Annali del Dipartimento di Metodi e Modelli per l'Economia, il Territorio e la Finanza
2024, DOI: 10.13133/2611-6634/1701

E-ISSN 2611-6634
ISSN 2385-0825

Critical review

First published online: December 30, 2024

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MOBILITY AND INNOVATION: A CRITICAL REVIEW

Abstract

The increasing attention given to inventors' mobility and its relationship with regional innovative activity has garnered significant interest among scholars. This review critically examines the key findings in this area, identifying both strengths and limitations in existing research. The discussion is organized into three primary areas: first, the mechanisms by which mobility influences innovation; second, the effects of mobility on the regions involved; and third, the factors that drive inventors' mobility. The review concludes that while recent studies have made notable contributions to understanding these dynamics, there remains a need for new analytical frameworks. These would be instrumental not only in reconciling divergent perspectives but also in shaping future research directions.

Keywords: brain drain, brain gain, innovation, inventors' mobility.

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1 Introduction

The positive relationship between human mobility and innovation is well-established, through its recognized role in driving human progress and the diffusion of knowledge since the Neolithic era (Manning & Trimmer, 2020; Skoglund et al., 2012). Recently, thanks to greater data availability, migratory waves – such as the Huguenots in Prussia or Jews and Soviets in the United States – have underscored the significance of mobility in the diffusion and production of innovation (De Rassenfosse & Pellegrino, 2024; Hornung, 2014; Moser et al., 2014)

It is quite intuitive that the topic of inventors' mobility is inherently interdisciplinary, intersecting fields such as economic geography, migration economics, economics of science, labor economics, as well as classical and modern historiography (Lissoni, 2018).

Although there is consensus on the importance of mobility for innovation, the diversity of approaches has led to contrasting positions regarding the theoretical motivations behind mobility's impact on innovation, as well as the effects on various geographic entities. Moreover, the discussion on mobility has often been confined to the phenomenon of migration alone. While migration certainly constitutes a significant aspect of mobility, it isn't exhaustive, representing only a specific case of mobility that often involves the spatial movement of entire communities, and so different effects compared to individual mobility (Lissoni, 2018).

The objective of this review is not to provide a comprehensive reconstruction of the literature on inventors' mobility but rather to offer a critical approach to the topic. It illustrates the most significant findings, highlights the contrasting viewpoints, identifies gaps and shortcomings in the existing narrative, and suggests ways these might be addressed.

The approach to gathering literature sources began with keyword searches in two major databases (Scopus and Google Scholar). The keywords used were "Inventors' mobility" and "Migration and innovation." The identified articles were then analyzed to determine the major thematic areas, with additional sources collected through citations.

The general topic will therefore be broken down into its major thematic areas, allowing for a focused analysis of the most important findings. This breakdown is reflected in the structure of the review. Specifically, the first section will explore the reasons why inventors' mobility is particularly important for innovation, distinguishing between the diffusion of knowledge across space and the generation of diversity. The second section will examine the spatial effects of this mobility, considering both origin and destination regions. The third section will focus on the drivers that influence mobility itself. The last section summarizes all the findings exposed previously and suggests new research directions.

2 Mechanisms of Impact: How Mobility Drives Innovation

One of the cornerstones of the geography of innovation, around which the entire literature revolves, is that innovative activity is not uniformly distributed across space but tends to concentrate in specific regions (Asheim & Gertler, 2006). This is largely due to the tacit and "sticky" nature of knowledge, which limits its spatial diffusion (Boschma & Lambooy, 1999; Jaffe et al., 1993). Therefore, it is crucial to investigate

the primary channels of knowledge diffusion. In this context, the inventors' mobility becomes a central theme in economic geography literature, whereas previously, it was largely confined to historiography (Miguelez & Noumedem Temgoua, 2020). Particularly, the pioneering work of (Breschi & Lissoni, 2009) identifies human capital mobility as the main channel for knowledge diffusion and low mobility as the reason for the high spatial concentration of innovative activity. Following this work, the literature increasingly focused on the role of mobility in knowledge diffusion. When discussing flows, there is inevitably at least one source and one destination. The origin-destination topic will be comprehensively revisited in the next paragraph; now, it is essential to define the theoretical mechanisms linking mobility and knowledge diffusion. Thus, we ask: Does mobility actually facilitate knowledge diffusion? If so, what kind of knowledge is diffused, and how does this process occur?

