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THE GEOGRAPHY OF INNOVATION: PATENT INSIGHTS INTO EUROPE'S GREEN AND DIGITAL TRANSITIONS

by Francesca Lotti* and Claudia Nobile**

Abstract

Innovation is a key driver of Europe's green and digital transitions, as well as of its global competitiveness. This report uses patent data from the Patent Cooperation Treaty (PCT) and the European Patent Office to assess where and how technological capabilities are evolving, with a focus on Italy's position in the European innovation landscape. The analysis reveals persistent cross-country and regional divides, but also signals a shifting global innovation frontier: China has rapidly emerged as a global leader in strategic technologies such as artificial intelligence and green innovation, overtaking the United States, the EU and Japan in international patent filings. This development highlights the need for Europe to reinforce its innovation leadership in high-value, globally competitive domains. Within Europe, Germany leads in both patent volume and quality, while France stands out in artificial intelligence (AI). Italy ranks fifth in patenting overall, with a strong industrial base and targeted specialization in green technologies, yet it grapples with marked regional imbalances and limited public sector involvement. AI patenting in Italy remains concentrated in the industrial North and is led by firms, whereas green innovation is more broadly distributed, offering potential for more inclusive growth. At the same time, the innovation process is becoming increasingly dominated by incumbent firms. The share of new and 'one-shot' patenting firms is declining, and the average age of first-time innovators is rising – pointing to structural barriers to entry and the growing complexity of frontier innovation. Stronger support for young, regionally dispersed innovators and complementary investments in adjacent technologies are essential to sustain and expand Italy's innovation capacity in the context of the Twin Transition.

JEL Classification: O33, O31, R11.

Keywords: green technologies, artificial intelligence, innovation geography, patent data, firm dynamics.

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1 Introduction

In September 2024, Mario Draghi published "The Draghi report on European competitiveness", highlighting the challenges and opportunities presented by the Twin Transition. The Draghi report outlines a strategic framework of incentives and policies required to stimulate public and private innovation and to secure a European competitive edge in advanced, contestable technologies. This advantage is critical for maintaining Europe's relevance and influence in an increasingly fragmented and geopolitically driven global environment. In this context, the present note aims to inform policy by addressing three core questions. Where are Europe's technological hubs that can act as engines of growth through international knowledge spillovers? What are the strengths and weaknesses of Italy's innovative firms in this broader European landscape? Which Italian regions play a leading role in innovation, and what are their areas of specialization? Clarifying these elements will help identify the key levers for place-based innovation policies—targeting both high-performing hubs and regions with untapped innovation potential.

To assess the comparative advantage of Europe's main innovation actors — particularly in the context of the Twin Transition — we analyze patent applications in green and artificial intelligence technologies filed at the European Patent Office between 1990 and 2021. In fields where intellectual property protection is critical, patents provide a robust proxy for innovation output across firms, individuals, and the public sector. By examining long-term trends and cyclical dynamics in patenting activity and its geographic distribution, this analysis sheds light on the evolving technological landscape and the interlinkages between emerging technologies and their industrial applications.

The analysis reveals a general upward trend in innovation activity across Europe; however, significant cross-country heterogeneity persists. While green and AI-related patenting has shown moderate growth in recent years, this expansion has further accentuated the underlying asymmetries in innovation capacity among Member States—highlighting divergent trajectories in the development and diffusion of key technologies.

2 Patents as a Measure of Innovation

Measuring innovation is a challenging task: restricting the focus to patents, all non-patented (or patentable) innovations that are protected by trade secrets are excluded [Fadeev, 2023]. As mentioned by Lotti and Marin [2013], on the one hand, patents as a measure of innovative activity underestimate the effective research and development efforts of firms, individuals, and public institutions, as innovations are patented to warrant ex post monopoly rights that are limited in time and space but require public disclosure. Patent applications are an objective, homogeneous measure of innovation. They are highly standardized and codified according to the patent office's procedures and are a rich source of information on the technology developed.

The analysis relies on two main sources of data: the PCT filings and the EPO's global patent statistical database (PATSTAT), structured in line with OECD guidelines.

For the comparison of patent propensity of the European Union, the United States, China and Japan, we rely

on patent applications filed under the Patent Cooperation Treaty (PCT) rather than those filed at national patent offices, such as the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO), China's CNIPA or Japan Pattent Office (JPO). This choice reflects the need for internationally comparable, high-quality, and economically meaningful data on innovation across major economies.

PCT filings follow a uniform procedure administered by the World Intellectual Property Organization (WIPO), which ensures consistent standards for documentation, classification, and publication. This allows us to avoid distortions that arise from institutional and procedural differences across national offices — such as divergent examination practices, local incentives, or jurisdiction-specific filing strategies. Moreover, the cost and strategic intent behind a PCT application serve as a quality filter: firms only pursue PCT filings when they expect the invention to have significant commercial value across multiple markets. By focusing on PCT data, we isolate innovations with clear international relevance and reduce noise from country-specific differences in patenting behavior. Data on PCT applications are available at the aggregate level from the OECD data portal (https://data-explorer.oecd.org/).

To examine innovation activity in selected EU countries and in Italy, we rely on granular information from PATSTAT. This comprehensive dataset covers patent filings from 39 EPO member states—including all 27 EU Member States—as well as over 40 additional countries. It provides detailed information on patent applicants and inventors (including names and addresses), as well as the technological scope of each patent (title, abstract, classification codes), links between related patents (families, priorities, technological proximity), bibliographic references (citations by other patents and scientific literature), and legal events associated with each filing. This richness makes it a valuable tool for monitoring innovation dynamics across time, technologies, and geographies. The data used in this analysis are based on the PATSTAT version released in February 2025, but we only consider the period between 1990 and 2021, to account for the truncation problem [Lerner and Seru, 2017]. Each patent belongs to one or more "families" of patents, i.e. a set of patent documents filed in different countries or jurisdictions to protect the same invention which shares the same priority application[1]

For each priority patent application, we extract key information including the filing date, the applicant's address and country of residence, and the associated International Patent Classification (IPC) codes—an internationally standardized system developed by WIPO to categorize the technical content of patents. Patent nationality is assigned on a fractional basis, proportionally attributing each application to the countries of the listed applicants. This method allows for a nuanced analysis of cross-border innovation and collaborative technological development.

To identify green technologies, we rely on the WIPO green inventory classification (as in [De Luca et al., 2021]). The subclasses allow us to distinguish between adaptation to climate change technologies and mitigation technologies. To identify patents in AI, we use the taxonomy developed by the OECD Calvino et al. [2024]. Each patent can be associated to various IPC codes, even within the main subclass (the first four digits): a patent is

[1]Using patent families as a unit of observation enables us to track the international coverage of an invention, to measure the value of patent - a larger family suggests higher expected returns, avoid double-counting when doing patent statistics and trace innovation diffusion across jurisdictions [OECD, 2009].

considered green or AI, if at least one of its associated IPC codes belongs to the fields reported in Table 1.

Table 1: IPC codes for AI and Green Technologies.

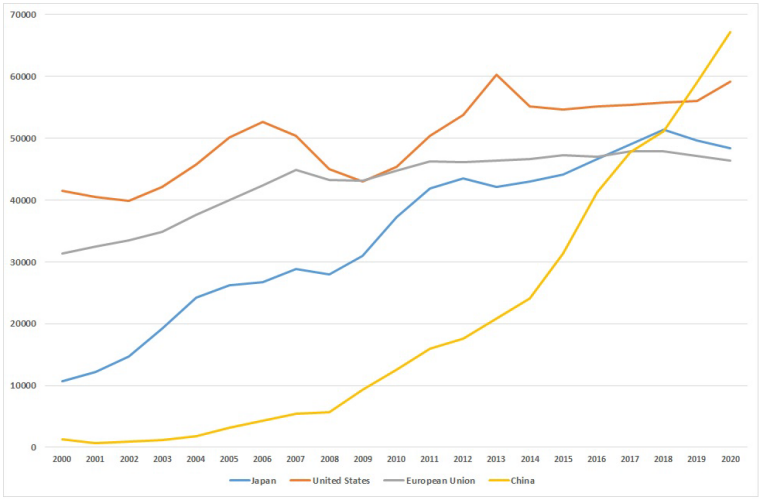
Category	**IPC Codes**
AI	B29C, B33Y, G06Q, G06T, G06F, H04L, C12N, C01B, H01M, B60W, G05D, G06K, B62D
Green Tech	A01B, A01G, A01P, B02C, B03B, B09B, B60K, B60L, B61, B63, B64, C02F, C10B, C10L, C12P, C22B, E03F, E04B, E04H, F01K, F02B, F02C, F02G, F16L, F23G, F24F, F24H, F24S, F24V, G01, G08, G09, G21, G21B, H01J, H01K, H01L, H01M, H02J, H02K, H02P, H02S

3 A New Leadership

This section provides a comparative view of the innovation trajectories of the four major global economies — China, the United States, the European Union, and Japan — based on PCT patent applications, which serve as a proxy for internationally oriented, high-value inventions.

