Mapping innovation in space

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Abstract

Mapping innovation in space is part and parcel of research on the geography of innovation. The maps we produce reflect both how we conceptualize innovation and the data and indicators we choose to measure it. They can shape research directions and policy strategies. As research on the geography of innovation expands, this paper asks the question: How do innovation maps reflect these evolving perspectives?

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Mapping innovation in space

1. Introduction

Mapping innovation in space is part and parcel of the by now established field of research on the geography of innovation (Feldman and Kogler, 2010, Shearmur et al., 2016). The maps we produce reflect both how we conceptualize innovation and the data and indicators we choose to measure it. Of course, mapping innovation is not an innocent descriptive exercise, but has far-reaching implications for research and policy.

As research on the geography of innovation is expanding, towards broadening the notion of innovation and interrogating the role that innovation plays in spatial economic processes (Binz and Castaldi, 2024, Boschma et al., 2025), the question arises of whether innovation maps are also keeping up with these broadened perspectives. This is the question motivating this paper: How do innovation maps reflect these evolving perspectives?

To answer this question, this paper aims to provide an overview of the many approaches to mapping innovation in space and their evolution in time. I discuss how mapping innovation has evolved over the past few decades, from early maps that emphasized the concentration of innovation in a few science and technology clusters to current maps that offer a more nuanced, rich, and inclusive perspective on where and what kind of innovation is taking place. I connect these different types of mapping to ongoing shifts in research and policy discourses on the geography (or better, geographies) of innovation (Shearmur et al., 2016; Breznitz, 2022). Looking ahead, I identify three directions for further research that seem particularly promising and relevant: (i) towards richer spatial mapping of innovation, (ii) towards more inclusive maps of innovation, (iii) towards normative mapping of innovation.

2. Early maps of innovation and their legacy

Early mapping of innovation was inspired by the emergence of modern industrial research and development (R&D) in the United States and Europe. Models of economic growth also clearly pointed at technological change and R&D as key sources of productivity improvements and growth, which in turn spurred pioneering efforts to compile reliable statistics of R&D activities at national statistical offices (Griliches, 1979). The national figures on R&D published by the OECD already showed considerable heterogeneity across countries, with concentration of these activities in a few countries. Studies at the national level demonstrated an equally strong concentration within countries. For instance, Malecki (1980) drew maps of R&D across the United States (see Figure 1 in that paper), with a clear concentration in a few places on the East Coast, back then.

Not long after, economic geographers began to develop a fascination with Silicon Valley. Hall and Markusen (1985) collected studies on this exciting place in a book called 'Silicon Landscapes'. Despite the title, a reviewer from economic geography could not help but express his disappointment that the book did not include simple maps capturing, for instance, the distinctive location of key activities in the region (Dingemans, 1985). That was later remedied in an extensive strand of research that unpacked the ins and outs of the Silicon Valley model (Saxenian, 1991, Kerr and Kominers, 2015).

Possibly one of the most iconic maps of innovation is the one included in the set of maps used by Florida (2005) in his "The World is Spiky' piece to demonstrate that geography still mattered. The innovation map depicted the world as having a few rare spikes of innovation activity, measured with patent counts. The message conveyed was one of most places globally being 'innovation deserts' and only a handful of places standing out as innovation centers. More recent updates of those maps, for instance in Crescenzi et al. (2020) or more sophisticated versions going beyond simple counts (WIPO, 2019) have shown that new spikes have emerged but the patent landscapes drawn remain highly spiky.

It is fair to say that most subsequent maps of innovation have relied on science and technology (S&T) metrics (patents, publications, R&D), in line with the key role of these activities in formal models of economic growth and innovation (Shearmur, 2012) and in knowledge production functions (Autant-Bernard, 2002), as well as the increasing availability of such data. This happened despite the fact that early innovation scholars clearly understood that R&D and technology activities were only one element of the innovation process (Pavitt, 1984, Freeman and Soete, 2009). Nevertheless, the stylized facts of the geography of innovation were often captured by S&T metrics, which were also the preferred data of economists of innovation. The early studies conveyed the message that regions without S&T activity had little chance of developing real innovation. For instance Malecki (1981) stated: "Other regions, where R&D and related activities do not take place, are unlikely to be the locations of new-product production, and instead will tend to specialize in the production of standardized products." (p. 312). In fact, Audretsch and Feldman (1996) found, for the United States, that product innovations in manufacturing were even more spatially clustered than R&D.