The first question might seem leading, but it is legitimate when trying to detect knowledge transfer by the effects of migration on local scientific production, where results are conflicting: while incoming human capital flows disproportionately increase patent production (Hunt & Gauthier-Loiselle, 2010), a more careful analysis shows that this is actually the result of a "displacement effect" (Borjas & Doran, 2015) where native inventors, rather than benefiting from the knowledge brought in by migrant inventors, tend to shift towards different areas of expertise. Furthermore, skilled workers tend to relocate to areas with already high concentrations of human capital (Kerr et al., 2016), raising the question of reverse causality – whether migrants are exploiting existing knowledge rather than contributing their own (Hilaire-Perez & Verna, 2006). While the extent of knowledge diffusion through migration remains ambiguous when measured solely by patent output, the results become more conclusive when patent citations are considered as a proxy for knowledge transfer, offering a clearer indication of the impact. Ganguli (2015) uses a difference-in-differences approach to estimate the causal impact of the migration of Russian scientists to the United States after the collapse of the Soviet Union on knowledge flows. The results show a disproportionate increase in citations of Soviet-era articles following the scientists' relocation to the United States, demonstrating how geographic mobility serves as a crucial channel for the transfer of ideas.

Regarding what is actually being diffused, knowledge is the main focus, as it is considered the primary fuel for innovation. However, it is well-known that innovation itself is a complex process that requires the coexistence of various factors. In this context, the classic distinction between technical/scientific knowledge and commercial/entrepreneurial information (Cowan, 2000) is useful. Regarding the latter, there is great evidence of the role played by migrant inventors in providing relevant information to firms in host countries for mergers and acquisitions operations undertaken in their origin countries (Useche et al., 2020), their ability to foster collaborative networks between companies (Tóth & Lengyel, 2021), their impact on local entrepreneurship (Balsmeier et al., 2020), and in promoting FDIs (Foley & Kerr, 2013). Despite this, many questions remain regarding the transfers made by migrant inventors, particularly about what type of knowledge they are able to diffuses and how it differs from native knowledge. But most importantly, does the specific type of knowledge possessed by inventors influence their propensity or patterns of mobility? So far, there is no answer to this question.

About how migrant inventors contribute to the diffusion of knowledge and/or information, two approaches can be distinguished: the transfer-based approach and the community-centered approach (Lissoni, 2018). The first considers the migrant as the unit of analysis, possessing specific knowledge and skills that can be transferred to the

destination country if there are the right conditions, such as a favorable and tolerant climate towards foreigners (Scoville, 1952). The second approach, in contrast to the first, focuses on the role of the community and ethnic ties in diffusion, emphasizing the importance of minority communities in facing social discrimination or legal restrictions that may arise in the host region. In this context, the migrant community tends to specialize in sectors left open by natives, facilitating the dissemination of information primarily among the migrants themselves (Lissoni, 2018). The importance of these ethnic ties is demonstrated not only by the tendency of co-ethnic inventors to cite each other, especially if they belong to a minority (Breschi et al., 2017), but also to collaborate more frequently among themselves (Freeman & Huang, 2015), even though this tendency towards homophily – where migrant inventors prefer to collaborate with other migrant inventors – seems to have a negative impact on the quality of innovation (Almeida et al., 2015). This brings to another relevant theme related to the inventors' mobility, which has recently gained prominence: diversity.