While the US and the EU have historically led global patenting, and Japan has maintained a strong, though more stable, position, the most striking feature is China's rapid and sustained takeoff in recent years, especially after 2008 (see Figure 1). From negligible levels in the early 2000s, Chinese filings have grown exponentially, surpassing those of the EU, Japan, and even the United States by 2019.

Figure 1: Total PCT patent applications: China, EU, Japan and US.

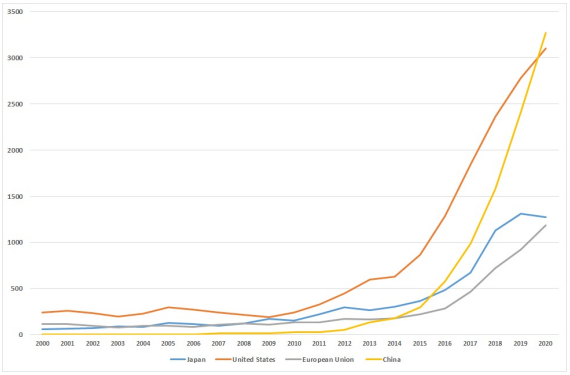


Source: OECD, Patents in OECD selected technologies (https://data-explorer.oecd.org/).

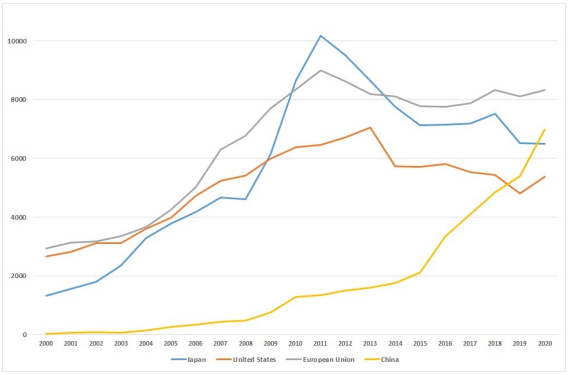
This signals a decisive shift in China's innovation strategy toward global markets and leadership in high-value technological domains, as it is evident from Figure 2.

Figure 2a, focusing on artificial intelligence, confirms this trend in a strategic frontier field. While the United

Figure 2: Total PCT patent applications for the Twin Transition: China, EU, Japan and US.



(a) AI patent applications



(b) Green patent applications

Source: OECD, Patents in OECD selected technologies (https://data-explorer.oecd.org/).

States initially led AI-related PCT filings, China's growth since 2014 has been dramatic, matching and overtaking the U.S. by 2020. This reflects the country's coordinated investments in digital technologies and its increasing ability to convert R&D into internationally competitive inventions.

Green technologies (Figure 2b), show a similar pattern, albeit with a slight lag. Europe and Japan initially dominated green PCT filings, consistent with early leadership in environmental innovation. However, from around 2015, China's filings began accelerating sharply, surpassing the U.S. by 2018 and converging with European levels by 2020. This indicates that China's innovation system is now fully mobilized around both the digital and green transitions, with growing international reach.

4 Mapping Innovation across Europe and Italy

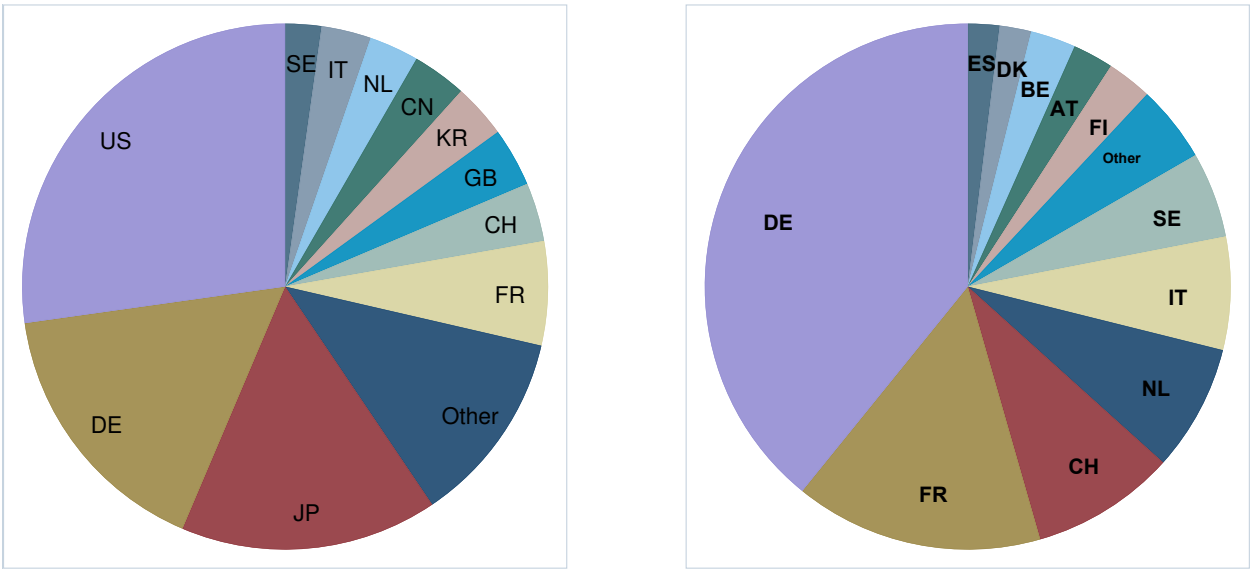
From this point onward, the analysis draws on patent application data filed at the European Patent Office (EPO). While the overall picture of technological development remains consistent with broader international trends, the EPO data offer a highly granular basis for analysis—enabling richer insights into the geography, quality, and actors of innovation across and within countries.

The following sections examine the heterogeneity of innovation activity between Italy and selected European countries, as well as across Italian regions. Section 1 presents historical patenting trends across European countries; Section 2 compares the regional distribution of knowledge stocks, both at the European level and within Italy, while Section 3 assesses whether differences in patent counts correspond to differences in patent quality. Section 4 analyzes patenting dynamics in green and AI technologies—key drivers of the Twin Transition. Section 5 explores the respective roles of firms and individual inventors in the innovation process and Section 6 focuses on firm demographics in Italy, shedding light on the structure and evolution of the national innovation ecosystem. This framework supports the design of targeted innovation policies by clarifying where and how technological capabilities are developing.

4.1 The Great Divergence

Figure 3 shows the cumulative stock of patent applications by country. While US and Japan account for more than 30% of the total applications (Figure3a), it is evident that, within Europe, Germany maintains a dominant position with a knowledge stock significantly larger than that of its peers (Figure3b). However, this dominance has gradually diminished over time, as the relative shares of Italian and Spanish innovators, respectively ranking fifth and eleventh, have increased—suggesting a slow but steady rebalancing in Europe's innovation landscape (Figure 4).

