social Networks as Drivers of Knowledge Diffusion" mimeo, *Harvard University WP*.

Singh J. and Agrawal A. K. (2011) “Recruiting for ideas: how firms exploit the prior inventions of new hires”, *Management Science* 57, 129–150.

Solow, R. (1957). “Technical change and the aggregate production function”. *The review of economics and statistics*, 39 (3). 312-320.

Song, J, Almeida, P. and Wu, G. (2003), “Learning by Hiring: When is mobility more likely to facilitate interfirm knowledge transfer?”, *Management Science* 49: 351-365.

Sonn, W. S. and Storper, M. (2008). “The increasing importance of geographical proximity in knowledge production: an analysis of US patent citations, 1975-1997”. *Environment and Planning A*, 40(5). 1020-1039.

Staiger, D. and Stock, J.H. (1997), "Instrumental variables regression with weak instruments", *Econometrica* 65, 557-586.

Stock, J.H. and Yogo, M. (2005), "Testing for weak instruments in linear IV regression" in J.H. Stock and D.W.K. Andrews (Eds.), *Identification and inference for econometric models: a Festschrift in honour of Thomas Rothenberg*, Cambridge University Press, Cambridge.

Stolpe, M. (2001) “Mobility of Research Workers and Knowledge Diffusion as Evidence in Patent Data – The Case of Liquid Crystal Display Technology” *Kiel WP* 1038.

Storper, M. (1997). *The Regional World: territorial development in a global economy*. New York: Guilford Press.

Stoper, M. and Venables, A. J. (2004). “Buzz: face-to-face contact and the urban economy”. *Journal of Economic Geography*, 4 (4). 351-370.

Sun, Y. (2003). “Geographic patterns of industrial innovation in China in the 1990s”. *Tijdschrift voor Economische en Social Geografie, 94 (3)*. 376-389.

Trajtenberg, M. , Shiff, G. and Melamed, R. (2006), “The Names Games: Harnessing inventors’ patents data for economic research”, *NBER WP* 12479.

UK Data Archive Service (2008), "Persistence and Change in UK Innovation", Report 6699

Usai, S. (2008). The Geography of Inventive Activities in OECD Regions. *OECD Science, Technology and Industry Working Papers,* 2008/03. OECD Publishing. Available online: http://dx.doi.org/10.1787/230083500260 Accessed October 19 2011

Uyarra, E. (2011). “Regional Innovation Systems Revisited: Networks, Institutions, Policy and Complexity”. Herrschelt, T. and Tallberg, P. (eds.): *The Role of Regions? Network, Scale, Territory.* Gothenburg: Region Skane.

Van Leeuwen, G. (2002). Linking innovation to productivity growth using two waves of the community Innovation Survey (No. 2002/8). OECD Publishing.

Zorn, C. (2005). A Solution to Separation in Binary Response Models. *Political Analysis* 13:157{170.

Zucker, L.G. and Darby, M.R. (2007), “Star Scientists, Innovation and Regional and National Immigration”, *NBER WP* 13547.

Zucker, L. G. and Darby M.R. (2006), “Movement of Star Scientists and Engineers and High-Tech Firm Entry”, *NBER WP* 12172.

Zucker, L. G., Darby R. M. and Armstrong Jeff (1998a), “Geographically Localized Knowledge: Spillovers or Markets?”, *Economic Inquiry*, 36 (1): 65-86.

Zucker, L.G., Darby, M.R. and Brewer, M.B. (1998b). "Intellectual human capital and the birth of U.S. biotechnology enterprises", *American Economic Review* 88: 290-306.