The emergence of this new strand can be traced back to the literature on unrelated diversification. Without delving too deeply into detail, the idea originates from the observation that innovative activity is highly path-dependent (Dosi, 1982), meaning that regions tend to diversify more in activities related to their specialization (Hidalgo et al., 2018; Pinheiro et al., 2018). This path dependence can lead to technological lock-in, and the only hope of avoiding this is by diversifying into unrelated activities (Saviotti & Frenken, 2008). However, the factors that enable this unrelated diversification are still under investigation (Boschma, 2017). What is certain is that regions need different and non-redundant knowledge, which can be obtained through various gatekeepers – actors who serve as intermediaries in the innovation network, facilitate novelty generation by external resource transfers – (Breschi & Lenzi, 2015; Morrison et al., 2013), and inventors' mobility can be one of them. Hence, the hypothesis is that migrant inventors not only diffuse their knowledge through their mobility but that this knowledge is also inherently different from native knowledge, thereby enabling a technological shift. This hypothesis is supported by studies on mass migration to the United States between 1870 and 1940, where the inventive activity of migrants not only brought regional benefits but also shaped the technological evolution of the United States through the introduction of new technologies (Diodato et al., 2022). But what mechanisms make this possible? These can be summarized into two main mechanisms: knowledge recombination and knowledge reuse (Choudhury & Kim, 2019).

Knowledge recombination occurs as a result of collaboration between inventors of different ethnicities or backgrounds. These "non-ethnic" teams (as the members do not belong to a single ethnicity) can combine their different knowledge to create something that otherwise would not have been possible, thereby increasing the value of their patents (Ferrucci & Lissoni, 2019). However, this phenomenon contrasts with the homophily tendency previously observed; thus, knowledge recombination cannot be taken for granted. Homophily is closely linked to the second mechanism, knowledge reuse, which involves continuing to work with the knowledge that migrants themselves have imported. This occurs in ethnic teams (whose members belong to the same ethnicity or region) formed in regions different from their origin. While both mechanisms can contribute to unrelated diversification, knowledge reuse has a more significant impact on it (Miguelez & Morrison, 2023). This is theoretically understandable, as the knowledge obtained through recombination is also derived from native knowledge, which is likely correlated with regional specialization, whereas reuse is more likely to result in non-correlated knowledge. This view is consistent with the historical work of Koch et al. (2023), which shows that the immigration of individuals

specialized in a particular area leads to the emergence of that specialization in the region, while emigration reduces the likelihood of maintaining that specialization.

However, the literature is not unanimous on the role of inventors' mobility in unrelated diversification and thus in technological change. Caviggioli et al. (2020) have even demonstrated that migration and technological diversification are negatively correlated. This can be explained by the tendency of companies to attract workers already specialized in their activities, leaving little room for diversity. To resolve this incompatibility, the same reflection seen previously applies: identifying the different types of knowledge and how they affect the mobility of inventors. Indeed, none of these studies consider the innovation process within which all this takes place, and that this process actually requires both diversity and specialization. Also, the apparent tension between diversity and specialization in regional innovation can be explained by considering the different factors that drive inventors' mobility. When inventors move to regions that are leaders in specific fields to enhance their human capital, the result could be greater specialization. Conversely, if mobility is driven by other factors, such as seeking a less discriminatory environment, this could foster greater diversity. Therefore, understanding the underlying drivers of mobility is crucial to understanding the relationship with regional innovation.

3 Regional effects of investors' mobility

As mentioned in the previous section, inventors' mobility involves a flow that inherently requires both a source and a destination, geographically identified as origin and host region. This section aims to examine the distinct effects of mobility on these regions, addressing the impacts on the host region and the origin region separately due to their differing characteristics.

3.1 Host Regions

The effects of inventors' mobility at the regional level have predominantly been examined with a focus on host regions, where these effects are more pronounced. Initially, the literature concentrated on the impact of inventors' inflows on destination regions. Bahar et al. (2020) find that regions can gain a patenting advantage ranging from 25% to 60% in specific technologies when the number of foreign inventors specializing in these technologies doubles, thereby confirming the role of migrant inventors in the importation of knowledge. Additionally, Capello and Lenzi (2019) highlight that the inflow of inventors can lead to structural changes in innovation models, facilitating the shift towards more complex models.

However, the impact of inventors' mobility is not uniform and appears to depend on the pre-existing innovation model in the destination region, particularly favoring models that can either strengthen existing knowledge networks or create new ones.

The ongoing debate on the potential displacement effect on native patenting remains unresolved. Borjas and Doran (2015) suggest that this displacement effect may vary based on different immigration regulations. In this regard, Kerr & Lincoln (2010) examine the impact of migration driven by H-1B visas (temporary U.S. visas for highly specialized personnel), finding that an increase in these visas results in a higher number of patents assigned to Indian and Chinese inventors, with limited displacement effects

on native inventors. This finding indicates that regulated migration can lead to a direct contribution from migrant inventors.