Meanwhile, many authors have warned about the limitations of relying on patents and other S&T metrics only. For instance, Carlino and Kerr (2015) state: "Innovation comes in many shapes and sizes, except in economic studies" (p.2). Three main problems stand out. First, S&T metrics mostly capture innovation in science-based and high-tech manufacturing sectors, while this is only one model of innovation (Pavitt, 1984, Miles, 1993). The rich conceptual and empirical literature on territorial innovation models and national/regional innovation systems has told of stories of geographie*s* of innovation, wherein places can develop all kinds of innovation systems, for instance based on creativity or process engineering (Nelson, 1993; Moulaert and Sekia, 2003; Asheim and Gertler, 2006). Secondly, reliance on S&T indicators reinforces policymakers' obsession with fostering technological inventions and aiming to be the next high-tech cluster. Breznitz (2021) talks about 'techno-fetishism' as a common bias of policymakers. For one, evolutionary economic geography tells us that replicating success is impossible, as a given place has gone through a whole history of events and circumstances that cannot possibly be replicated. And even more importantly, the very ambition of replicating the Silicon Valley model appears particularly problematic at a time when high-tech specializations in general and the Silicon Valley model in particular are increasingly under scrutiny for their sustainability (Breznitz, 2014, Kwon and Sorenson, 2023). Finally, maps of innovation constructed with S&T metrics characterize at best the geography of invention, but not (directly) actual innovation. A key reminder from innovation studies is that invention and innovation are two different things. Enough places, if not most, specialize in the application and market formation phases of the innovation processes rather than being at the frontier of invention (Castaldi and Drivas, 2023).

Given the above, it seems clear that maps of innovation based on S&T metrics only tell a specific part of the story and hide interesting bits that are often about people and places whose innovation remains hidden. To be fair, many authors have updated their notions and maps. Malecki (2021) provides a very different picture of the geography of innovation than his earlier maps, with room for non-technological innovation and innovation beyond the R&D-based model. Yet, the richness and availability of S&T indicators have created a certain path-dependence in the preference of spatial economic studies for these indicators: the more they were used, the more efforts were put in making them even more available and known. This has happened at the expense of efforts to develop alternatives. Fortunately, one can see varieties of innovation maps emerging, that rely on a whole range of indicators. Next, I will provide a brief overview, trying to do justice to the many efforts so far.

3. Emerging varieties of innovation maps

Without being fully comprehensive, it seems useful to provide an overview of how varieties of innovation maps have emerged in the last decades. Table 1 summarizes the main indicators uses so far. They are grouped by their main perspective, being either about: (i) inventions, (ii) innovations, (iii) innovators or (iv) innovation activities. The distinction between invention and innovation is one of the tenets of the economic approach to innovation (Freeman, 1974), which is admittedly a specific connotation of the concept of innovation albeit the one at the foundation of innovation studies (for an historical reflection see Godin, 2012). Invention refers to a new idea, innovation is the actual implementation, either application or commercialization. This distinction resonates with the guidelines of the Oslo manual (OECD/Eurostat, 2018), the international reference for innovation measurement. That manual also makes the distinction between innovation and innovation activities. Instead, the distinction between innovation and innovators aligns with conceptualizations by Archibugi and Simonetti (1998) and others that distinguished an 'object' and a 'subject' approach to innovation measurement. Actors and organizations are subjects of innovation, i.e. innovators, inasmuch they produce or use (some) innovation, while innovation is instead the very object being produced or used.