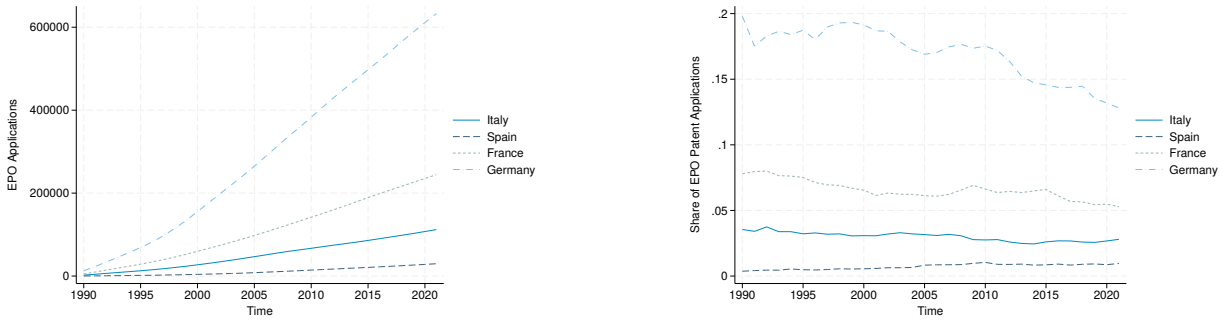
Figure 3: Country average share of patent applications at the EPO, 1990-2021



(a) All Countries

(b) EU-27

Figure 4: Patent applications, selected countries (1990-2021)



(a) Simple patent count

(b) Share of new applications

It is evident that since 1977, when the EPO was instituted in Munich, Germany, German innovators have been the most responsive to the new proximity of the Patent Office (the so-called "Home Bias" effect[2]), which has further

[2]Harhoff [2016]

enhanced the patent propensity in Germany.

4.2 The Regional Divide

Innovation activity across Europe is not evenly distributed but tends to concentrate in specific regions [Bergeaud et al., 2022]. This spatial concentration — often referred to as innovation clustering — is driven by a range of mutually reinforcing economic, institutional, and social mechanisms. Innovation benefits significantly from the proximity of firms, research institutions, and skilled individuals. Geographic concentration facilitates the informal exchange of ideas, collaborative projects, and rapid dissemination of tacit knowledge. These knowledge spillovers are a key driver of innovation intensity in clustered regions. Also, innovative activity requires a highly skilled and often specialized workforce. Regions with strong universities, research centers, and established technology sectors attract and retain these talents. In turn, firms in these regions benefit from a deep labor pool, specialized suppliers, and complementary services, further reinforcing the cluster and generating economies of scale and scope. Firms benefit from lower transaction costs, shared infrastructure, and easier access to finance and venture capital. These agglomeration effects enhance productivity, innovation efficiency, and resilience in the face of shocks. Once established, innovation clusters tend to reinforce themselves. Success attracts additional investment, talents, and institutional attention, creating a cycle of cumulative advantage. This dynamic leads to persistent spatial disparities in innovation performance.

The map depicted in Figure 5 shows the cumulative patent applications, between 1990 and 2021, attributing the nationality of the patent application in proportion to the residence of the applicants. The most relevant European innovation ecosystems are evident: Berlin, Amsterdam, Stockholm, Paris, Barcelona and Madrid, Helsinki and Copenhagen.

Figure 5: Cumulative stocks of patent applications across Europe

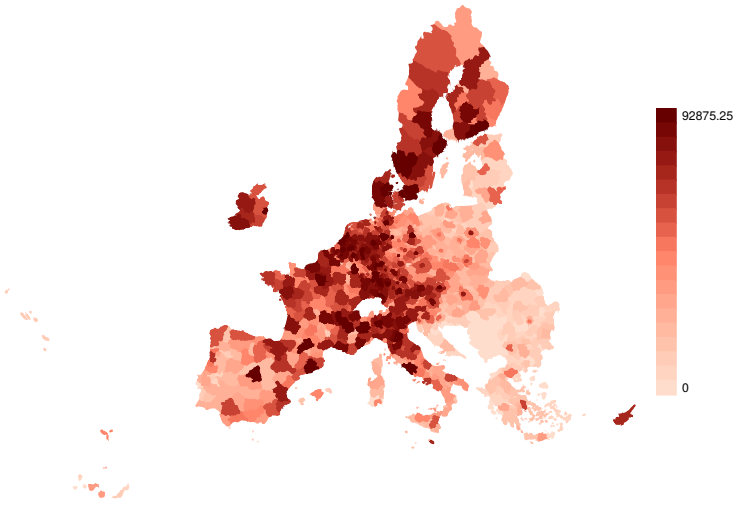
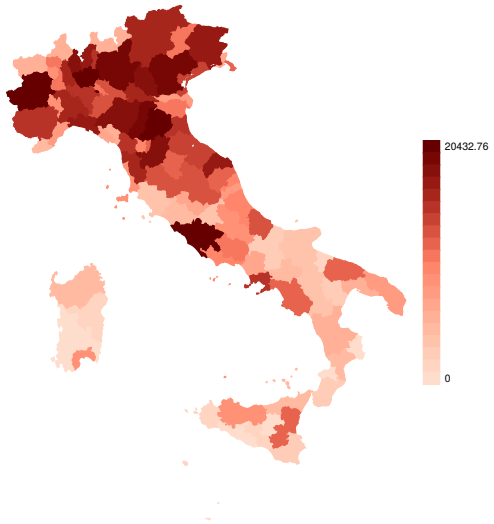


Figure 6: Cumulative stocks of patent applications across Italy



Innovation activity across Italian regions remains highly uneven. The North accounts for the largest share of patent applications; distinct innovation ecosystems have emerged around Milan, Turin, Bologna. In Central Italy, Rome stands out as the most prominent innovation hub, concentrating a significant share of the region's patenting activity.

To better understand the extent and nature of this regional divide, we examine not only the volume of patenting but also its quality — using established indicators of technological relevance and complexity. This approach helps identify whether regional differences stem from disparities in innovation capacity, technological specialization, or both ([Squicciarini et al., 2013]).

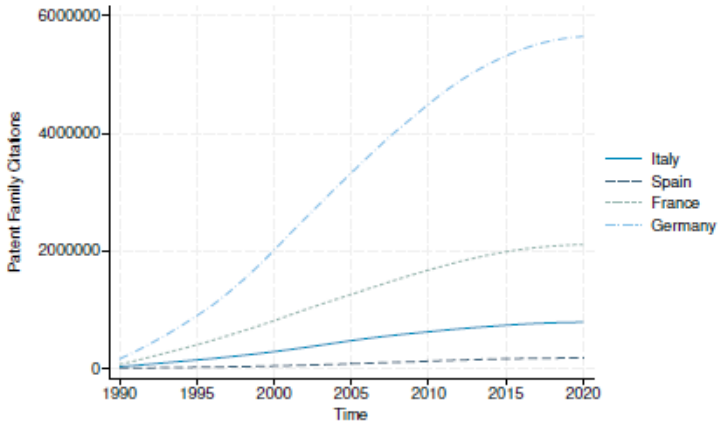
4.3 Patent Quality

We use two standard measures of quality, forward citations by subsequent patents [Jaffe and Lerner, 2011] and family size [Putnam, 1996].

The size of a patent family is the number of patents applications which share a priority date (the date of the first patent application for the same invention) and it is used to infer patent complexity. Larger families are typically associated with inventions that are valuable, broadly applicable, and strategically important, which are common traits of complex technologies [OECD, 2009]. Filing patents across multiple countries is costly, so applicants are more likely to seek broad protection when the invention reflects a significant R&D investment, involves multiple technical domains, or contains several interrelated components. Moreover, complex inventions often require complementary filings or variations tailored to different legal contexts, further expanding the patent family. As such, patent family size captures not only the commercial significance of an invention but also the

underlying complexity of its technological architecture. In Figure 7, we plot the cumulative count of citations by patent family (a set of applications related to the same invention) for Italy, Spain, Germany, and France. The patterns of the citations replicate the divergence of the patent stocks among European countries. This is partially due to a scale effect and to the home bias of patent citations, as documented by [Bacchiocchi and Montobbio, 2010] but also to the frictions in the international diffusion of knowledge.

Figure 7: Cumulative citations per patent family, selected countries, fractional counts.



The average family size follows a general trend across the countries, indicating the cyclical expansions and contractions of new sectors (see Table 2). Specifically, the second decade is permeated by the digital revolution, which sees a great expansion of the average family size of German patents. The third decade saw the aftermath of the Global Financial Crisis, when patenting activity contracted; all countries but Germany and Spain reverted to their pre-2000 level.