Interestingly, inventors do not need to travel long distances to benefit regions with their positive effects. Even intraregional mobility is associated with improved innovative activity (Miguélez & Moreno, 2013). This improvement may stem from both an enhancement in human capital and a better match between skills and opportunities, which can increase inventors' productivity by 30% (Pellegrino et al., 2023). It is also important to note that geographic mobility may, but not always, coincide with job mobility, and that could influence the impact. For instance, corporate mobile inventors tend to be more productive than those who do not change jobs, while higher initial productivity reduces the likelihood of changing employers (Hoisl, 2007).

This relationship is also geographically evident: Cappelli et al. (2019) analyze the impact of inventors' inflows and outflows on total factor productivity growth in Italian regions. Their results indicate that inflows have a positive impact on the host region, although the positive effects may take longer to materialize when the inventor also changes employers. Conversely, the negative effect of outflows is even more pronounced when the inventor changes employers, underscoring the potential negative impact of brain drain. In contrast, Prato (2022) proposes a model in which migrants not only become more productive after relocating (due to a better spatial allocation of talent) but also maintain relationships with inventors in their home countries, generating knowledge spillovers that benefit both the destination and origin countries – a win-win scenario.

3.2 Origin Regions

The aforementioned observations exemplify the ambiguity within the literature regarding the effects of inventors' mobility on origin countries. Initially, the phenomenon was predominantly seen with concern, especially as a loss of human capital with potentially disastrous effects for developing countries (Bhagwati & Hamada, 1974). However, recent studies have identified various channels and mechanisms through which origin countries may also benefit from mobility, possibly offsetting the initial loss of human capital. Although the primary concern remains the loss of human capital in already fragile contexts, the brain drain phenomenon is not limited to developing countries but affects various regions to differing degrees. An illustrative case is Poland, where between 2004 and 2012, emigrant inventors produced a greater number of patents abroad than those filed in Poland during the same period (Wachowska, 2018), highlighting how brain drain can pose a significant challenge to growth. Therefore, identifying the mechanisms through which this loss can be mitigated has great importance for innovation policy.

One mechanism can be defined as the "incentive effect", which arises from the prospect of achieving higher economic returns by first investing in one's education and then emigrating to countries that can better compensate for one's talent. When migration opportunities are not perfect, the origin country can still experience an increase in human capital (Faini, 2003). Empirically, Beine et al. (2011), using a dataset of 147 countries from 1975 to 2000, found evidence that the prospect of emigration can indeed incentivize investment in education, though under specific conditions: the wage differential between the destination and origin countries must be substantial, and the emigration rate must not become excessively high; otherwise, the effect reverses.

The most studied compensation mechanism, however, is the so-called "knowledge remittances," the technical-scientific equivalent of the monetary remittances that migrants send to their origin countries. These remittances can take various forms that are not mutually exclusive and can be broadly categorized into two main types: knowledge transfer through social contacts and return or circular migration.

The first type intuitively involves the transfer of foreign knowledge by migrants to their origin countries by maintaining contact with inventors there. Agrawal et al. (2011) call this phenomenon the "brain bank" effect, in contrast to the "brain drain," and they attempt to analyze it by focusing on the case study of India. They find that, on average, the brain drain effect prevails, although the brain bank effect is significant for more substantial innovations. Using a citation-based approach to trace knowledge flows, Breschi et al. (2017) explore the "brain gain" effect, which occurs when foreign-born inventors operating in the United States are disproportionately cited by inventors in their origin countries. Their findings indicate that this effect is significant only in specific countries (China, Russia, South Korea), underscoring the critical role of origin countries' characteristics, particularly their absorptive capacity. Moreover, the same study emphasizes the importance of multinational corporations in facilitating these knowledge transfers. Similar results are obtained by Miguelez and Noumedem Temgoua (2020) who find a positive impact only in developing countries, with multinational corporations playing a key role in promoting these transfers. It appears that such knowledge transfers occur spatially but within the same multinational companies, where migrant inventors act as bridges between the headquarters and subsidiaries in their origin countries, so the transferred knowledge can be limited to that within the multinational itself (Marino et al., 2020).