INSERT TABLE 1 about here

The overview in Table 1 has a focus on studies concerned with the geography of innovation. Of course, much more has been done when it comes to innovation measurement (see also Hall and Jaffe, 2018), but has not (yet) found its way to spatial economic analyses of innovation.Some general remarks seem appropriate. First, most indicators can be geocoded but not all. Even when geocoding is possible, data might only be available at a certain spatial scale, for instance the region. This is for instance the case with survey-based indicators for which anonymity concerns restrict access to full information. Hence, the granularity at which maps can be drawn depends on the possibilities offered by the indicators, as much as on the focus of the research. Yet, it is clear that spatial scale matters, also when drawing maps of innovation (Sorenson, 2024). Second, maps can display a whole variety of indicators: counts, stocks, intensities, flows. General considerations about choosing the right visualization apply to mapping innovation indicators in a same fashion that they apply to all data visualizations. For instance, Ó hUallacháin & Douma (2020) warn about using absolute counts to rank regions in terms of patent intensity and advise relative counts instead. Dividing patent or more generally innovation counts by population, employment or even employment in innovation-related occupations (Wojan et al., 2015) appear sensible approaches. Third, maps can also rely on scoreboards, indexes or factor analysis of combination of indicators based on some underlying conceptualization of the variegated inputs, processes and outputs of innovation. Maps can then convey rankings of spatial units according to aggregate innovation scores or instead on select dimensions. This is the approach taken by maps based upon the Regional Innovation Scoreboard of the European Union and the classification of regions into performance categories, from leaders to followers (Hollanders, 2013). Alternatively, one can categorize spatial units according to innovation modes corresponding to specific combinations of indicators. For example, the map included in Capello and Lenzi (2013) categorizes European regions into different territorial innovation modes. The map itself is rather simple and yet it conveys two clear messages: there is no one-size fits all when it comes to regional innovation and also no superior regional innovation mode, just different ones.

3.1 Mapping inventions

Early stages of the innovation processes have been defined as those where broad explorations of scientific and technological opportunities happen, often within public research institutions but not only (Dosi, 1988). Scientific publications and (utility and design[i]) patents have offered an effective way of capturing single scientific and technological inventive steps, as they both require formal examination of their novelty, either through peer review or through examination at intellectual property offices. Both data have been amazing sources of information about inventions, not the least because of their availability in user-friendly public databases, their timeliness and richness of information, also for spatial analyses. Two other features have made them attractive for geography of innovation research (Breschi and Lissoni, 2001). Firstly, information on citations to and from other records and even between publications and patents, has served both as measure of knowledge spillovers and as measure of value (e.g. Frenken et al., 2009, Kerr and Kominers, 2015, Castaldi and Los, 2017). Secondly, information on co-authorship, co-ownership and co-inventorship of publications/patents, serves as proxy for collaborations, which have been be studied from a spatial perspective too (e.g. ter Wal, 2014, Wanzenböck et al., 2014).

3.2 Mapping innovations

As for actual, commercialized, business innovation, the traditional take has been to use literature-based indicators: early studies relied on new product announcements in specialized magazines (Acs and Audretch, 1988). More recently, new product announcements are also collected from online data, including web-scraping of company websites (Nathan and Rosso, 2022, Abbasiharofeth et al., 2023).

An alternative take has been to use trademarks as indicator of commercial innovation (Mendonça et al., 2004, Gatrell and Ceh, 2004, Flikkema et al., 2014). The intuition is that firms will register a new trademark when they introduce a new product to the market. Trademark records have very similar characteristics to patent data, even though they lack citation information and are not relational data (Castaldi and Mendonça, 2022). Next to capturing later stages of the innovation process, trademarks also represent an alternative for capturing innovations in contexts where patents are not used, including small firms, non-technological innovation and low-tech sectors (Flikkema et al., 2014, Morales et al., 2024). This is the reason why maps of innovation using trademarks allow uncovering different places than those identified with patents (Castaldi, 2023).

3.3 Mapping innovators

If not trying to capture single innovations themselves, one can endeavor to map the actors behind those innovations, either *individuals* or *organizations*.

Individuals mostly associated with innovation have been inventors, both scientists and engineers. Patent and publication data have offered a great resource to track their activities, given that both data sources include names of the individuals responsible for the technical or scientific invention and their work location. The individual level of analysis has allowed following the movements of inventors in space, as a key channel for the diffusion of ideas (Lissoni and Miguelez, 2024). Other individuals linked to innovation have been broader categories of high-skilled workers, either technical personnel or creative workers (Rodríguez-Pose and Lee, 2020). Increasingly, these workers and their specific activities, can be mapped with occupational data provided by national statistical offices or by data sources, such as Linkedin.