Table 2: Average patent family size per country

Country	1990-2000	2000-2010	2010-2020
Germany	19.8	26.0	25.6
Spain	13.8	15.9	15.7
France	18.7	19.4	19.0
Italy	16.0	17.7	15.9

Figure 8 illustrates the geographic distribution of average patent quality across European regions, using the two standard indicators: average citation count (Panel a) and average patent family size (Panel b), both based on fractional counts over the period 1990–2021.

The maps reveal a highly uneven landscape of innovation quality across Europe. Regions in Germany, the Netherlands, and parts of the Nordic countries consistently score above average on both measures, indicating strong innovation ecosystems that produce patents with greater technological relevance (as captured by citations) and broader international protection (as measured by family size).

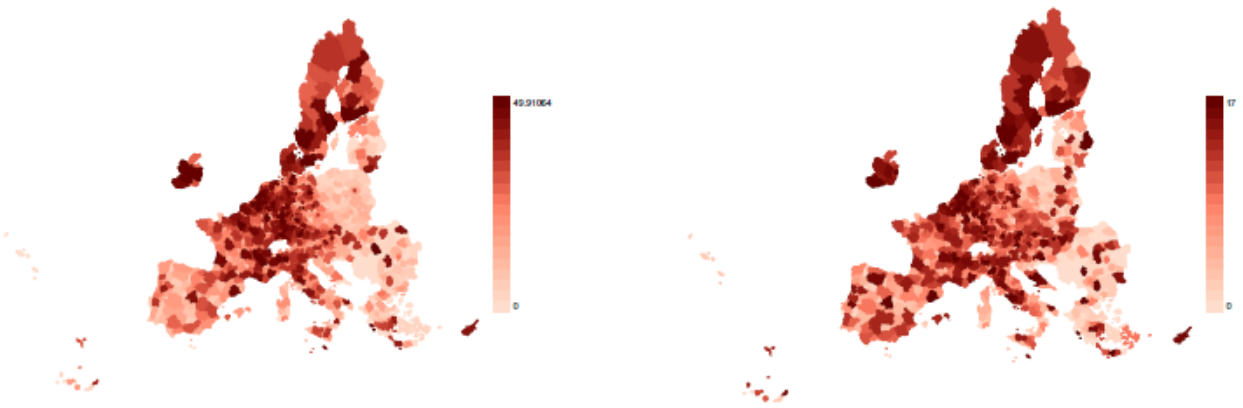
In contrast, Southern and Eastern European regions generally display lower values for both indicators, suggesting more limited international diffusion and impact of their innovations. Notably, some regions in Italy, France,

and Spain show intermediate performance, with some local hubs outperforming national averages, highlighting the importance of regional dynamics.

A clear divergence emerges between regions that lead in the quantity of patenting and those that lead in patent quality. As shown in Figure 5, cumulative patent stocks are concentrated in Central and Southern Germany, Northern Italy, the Paris region, and the Benelux countries—traditional hubs of industrial and technological activity in Europe. However, Figure 8 reveals a different geography of innovation leadership: regions in Northern Europe, particularly Sweden, Finland, and parts of Denmark and the Netherlands, consistently outperform in terms of average patent citations and family size — two indicators of technological relevance and international reach. This contrast highlights that high-volume patenting does not necessarily equate to high-impact innovation.

Focusing on Italy, Figure 9 shows that the highest quality patents appear to be in the Center and in the North: the latter is more well connected through citations, and thus creates influential patents, while the center produces more complex patents, which require multiple patent applications.

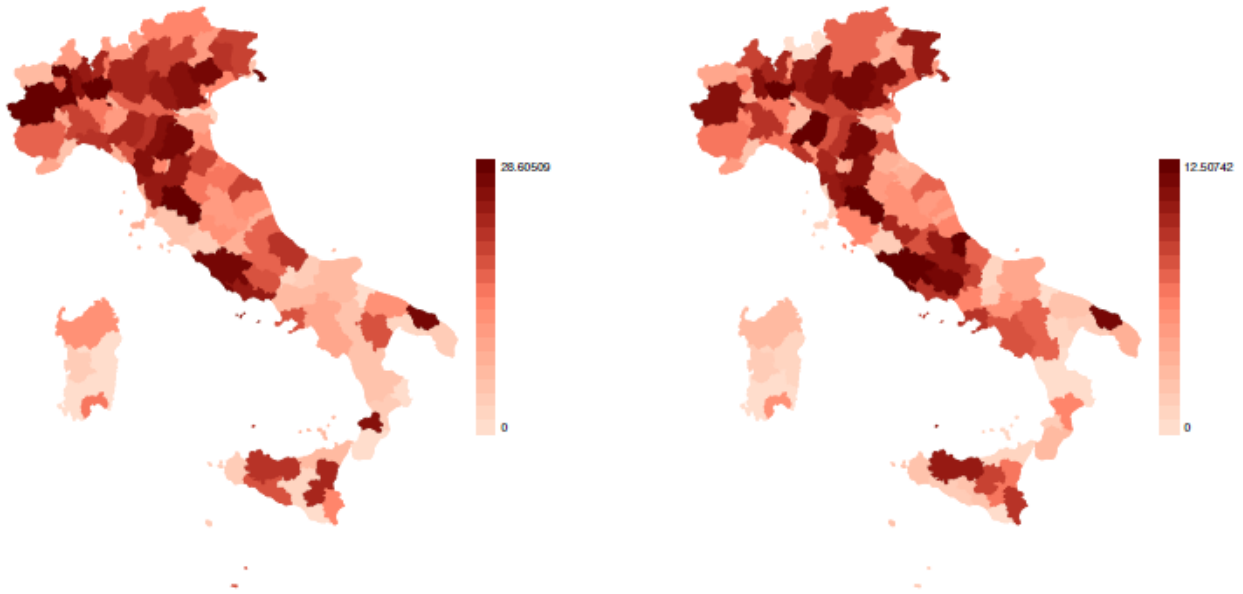
Figure 8: Average patent quality within European regions



(a) Average citation count

(b) Average patent family size

Figure 9: Average patent quality within Italian regions



(a) Average citation count

(b) Average patent family size

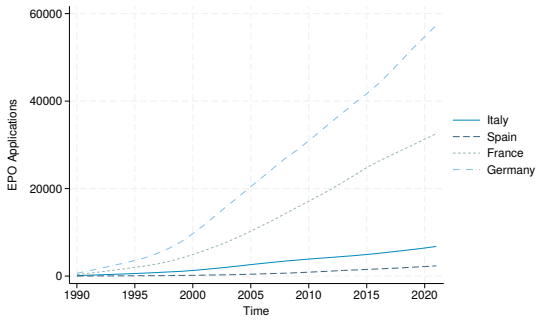
4.4 Technologies for the Twin Transition: Artificial Intelligence and Green Patents

Figure 10 tracks the evolution of AI-related patenting activity across four major European countries—Germany, France, Italy, and Spain — based on fractional counts. Panel (a) shows absolute patent volumes; Panel (b) depicts the share of AI patents within each country's total patent stock.

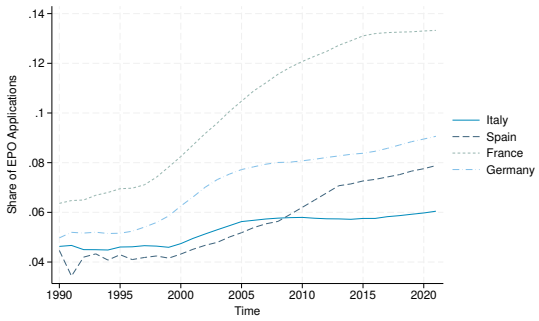
Panel (a) highlights Germany's clear leadership in AI patenting, with a steep increase since the early 2000s, followed by France. In contrast, Italy and Spain lag significantly behind in terms of raw patent counts, with only modest growth over the past two decades.

Panel (b) provides additional insight by normalizing AI patents as a share of each country's total patent applications. France stands out for its sustained and growing focus on AI, indicating a strong national orientation toward this strategic technology. Germany maintains a relatively stable share, reflecting a solid but less dynamic engagement with AI technologies, while Italy and Spain —despite marginal gains since 2005 — remain well below their European peers in AI patent intensity.