The second category of knowledge remittances considers the possibility that migrants may not permanently settle in the destination country but might return to their home countries. Saxenian (2005) argues that the increasing mobility of inventors, particularly engineers and entrepreneurs born in China and India but operating in Silicon Valley, has transformed brain drain into "brain circulation". These migrants, through their mobility, act as bridges to their home countries, facilitating the transfer not only of technical knowledge but also of organizational and entrepreneurial models, thereby transforming the innovation ecosystem in their countries. However, this study focuses on China and India; entirely different results are obtained when considering countries like Mexico, where return migration has ambiguous effects and then dissipate within five years (Diodato et al., 2023). To achieve positive results, it is necessary to reintroduce a player previously identified as crucial: the multinational corporation. When considering managers of multinational corporations who are return migrants, it is observed that their team' members not only file a disproportionately high number of patents but also tend to cite the patents of the headquarters much more than others (Choudhury, 2016).

The mechanism of knowledge remittances fundamentally relies on the migrants' ability to diffuse knowledge, but as previously discussed, they can also diffuse other information useful for business decisions. Here, too, the role of multinational corporations is crucial, as they can obtain information from migrant inventors that can reduce costs and encourage investments in the inventors' origin countries (Foley & Kerr, 2013).

The emerging research on the role of migrant inventors in generating diversity has also contributed to the study of mechanisms that could compensate the brain drain, asserting that migration leads to unrelated diversification even in the origin countries (Di Iasio & Miguelez, 2022), potentially serving as a channel for developing countries

to catch up with advanced economies. Despite all these efforts, it cannot be definitively stated that inventors' mobility leads to a win-win situation for both origin and host regions, especially considering that the highest levels of brain drain are observed in Africa and the Caribbean (Miguélez & Fink, 2023), which do not seem to possess the necessary characteristics to benefit from the brain gain effect. The most significant finding is certainly the understanding of the role of multinational corporations in facilitating this effect. It raises the question of how institutions such as multinational corporations (but not exclusively) contribute to shaping this geography. Furthermore, the literature has predominantly adopted a perspective where countries are the geographic unit of analysis, with little consideration of other forms of mobility and their significance within the innovation process.

4 Factors influencing inventors' mobility

Having established the importance and effects of inventors' mobility on the innovative capacity of the regions involved, the question arises as to what factors determine and drive mobility. Understanding the drivers of mobility is crucial from a regional perspective, as it would enable the implementation of precise policies aimed at attracting talent and increasing productivity and, as mentioned previously, it could also shed light on the diversification-specialization debates. So, what factors motivate inventors to relocate? First, it has been observed that mobility enhances the productivity of inventors themselves (Van Der Wouden & Rigby, 2021), which could already serve as an incentive, especially when higher productivity translates into higher wages. From a microeconomic point of view, the decision to move will be made when the benefits outweigh the costs incurred for the relocation. It is therefore not surprising that key factors in mobility include significant wage differentials between countries, greater employment opportunities, or the chance to broaden one's skills (Kerr et al., 2016). All these have the aim of maximizing benefits. On the other hand, it is also necessary to minimize costs, and that influences the choice of destination, with a preference for regions that have a geographical, cultural, technological, and institutional proximity (Gorin, 2016). The opportunities seeking in a different region can lead to higher costs, especially in the presence of information asymmetries, and this is where another crucial factor comes into play: the social network. Dorner et al., (2016), leveraging the natural experiment of German reunification after the collapse of the Soviet Union, find that stronger social ties between regions in West and East Germany lead to greater migration of inventors, due to the reduction of information asymmetries and associated costs. Although these social networks are often co-ethnic and provide support to the migrant inventor, the ethnic diversity of the network can also play a crucial role in attracting migrants to a region (Campo et al., 2022), likely due to the inventors' desire to benefits of the externalities generated by diversity.