Moving from the individual to the organizational level, entrepreneurship data have allowed to map innovation as being developed by risk-taking new ventures. Herein, scholars have sought to separate high-quality, innovative entrepreneurship from other forms, such as necessity-based one, that are less likely to be about innovation. Examples of mapping innovative entrepreneurship include using data from listings of start-ups like Crunchbase (Tiba et al., 2021; Yu and Fleming, 2022) or developing methods to identify high-quality entrepreneurship from new business registration data (Guzman and Stern, 2020).

When it comes to large and established firms, innovators have often been equated with firms in high-tech sectors or R&D intensive firms. For instance, several studies have explored the geography of innovation exploiting the COR&DIP© database about top R&D investors, jointly released by the European Commission and OECD (Dernis et al. 2019, Amoroso et al. 2021). This data has a global perspective, hence also allowed to uncover shifts in technology or market leadership of countries worldwide. Alternative definitions of innovative firms have relied on defining them as those that introduced at least an innovation in a given period or whose sales depend for more than a certain percentage on innovations. This is the typical approach when studies rely for instance on Community Innovation Survey data or similar innovation surveys: innovation intensity from such survey data can only be used at the firm level- rather than the level of single projects and spatial analysis typically stops at the regional level if not the national one, because of firm anonymity constraints (Evangelista et al., 2001).

Ad-hoc, often country-specific, lists of innovators have also delivered useful insights. For instance, Fritsch and Wyrwich (2021) exploit the database on so-called 'hidden champions', i.e. firms that are global market leaders in their specific market segment but tend to be underestimated in patent or R&D statistics. Mapping their location revealed innovation beyond core German regions, as these firms often thrive in smaller cities where they play a key role in driving local prosperity.

3.4 Mapping innovation activities

As already discussed, early maps commonly relied on high-tech industry data, for instance capturing intensity of employment in those industries by region (Hall and Markusen, 1985). Tracking the location of R&D labs is another way to map high-tech innovation activities (Carlino et al., 2012). The geography of R&D can be inferred from different types of information, for instance surveys (Ouwersloot and Rietveld, 2000).

When matched to data on multinational firms and their subsidiaries, R&D data has been key to reveal the globalization of innovation activities. A rich strand of research in international business has focused on understanding the processes through which multinationals decide to establish R&D facilities beyond their headquarter locations (Iammarino and McCann, 2013) and revealing the emergence of R&D activities beyond the US and Europe. At the same time, the development and standardization of R&D statistics nationally and internationally allowed capturing R&D intensity, either in value or employment, by region and country in a systematic way. Moreover, information on R&D collaborations, either funded by national or international funding agencies or started by companies for strategic reasons, has been exploited in a rich strand of research on knowledge diffusion and the network nature of innovation (Broekel et al., 2014).

Another proxy for innovation activities, focused on the financing of entrepreneurship, is venture capital. Geography of innovation analyses have mapped venture capital activities themselves (Chen et al., 2010) or used them to identify innovative firms as those backed by venture capital (Florida and King, 2018; Shi et al., 2024). The main limitation is that these indicators mostly focus on activities in those few high-tech sectors where venture capitalists invest (Carlino and Kerr, 2015).

4. Further opportunities: three directions

4.1 Towards richer spatial mapping of innovation

Assigning innovation indicators to spatial units such as regions or cities is one thing, but analyzing the spatially uneven processes underlying these maps is another (Autant-Bernard, 2012). Such spatial economic analyses are clearly complementary to regional investigations and, for some authors, the way to truly understand the geography of innovation (see McCann 2007, Shearmur, 2011). Regional analyses of innovation rely on regionally aggregated statistics, which not only hide heterogeneity within regions, but also assume that regional administrative boundaries are most salient in delineating what is 'proximate'. In reality, concentrations of innovation activity often span more than one region or intersect several regions. The most famous innovative region itself, Silicon Valley, does not even correspond to a single spatial unit, although many studies equate it with the San Jose' metropolitan statistical area.