Figure 10: Patent applications in AI: raw counts and relative share, selected countries



(a) Patent applications, fractional counts

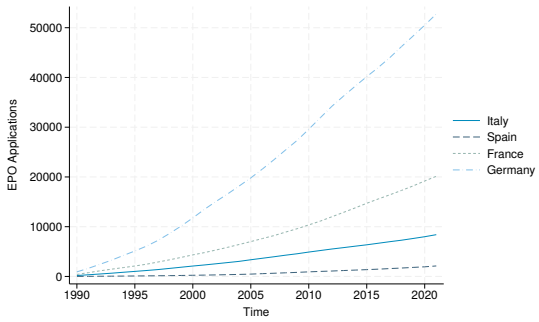


(b) Share of patents, fractional counts

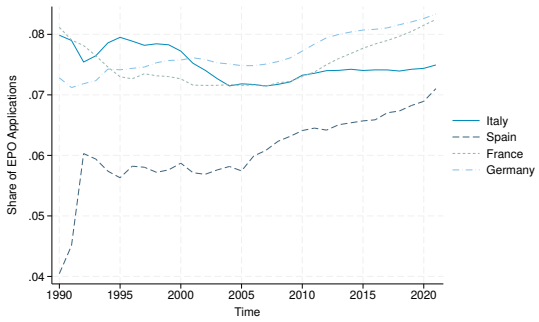
These patterns point to substantial cross-country differences in AI innovation capacity. France is consolidating its position as a European AI leader, while other countries risk falling behind in this critical area unless proactive measures are taken. This calls for targeted public support for AI R&D, talent development, and technology transfer — particularly in Italy and Spain — to close the emerging gap and fully participate in Europe's digital transformation.

Figure 11 compares the evolution of green technology patenting in Germany, France, Italy, and Spain using fractional counts. As before, Panel (a) shows the absolute number of new green patent applications, while Panel (b) presents the share of green patents relative to each country's total patent stock.

Figure 11: Patent applications in Green Technologies: raw counts and relative share, selected countries



(a) Patent applications, fractional counts



(b) Share of patents, fractional counts

Panel (a) confirms Germany's leading role in green innovation, with a sustained and steep rise in patent applications over the past two decades. France follows at a considerable distance but shows steady growth. Italy and Spain maintain lower levels of green patenting, with a relatively flat trend in recent years.

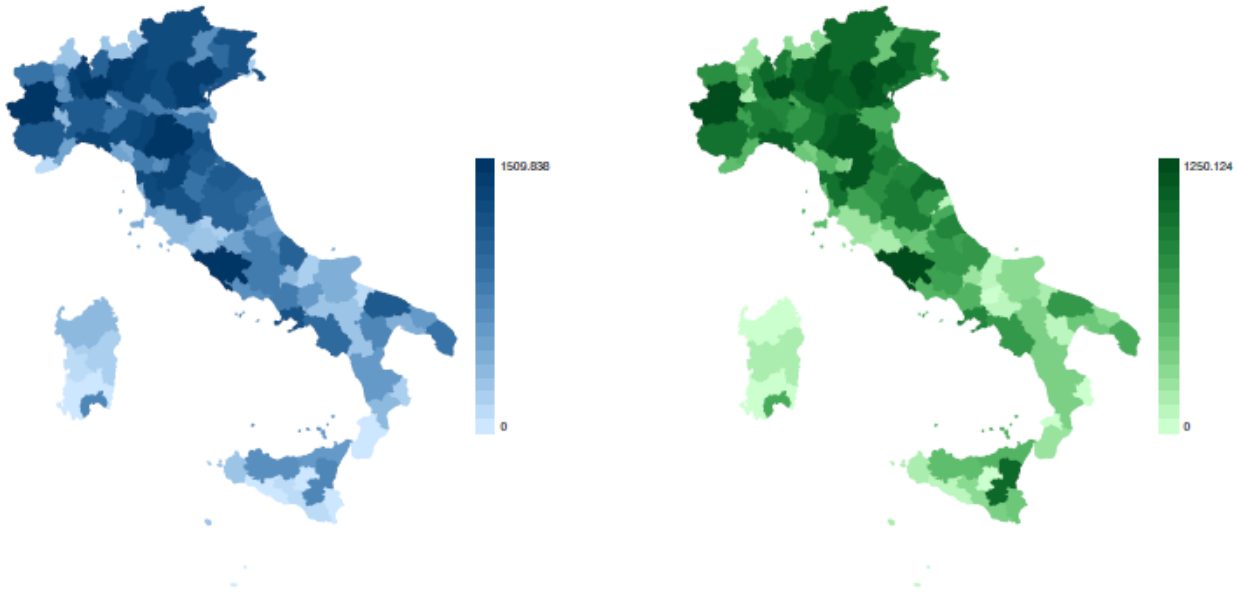
Panel (b), which normalizes for overall patenting activity, reveals a more nuanced picture. Italy stood out for its relatively high share of green technologies in its total patent output, consistently outperforming France and approaching the level seen in Germany, until the Global Financial Crisis. This suggests that, while Italy generates fewer patents overall, its innovation activity has been relatively more focused on green technologies. France,

by contrast, shows a lower and stable green share, indicating that its innovation system is less oriented toward environmental or clean technologies, with some progress since 2011.

These findings reflect different national specializations and strategic orientations in green innovation. Germany combines scale and focus, while Italy exhibits a more targeted green innovation profile towards mitigation technologies related to transportation. France appears less engaged in green technologies relative to its overall innovation capacity, which may call for policy realignment given the centrality of green innovation in the EU climate and industrial policy agendas.

Figure 12 shows the geographic distribution of patent stocks in artificial intelligence (Panel a) and green technologies (Panel b) across Italian regions, based on EPO applications (fractional counts) from 1990 to 2021.

Figure 12: Patent applications in AI and Green Technologies within Italian regions



(a) AI

(b) Green Technologies

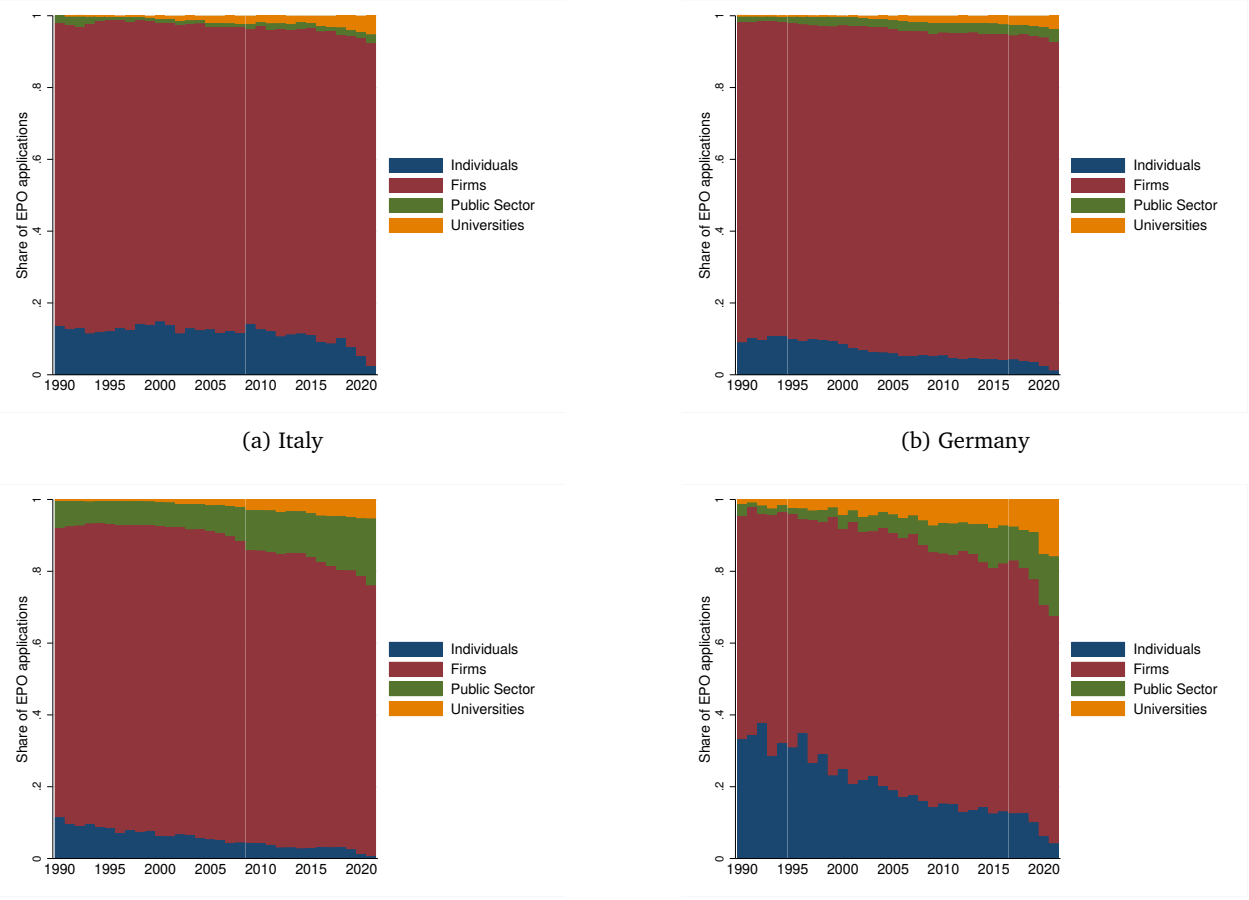
Panel (a) reveals a strong concentration of AI-related patenting activity in Northern Italy, particularly in the regions of Lombardy, Piedmont, and Emilia-Romagna, with Milan and Turin standing out as key innovation hubs. Central and Southern regions display considerably lower levels of AI patenting, with only isolated peaks of activity.