Tables

Table 1: Firms' Innovative performance and Inventors' Inflows

Period	Innovative Performance	Inventors Inflows			
		NO		*YES*	
		Obs.	*Share*	*Obs.*	*Share*
	Product Innovation	4868	0.29	1004	0.31
	Process Innovation	4868	0.20	1004	0.20
TOTAL	*Product or Process Innovation*	4868	0.35	1004	0.37
	Product Innovation	2284	0.30	652	0.32
	Process Innovation	2284	0.23	652	0.21
2002-2004	*Product or Process Innovation*	2284	0.37	652	0.39
	Product Innovation	2584	0.27	352	0.30
	Process Innovation	2584	0.17	352	0.18
2005-2007	*Product or Process Innovation*	2584	0.32	352	0.34

Source: UK-CIS; EPO-KITES

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.

Table 2: Variables List

Variable	Description	Source	Obs.	TOTAL		2002-2004		2005-2007	
				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	Proportion 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
Inventors' inflows	Dummy variable taking value 1 if the firm is located in a TTWA that experienced inflows of inventors.	KITES-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

Source: UK-CIS; EPO-KITES

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" refers to firms declaring that the make an medium/high use (with respect to a low/no use) of suppliers and customers respectively as knowledge source for the development of their innovations.

Table 3: Firms' Innovation and the Mobility of Knowledgeable Individuals

	(1)	(2)	(3)
Dep.Var. Product or Process Innovation	FE	FE	FE
R&D	0.2544***	0.2543***	0.2541***
	(0.0232)	(0.0233)	(0.0233)
Employment with degree	0.0855*	0.0866*	0.0864*
	(0.0459)	(0.0462)	(0.0462)
Inventors' Inflows		0.0228	0.0226
		(0.0190)	(0.0190)
Export Orientation			0.0075
			(0.0267)
Observations	5872	5872	5872
R2	0.0683	0.0688	0.0688

Clustered robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Note: Firm and time fixed effects included in all specifications

Table 4: Robustness Checks

Dep.Var.	(1) Product or Process Innovation OLS	(2) Product or Process Innovation OLS	(3) Product Innovation FE	(4) Process Innovation FE
	Panel I		Panel II	
R&D	0.4085***	0.4006***	0.1986***	0.1714***
	(0.0136)	(0.0138)	(0.0222)	(0.0203)
Employment with degree	0.1478***	0.1430***	0.1636***	-0.0259
	(0.0299)	(0.0300)	(0.0460)	(0.0428)
Inventors' Inflows	0.0309**	0.0452**	0.0251	-0.0120
	(0.0150)	(0.0228)	(0.0174)	(0.0172)
Export Orientation	0.1234***	0.1168***	0.0158	0.0151
	(0.0128)	(0.0130)	(0.0260)	(0.0242)
TTWA Dummies	NO	YES	-	-
Observations	5872	5872	5872	5872
R2	0.2170	0.2455	0.0495	0.0449

Clustered robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Note: Firm and time fixed effects included in the specification reported in column 3 and 4 (Panel II).
Pooled OLS results reported in column 1 and 2 (Panel I).

Table 5: Instrumental Variables Estimation

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

Clustered robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: Firm and time fixed effects included in all specifications. Columns 2 and 4 refer to the sub-sample of firms exploiting external sources of information to develop their innovative activities. The subsample 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.

Table 6: Instrumental Variables Estimation – Robustness Checks

	(1)	(2)
Dep.Var. Product or Process Innovation	IV	IV
R&D	0.2122***	0.1596***
	(0.0232)	(0.0301)
Employment with degree	0.0830*	0.0882
	(0.0458)	(0.0715)
Inventors' Inflows	0.0551	0.2042**
	(0.0630)	(0.1001)
Export Orientation	0.0019	-0.0036
	(0.0263)	(0.0383)
Backward Linkages	0.1060***	0.0548**
	(0.0188)	(0.0266)
Forward Linkages	0.0864***	0.0305
	(0.0192)	(0.0335)
Observations	5872	3084
R2	0.1004	0.0202
F	33.31	17.33

Clustered robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: Firm and time fixed effects included in all specifications. Column 2 refers to the sub-sample of firms exploiting external sources of information to develop their innovative activities. The subsample is constructed drawing from the section "Context for Innovation" and 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.

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