The discussion thus far has focused exclusively on the factors influencing inventors' choices, but there are also demand-side factors that are fundamentally responsible for creating the opportunities inventors seek. First, companies tend to hire based on a learning-by-hiring logic, meaning they are inclined to recruit inventors with strong skills, particularly those skills that are complementary to the competencies of other inventors and/or regarding areas where the company is not dominant (Palomeras & Melero, 2010). It is therefore no coincidence that the likelihood of an inventor moving, including geographically, is linked to the diversification of their skills and their

productivity (Haller, 2022). This trend is also observable in the transfer of inventors between universities and the private sector, with such mobility strongly connected to the patenting productivity of inventors, while being indifferent to their scientific output (Crespi et al., 2007), indicating that opportunities for inventors arise when they possess tacit knowledge that can be transferred.

The factors discussed so far primarily focus on objective, economic or non-economic influences on inventors' mobility. While this is an excellent starting point, continuing solely along this path eventually leads to a dead end, as the decision-making process is undoubtedly a subjective matter. Behavioral studies are often confined to inter-firm mobility and typically reference the productivity of inventors and their subsequent risk propensity (Di Lorenzo & Almeida, 2012). Adopting a qualitative approach could shed light on hidden dynamics within inventors' decision-making processes, thereby contributing new insights that could generate novel research paths.

5 Discussion and future research directions

Inventors' mobility has emerged as a central topic in academic discourse, especially in relation to its impact on innovation and regional economies. This review has sought to highlight various aspects of this phenomenon, emphasizing both its potential benefits and the challenges it presents, thus revealing a complex landscape filled with opportunities and obstacles.

While it is undeniable that inventors' mobility plays a crucial role in facilitating the spatial diffusion of knowledge and enhancing innovative output, the literature remains ambiguous in explaining the mechanisms that enable these outcomes. A primary point of contention concerns the actual contribution of migrants' inventors to innovative production in destination regions. While an increase in patenting activity is often observed, some argue that this may result from the displacement of native innovation by migrants, who primarily choose their destination to exploit existing knowledge. These conflicting positions become even more evident when considering the kind of impact on destination regions, where mobility seems to simultaneously drive both diversification and specialization. This duality is shaped by the interplay between diversity and homophily, presenting a paradox in the dynamics of innovation. Perhaps the best way to understand how these seemingly contradictory characteristics arise from the same phenomenon would be to analyze mobility within the broader innovation process – a complex phenomenon requiring both variety and specialization – and to examine its relationship with mobility.

It has also been demonstrated that the narrative of inventors' mobility, and highly skilled migration more broadly, being universally beneficial to both destination and origin regions is, in fact, quite fragile. The so-called "brain gain" occurs predominantly under stringent conditions and is closely linked to intra-firm mobility within multinational corporations. This finding underscores the necessity of exploring the "dark side" of innovation, a topic frequently overlooked (Morrison, 2023), wherein inventors' mobility and the consequent concentration of human capital may indeed be key factors in understanding the growing spatial inequalities (Storper, 2018).

To achieve this understanding, it may be necessary to partially depart from the approach predominantly used so far, which has focused mainly on countries as the primary geographic unit. This approach has largely ignored, with few exceptions, intra-regional mobility and, consequently, intra-regional disparities. The country-level

approach overlooks critical dynamics at multiple scales, including intra-regional and urban levels, as well as interactions between innovative and less innovative regions. Neglecting these dimensions risks missing key mechanisms that drive spatial inequalities. Additionally, there is a need to move beyond the origin/destination dichotomy, as these two dimensions can coexist within the spatial trajectories of inventors, shaping a complex geography that deserves to be analyzed to better understand the role of regions in the innovation process.

Finally, this review has highlighted the multiplicity of factors driving inventors' mobility, including both economic and non-economic factors. However, literature has predominantly concentrated on the attractiveness of regions, using a microeconomic approach to explain inventors' choices and the technical characteristics that make an inventor more mobile. What has been almost entirely overlooked is the subjective decision-making process of inventors, who may be motivated by a much broader range of factors. Therefore, a qualitative analysis of the factors that inventors themselves perceive as most influential in their spatial location choices is necessary. Such an analysis could reveal previously unconsidered factors, potentially opening new research directions.

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