Panel (b), showing green technology patents, presents a somewhat more diffuse distribution, though Northern regions again dominate. Regions such as Veneto, Emilia-Romagna, Lombardy, and Trentino-Alto Adige exhibit strong engagement in green innovation. Notably, some Southern and island regions (e.g. Apulia, Sicily, Sardinia) show relatively higher levels of green patenting compared to their AI activity, suggesting a more regionally balanced orientation toward environmental technologies.

These patterns point to persistent regional disparities in Italy's innovation landscape, with AI innovation heavily concentrated in industrial Northern regions, while green technologies show broader territorial diffusion, though still with a North-South gap, with the North as a driver of digital transformation, and potential for place-based green innovation in the South.

4.5 Structural Change in the Innovating Process

Cross-country differences in patent propensity may partly reflect a composition effect. PATSTAT classifies patent applicants into five categories: universities, government/non-profits, individuals, companies, and hospitals. However, outside of Italy, patent filings by hospitals and public institutions are negligible—suggesting poor data quality for these categories. For this reason, we aggregate the patents filed by hospitals and by the government/non-profits and focus our analysis on Italy, Germany, France and Spain.



(a) Italy

(b) Germany

(c) France

(d) Spain

Figure 13: Sectoral composition of EPO patent applications, 1990–2021

.

Since 1995, the share of applications submitted by firms has increased across countries, while the share filed by individuals has declined in all countries (Figure 13). However, Italy and Spain stand out: the decline in the

individual share is less pronounced—except in recent years. This pattern reflects the smaller average size of firms and the widespread presence of sole proprietorships, where business owners tend to file patents in their personal name. Firms file the vast majority of patents, especially in Italy and Germany, and this share has increased at the expense of the share of individuals. On the other hand, France and Spain stand out for the sizeable and increasing share of patents filed by universities and the public sector, respectively.

We then conduct a more detailed analysis of composition effects within the two most relevant technology domains—artificial intelligence and green technologies within Italy. These sectors are of particular interest due to their strategic importance for innovation policy and the green and digital transitions.

Figures 14 and 15 show the regional distribution of patent applications in AI and green technologies in Italy, broken down by applicant type—companies, individuals, universities, and the public sector. Companies account for the largest share of patent filings.

Innovation activity is heavily concentrated in the Center-North, particularly in the country's main industrial hubs. South of Lazio, corporate innovation is minimal. This reflects a combination of factors: the smaller average firm size, the higher prevalence of informality, and a weaker innovation infrastructure in Southern regions. These conditions may also lead to patents being filed under individual inventor names, operating outside formal innovation networks, rather than through firms or small businesses.

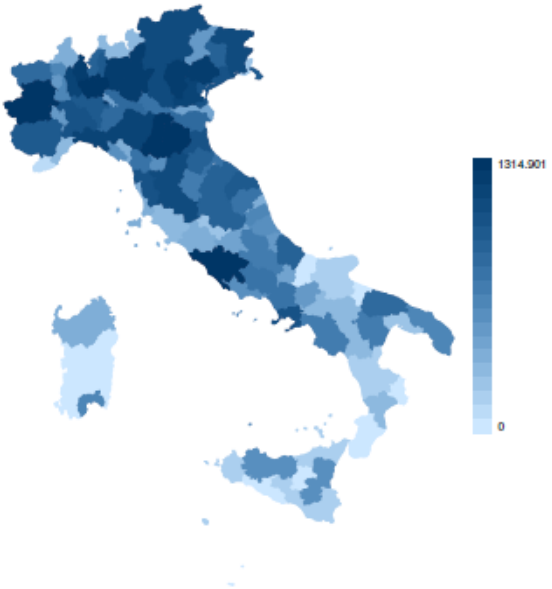
Over the past 20 years, universities and the public sector (including non-profits and hospitals) have accounted for less than 10% of total patent filings. As a result, the maps display lower overall patent counts for these sectors but reveal significant regional heterogeneity. Each Italian region typically hosts a major public university in its capital city, which acts as a local innovation hub. In larger cities like Rome, the presence of multiple universities and public research institutions fosters research spillovers and collaboration. Hospitals engaging in innovation are primarily located in major urban areas, though some, such as those in Trieste, also stand out in more peripheral locations.

The regional pattern of patent filings by the public sector closely mirrors that of individual applicants, as it includes a wide range of non-profit institutions. However, these comparisons should be interpreted with caution: sectoral differences in patenting intensity, along with divergent technological specializations between public and private actors, limit the comparability of regional distributions. For example, in pharmaceutical research—a field with strong intellectual property protection—hospitals and firms contribute to innovation with differing goals, inputs, and expected outcomes.

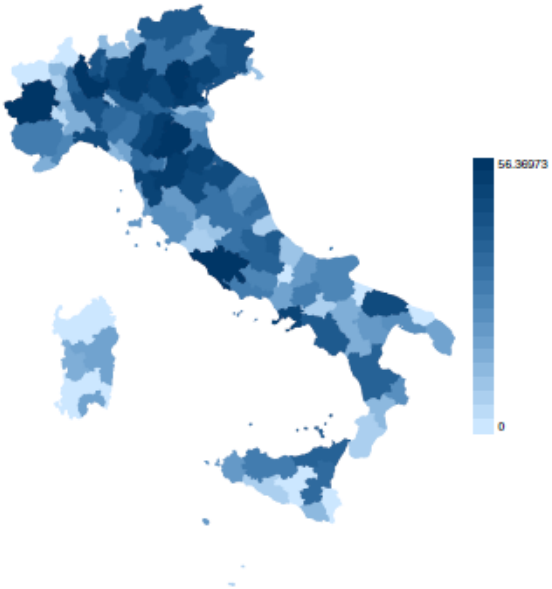
Summing up, in AI, innovation is heavily concentrated in the Center-North, driven primarily by firms. The highest volumes of patent filings are observed in the main industrial regions such as Lombardy, Emilia-Romagna, and Veneto. Universities and public institutions play a more marginal role, with activity limited to a few urban hubs. In the South, AI patenting is minimal, reflecting structural weaknesses such as smaller firm size, informality, and limited research infrastructure.