In this sense, the use of geocoded data opens up a wider range of possibilities for spatial analysis, where proximity and accessibility may prove to be more significant predictors of spatial patterns of innovation than local factors shaped by administrative boundaries. The emerging literature on the micro-geography of innovation has already explored a range of innovation indicators: scientific activity (Catalini, 2018), patenting (Agrawal et al., 2017), survey-based firm innovation (Rammer et al., 2020, Matsiuk et al., 2024), entrepreneurship data (Donegan and Lowe, 2020). When exploiting geocoded data is not an option, for instance because the matched economic variables are only available for given spatial units, relying on more granular spatial units than large regional ones is an option (see for instance Roper and Jibril, 2024)

Further maps could be drawn by combining multiple data sources that capture different events or phases within innovation processes. This seems particularly fruitful when it comes to understanding the diffusion of innovations in space, as a complement to the analysis of where innovations originate. One can trace ‘innovation journeys’, being trajectories that link locations according to their role in different phases of the innovation process. Many investigations have relied on scientific and patent citations to follow the journey from science to technology (Bikard and Marx, 2020; Pezzoni et al., 2023) or on linking scientists and inventors to entrepreneurship data to trace the journey from technology to commercialization (Audretsch and Feldmann, 2004). Recent ones are linking patents with information on patent licensing (Losacker et al., 2023), patent data with job vacancies (Kalyani et al., 2025), patent and trademark records through textual similarity, to identify market applications of specific new technologies (Abbasiharofteh et al., 2022) or innovative and imitative trademarks to study the role of distance in diffusion of new products (von Graevenitz et al., 2022). These types of studies can complement existing work based on relational data from a single data source (including co-inventor links in patents or R&D collaborations) and build upon their established methods of spatial economic analysis (network analysis, gravity models and more). At the same time, mapping innovation journey can broadly benefit from methodological and technological advances relevant to the whole pipeline of map production, from data collection to analysis and visualization: these include GIS tools but also artificial intelligence (Nagaraj and Stern, 2020).

4.2 Towards more inclusive innovation maps

The overview in the previous section has already shown how different maps can be drawn by using different indicators of innovation. However, the potential of using a wide range of indicators has not yet been fully exploited. Importantly, efforts in this direction offer many opportunities to draw more inclusive innovation maps in at least three dimensions: more places, more geographies, and more actors than those that rely only on preferred innovation indicators.

When it comes to places, obviously some indicators will tend to chart similar spatial patterns, as they are strongly correlated. This is the case for S&T metrics, which will typically lead to drawing maps that highlight the same usual suspects as key places of innovation, namely high-tech clusters. Instead, leveraging alternative indicators allows revealing more and different innovative places. An example is how different authors have combined patents, trademarks and design rights to capture different regional innovation specializations (Castaldi and Drivas, 2023, Roper and Jibril, 2024). Figure 1 in Castaldi (2024) shows maps for the United States: the map based on patents confirms the dominance of Silicon Valley, the other maps show concentration in more and different cities, also secondary ones. Clearly, each indicator focuses not only on a different phase of the innovation process (technology, design, market) but also on different types of innovation, beyond technological ones. For the case of trademark data, von Graevenitz et al. (2022) unleashed text analytics to define innovation as first-time keywords: they were able to identify a very broad list of innovations, defined as goods or services for which new names were created, including hyperlink, homepage, teleconferencing, wellness, smoothie, microblogging, outsourcing, coworking, and many more. This list includes more types of innovation than could be identified using patent data alone. It also helps explain why cities that specialize in activities other than high-tech manufacturing are more likely to appear on maps drawn with trademark-based indicators. Another example is how Fritsch and Wyrwich (2021) have challenged the stylized fact that innovation concentrates in large cities by leveraging the database on German hidden champions. Survey-based indicators remain important to understand how innovators can thrive in unexpected places, including rural and peripheral areas (Wojan and Nichols, 2018). Spatial economic analyses could then include different dimensions of distance and accessibility that might help characterize and understand innovation in peripheral regions beyond their geographical location only (Grabher and Ibert, 2014, Glückler et al., 2023).

In terms of geographical coverage, it is clear that most maps have either focused on Europe or the United States only or they have used data with a bias towards those geographical contexts. For instance, it has not been uncommon for global maps of innovation to rely on patents registered at the USPTO as a convenient standard, given that many internationally-oriented firms would register at this office. Still, much has been gained from releasing this assumption and counting patents registered at different national offices, for instance looking at triadic patents or focusing on Chinese patenting at home. This clearly requires careful consideration of the institutional differences between countries so that meaningful comparisons can be made (Criscuolo, 2006). Still, innovation mapping would significantly benefit from giving more credit to what is happening beyond Europe and the United States, in emerging economies and the Global South.