In green technologies, firms again dominate the patenting landscape, particularly in the North and Center. However, the regional footprint is somewhat broader than in AI, with more visible contributions from individuals

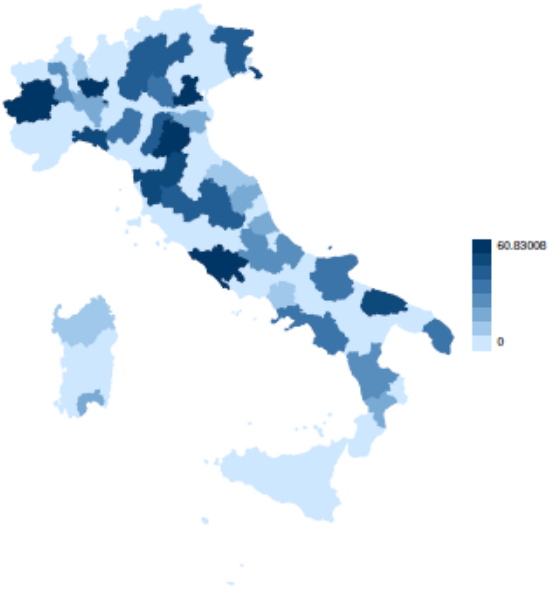
Figure 14: Patent filings in AI by applicant type in Italy



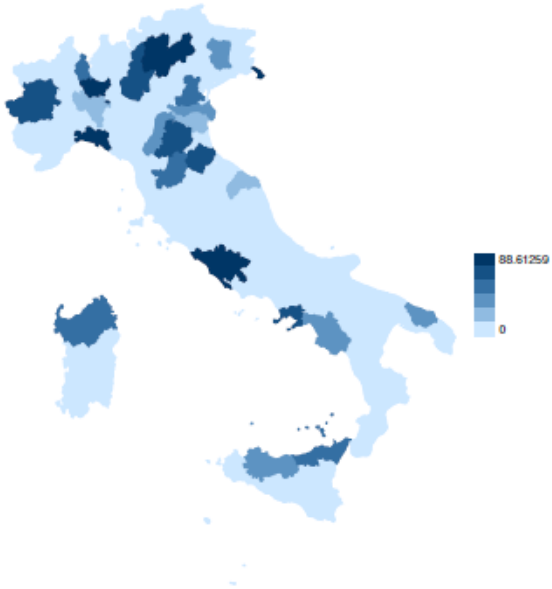
(a) Firms



(b) Individuals

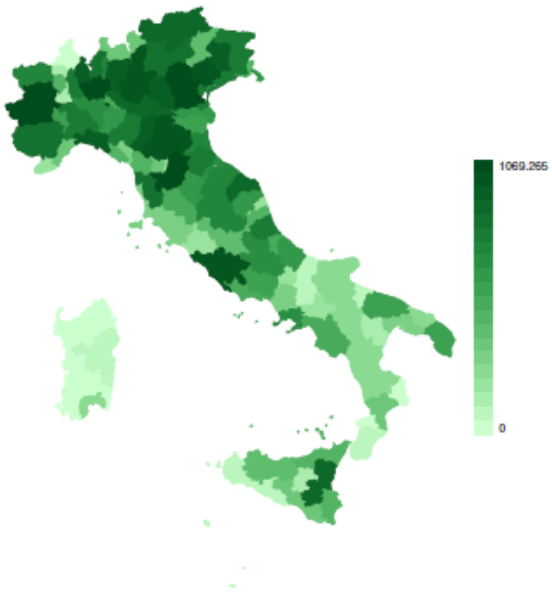


(c) Universities

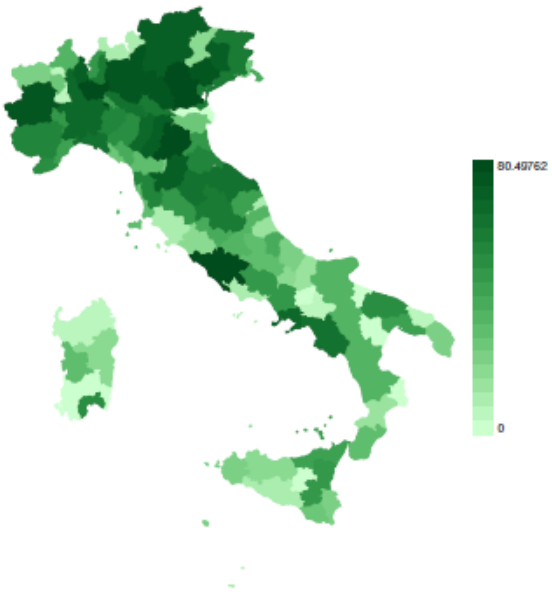


(d) Public Research Institutions

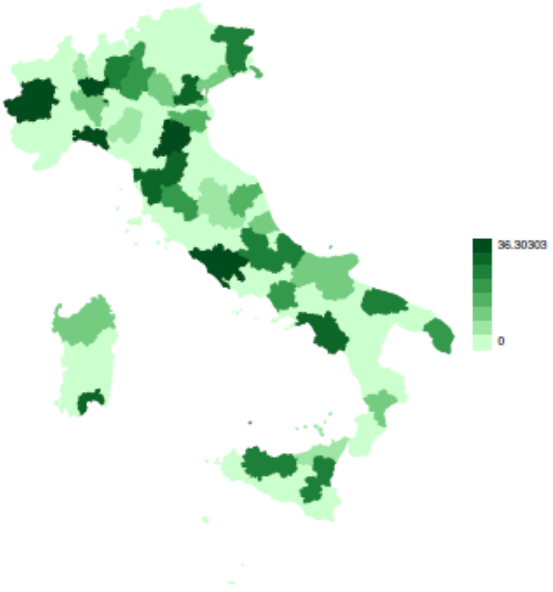
Figure 15: Patent filings in Green Technologies by applicant type in Italy



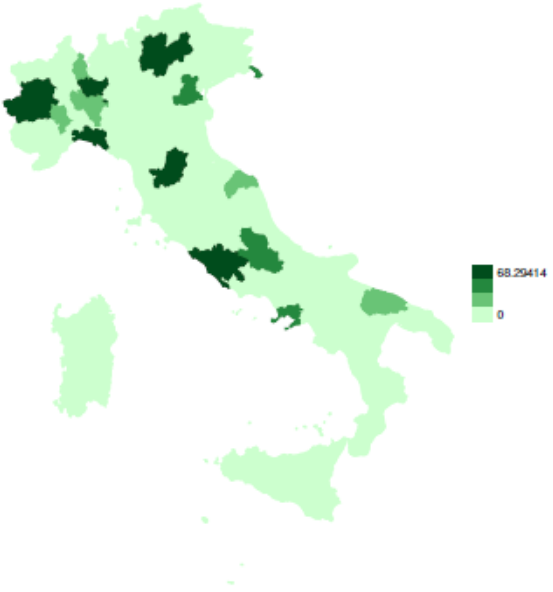
(a) Firms



(b) Individuals



(c) Universities



(d) Public Research Institutions

and public institutions in Southern regions and islands. This may suggest a wider base of potential innovators and stronger alignment with locally relevant sectors, such as energy and environmental services.

Comparing the two domains, both show a clear concentration of innovation in the industrial North and a central role for firms. However, green technologies exhibit a more inclusive pattern, both geographically and institutionally. This highlights the potential for green innovation to serve as an entry point for expanding the national innovation base, especially in less developed regions.

4.6 Italy: Firm Demography

Given the central role of firms in patenting activity, we now focus on Italy's corporate sector. To deepen the analysis, we link patent data from PATSTAT with firm-level information from Infocamere's business registry as in [Akcigit et al., 2023] and [Lotti and Marin, 2013].

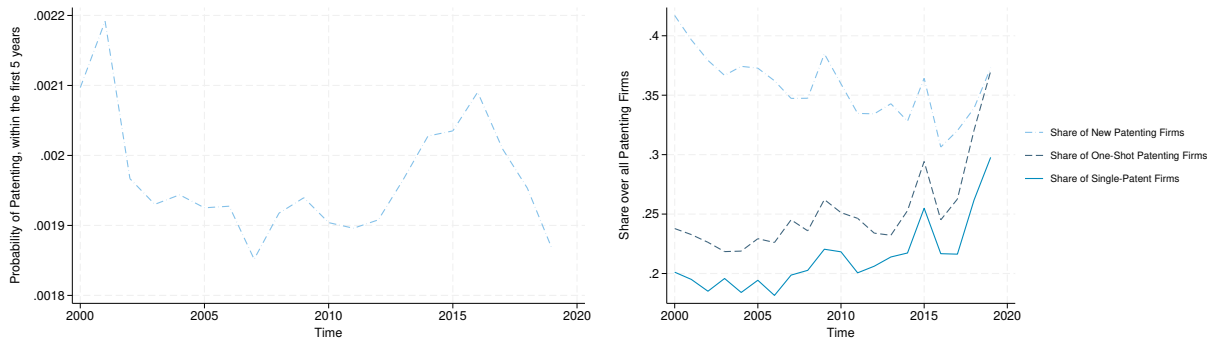
The business registry records the demography of all 4.2 million Italian firms, of which firms that file for a patent represent less than 1%. In graph 16a we plot the probability of filing a patent between 2000 and 2019, among firms under five years, born in these years. We see that the probability of filing for a patent for young firms oscillates cyclically, following the periods of economic crisis and expansion.