When it comes to mapping the individuals most involved in innovation, the reliance on information about scientists, inventors and engineers has reinforced two long-standing biases. The first is the bias towards S&T graduates as the main contributors to innovation. For example, the large literature on migration and innovation has focused on S&T migrants to a much lesser extent than other migrants, including artists, professionals and entrepreneurs (for exceptions, see Pinate et al. 2023, Glennon, 2024). A second one is the gender and ethnic bias in innovation indicators: women and ethnic minorities are underrepresented in inventor statistics (Frietsch et al., 2009). Preliminary hints suggest that of all intellectual property rights, trademarks have the least gender bias (Heikkilä, 2019; Schuster et al., 2020). Also, entrepreneurship indicators that do not rely exclusively on high-tech entrepreneurship appear useful in this respect (Zhang et al., 2024). Many opportunities are there to draw more gender and minority-inclusive maps of innovation. A final consideration is that most innovation mapping has looked at corporate innovation. Innovation also happens outside corporate boundaries, in households, user communities, neighborhoods and collective experiments. Indicators for these forms of innovation are emerging (Gault et al., 2023, Wachs et al., 2022), they could provide fresh perspectives for spatial economic analyses too and further help to reveal innovation in hidden places.

4.3 Towards normative mapping of innovation

A final emerging trend in innovation mapping is the incorporation of 'normative' innovation metrics (Castaldi et al., 2024). This involves focusing on specific directions of innovation that are of interest from a normative perspective because they contribute, either positively or negatively, to societal goals related to sustainability along any of its dimensions (social, economic, and environmental/ecological). This normative mapping is emerging alongside research that questions the actual impact of innovation on people and places, including investigations into the negative implications of the geography of innovation in terms of economic (Pineiro et al., 2022), social (Lee and Rodríguez-Pose, 2013) and environmental (Hansen et al., 2021) consequences.

A first generation of normative maps benefited from policy interests in mapping directions of innovation linked to societal goals. Methodological advances in identifying specific qualities of innovations or innovators, often using textual analysis, have been instrumental in these ongoing efforts. Several studies have already examined the spatial properties of these indicators. Examples include geographical analyses of scientific publications related to sustainable development goals (Confraria et al., 2024), green patents (Dechezleprêtre et al., 2011, Perruchas et al., 2020), green trademarks (Amoroso et al., 2021), sustainable entrepreneurship (Tiba et al., 2021), circular economy initiatives (Katz-Gerro and López Sintas, 2019). A few studies have instead focused on innovations with negative impacts, mapping the geography of toxic patents (Biggi et al., 2024) or critical resource-intensive patents (de Cunzo et al., 2024).

A next step in normative mapping can be based on reconstructing innovation journeys, as discussed earlier in this section, but adding a normative perspective to assess or value the position that places take in these journeys. The places where innovations emerge, are produced, and are adopted may be different places that experience positive or negative implications of this position according to given values or norms. To illustrate, electric cars and related new technologies and products would be identified as innovations with positive impacts on economic and environmental sustainability in the places where they are developed and used, but one might want to highlight the negative externalities in terms of environmental costs in the places where the materials needed for their production are sourced (Li et al., 2024). This example also illustrates the need to map innovation journeys that include diffusion phases, where the impact of innovation is fully realized (Binz and Castaldi, 2024). Early work on the diffusion of innovation by Hägerstrand (1953/1967) and Rogers (2003) can be revisited for this purpose too.

In sum, more normative maps than those descriptively charting all innovation without characterizing its nature or impact can help to question the quality of the development paths offered by innovation to places and people (Iammarino et al., 2019; Binz and Castaldi, 2024; Boschma et al., 2025). Methodologically, inspiration can be drawn from similar exercises of mapping in sustainability science (Kraak et al., 2022), but also from complementary art-based and creative cartography (Duxbury et al., 2018). In terms of spatial economic analysis, normative innovation metrics are likely to open opportunities for linking spatially uneven innovation and economic dynamics in ways that resonate with questions and concerns high on the public policy agenda's, locally and globally.

INSERT TABLE 2 about here

5. Conclusions

In this paper, I have focused on the exercise of mapping innovation in space, reflecting on the implications of drawing certain maps and not others. I have traced a brief history of innovation mapping to understand the legacy of early maps that have been highly influential in shaping how we think about the geography of innovation. But several new approaches have also emerged, prompted by changing interests among researchers and policymakers that have fueled the demand for new data and indicators. Of course, mapping has also evolved thanks to the possibilities offered by methodological advances in data collection, analysis, and visualization tools. All of this has led to a variety of innovation maps being drawn, more in line with the idea that one should indeed speak of geographies of innovation (Shearmur et al., 2016).

I have outlined three main areas for further research that appear exciting, relevant, and feasible (see the overview in Table 2). First, spatial mapping of innovation can take even greater advantage of advances in innovation measurement and the availability of geocoded data. Second, the maps drawn can become even more inclusive of different places, geographies and actors. Third, normative innovation maps can be drawn, taking a stance and marking either positive or negative directions of innovation. Overall, maps are slowly but steadily moving from conveying the message of a strong concentration of innovation activity and the (persistent) success of a few places, to questioning these innovation success stories and uncovering hidden innovation happening in less expected places by less expected actors.

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Indicators	Key focus	Spatial information	Data type/sources
Inventions			
- Scientific publications	Scientific invention, including citations to prior work and scientific classification	Location of scientist's affiliation	Secondary data, from public and commercial databases
- Patents	Technological invention (process and design too), including citations to prior art and technological classification	Location of inventor and assignee	Secondary data, from national and international offices
Innovations			
- New products/processes	New product/process announcements, by all firm types	Location of firm	Literature-based, survey-based, web-scraped
- Trademarks	Distinctive symbols flagging goods and services introduced in specific markets	Location of owner	Secondary data, from national and international offices
Innovators			
- Innovative individuals	Inventors, scientists, engineers, other workers	Location of residence or work	Publication and patent databases, occupational data from statistical offices
- Innovative entrepreneurship	High-quality new ventures	Location of operation	Business register data from statistical offices or listings
- Innovative firms	Firms declaring innovation activities, Technology or market corporate leaders	Location of headquarters and/or subsidiaries and/or plants	Different ones, including innovation surveys, rankings of firms matched to innovation data
Innovation activities			
- High-tech industries	Industries strongly relying on science and technology	Regional and national level	Secondary data from statistical offices
- R&D (expenses, labs, personnel, collaborations)	Location, intensity and distribution of R&D activity	Location of R&D labs, regional and national level of expenses and employment	Secondary data from statistical offices, firm-level data
- Venture capital	Distribution of venture capitalist activities, distribution of venture capital-backed firms	Location of venture capitalist, location of venture capital-backed firm	Commercial databases

Table 1: Overview of key indicators for mapping innovation in space

Mapping innovation in space	Further opportunities
Towards richer spatial mapping	From regional comparisons to detailed spatial analyses Further revealing micro-geographies of innovation, using geocoded data Tracing ‘innovation journeys’ in space, combining indicators of different innovation phases/events
Towards more inclusive mapping	Mapping more places than the usual suspects of high-tech clusters or large cities, by exploiting alternatives to S&T-focused indicators Mapping more geographies than Europe and the United States, by considering geographical biases of innovation indicators and seeking alternatives Mapping more actors, with consideration of gender, minorities and non-corporate actors, starting from conceptualizing more occupations and economic activities linked to innovation
Towards more normative mapping	Mapping geographies of innovations with either positive or negative implications, by taking stock of methodological advances in measuring qualities of innovation Characterizing innovation journeys by the positive or negative effects afforded to locations with different roles in those journeys, bringing normative and valuation perspectives in the picture

Table 2: Emerging varieties of innovation maps: three directions for further opportunities

[i] Most studies have counted utility patents only, but design patents can also be used to track new technological designs, in some national offices. In Europe design rights cover aesthetic rather than technical design hence are more similar to trademarks (see Castaldi and Drivas, 2023 for a discussion of the differences).