Decker et al. [2016] attributes the decline in business dynamism to the growing dominance of incumbent firms, which consolidate market power through strategies like product bundling and demand accumulation—raising barriers to entry for new competitors. We examine whether a similar pattern holds in innovation: are incumbents also dominating patent activity, limiting the role of new entrants in technological advancement?

While the share of new patenting firms — i.e. those firms filing a patent for the first time — remains relatively high due to the inherent riskiness of innovation, it has been steadily declining. This trend aligns with the increasing market dominance of incumbent firms and mirrors the slowdown in breakthrough innovation noted by Bloom et al. [2020].

Just as young firms face barriers to entering outlet markets, both new patenting firms and serial innovators struggle to sustain innovative activity. Figure 16b highlights the share of "One-shot" patenting—firms, i.e. those firms that enter the innovation space with a few patents but do not continue patenting in subsequent years. This group, shown by the dark line, is growing steadily. Most One-shot patenting firms are also single-patent firms (firms that patent only once in their lifetime), and this share too is on the rise.

Part of this trend may be due to right-censoring in the data: many newly established firms have only a short observation window, making it less likely that follow-up patents are yet visible. Still, the persistence of One-shot innovation suggests that translating a first invention into sustained innovation remains a challenge for many firms.



(a) Probability of filing for a patent, for firms under five years

(b) Life-cycle dynamics of patenting firms

Figure 16: How rare is patenting?

Age

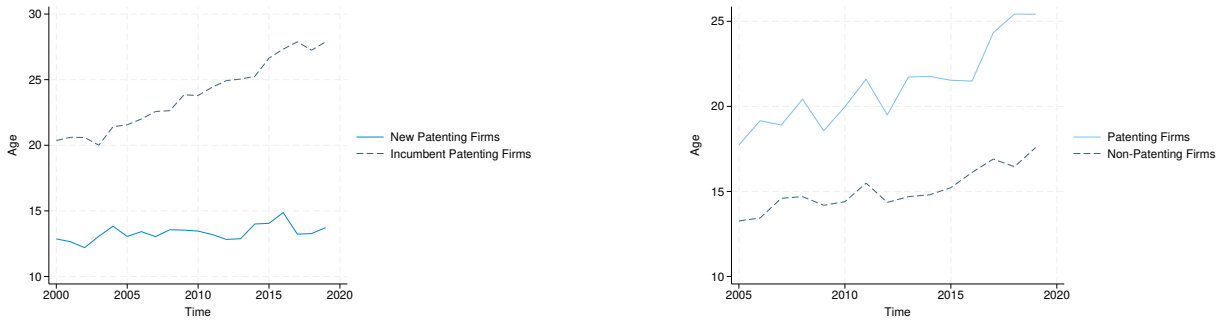
In the U.S., breakthrough innovation is often associated with young, small firms. But is the same true for Italy? Between 2000 and 2020, the average age of new Patenting Firms (i.e. firms that are filing a patent for the first time in a given year) ranged between 14 and 16 years, significantly older than the typical image of the young disruptor (see the line New Patenting Firms of Figure 17a).

Average age is increasing for incumbent innovators as well (see Figure 17a), may be partially due to increasing innovation complexity or barriers to entry, which tend to favor established firms with more experience and resources.

Overall, this higher age may reflect several structural factors: the increasing complexity and cost of innovation, as well as the lasting impact of economic downturns. Financial market scars from past recessions may have tightened credit conditions, making it harder for younger firms to access funding for R&D and patenting activities.

In the right panel, we compare the average age at exit of patenting firms, which has sharply increased during the recent years, even more than the mean age of non-patenting firms. Patenting firms, on average, exit the market at much later stages.

Figure 17: Average age of patenting firms at entry into innovation and at exit from the market

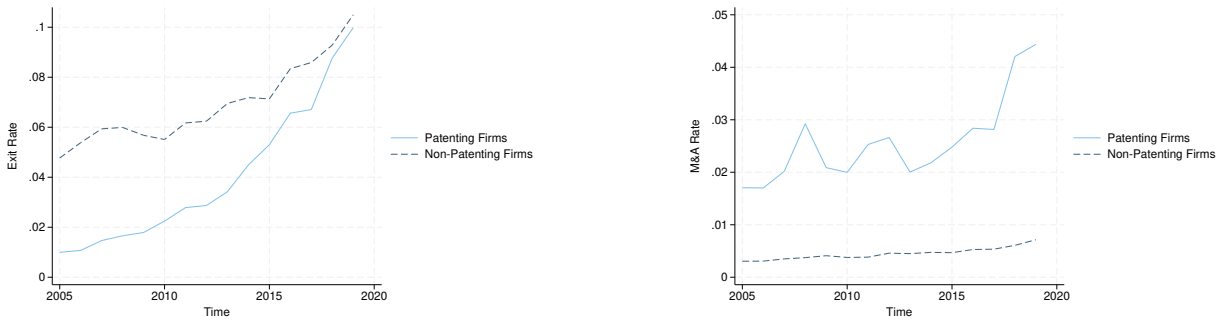


(a) Average age of patenting firms

(b) Average age at exit

We then compute the exit rate, for two mutually exclusive scenarios, failure and M&A. The failure rate is the ratio of the number of exiting firms due to insolvency and bankruptcy to the number of firms in the market. Comparing firms that have filed at least one patent application ("Patenting") to firms that have not, shows that innovation is positively correlated with the likelihood of survival on the market, even though the two curves are converging in the recent years. If on the other hand, we look at the M&A rate, the ratio of firms which get acquired, merged or split, to those which stay on the market, we see that innovation is positively correlated to the exit through mergers and acquisitions, consistently with previous evidence [Cunningham et al., 2021].

Figure 18: Failure and M&A rates: patenting vs non-patenting firms



(a) Failure rate

(b) M&A rate

5 Conclusions

This note provides a comprehensive overview of the geography and dynamics of innovation in Europe, with a focus on Italy's position in the green and digital transitions.

First, a new global innovation leadership is taking shape. China has rapidly overtaken traditional leaders—the United States, the European Union, and Japan—in international patent filings, particularly in strategic technologies such as artificial intelligence and green innovation. This shift underscores China's move from quantity-driven to quality-driven innovation, with increasing international reach. For Europe, this trend signals the urgency of reinforcing its competitive edge in high-value, globally relevant technological domains.

Second, European innovation remains highly concentrated, both across and within countries. Germany dominates in both patent volume and quality, while France leads in AI specialization. Italy, although ranking fifth in total EPO patent filings, shows a more modest performance, with a strong industrial base but weaker diffusion across regions and sectors.

Third, Italy's innovation ecosystem is marked by sharp territorial imbalances. Patent activity is heavily concentrated in the Center-North, driven largely by firms located in key industrial hubs. Southern regions lag behind, reflecting structural constraints such as smaller firm size, informality, and limited innovation infrastructure. These regional gaps suggest the need for targeted, place-based innovation policies to unlock underutilized potential, particularly in green sectors.

Fourth, technological specialization matters. Italy displays a relatively stronger focus on green technologies — both in absolute terms and as a share of total patenting—compared to AI, where it trails behind major European peers. While AI innovation is more concentrated and dominated by firms, green technologies show a broader regional and institutional base, offering an opportunity for more inclusive growth and diffusion.

Fifth, structural changes in the innovation process are reshaping the landscape. Innovation is increasingly concentrated in the hands of incumbent firms, while the share of new and "One-shot" patenting firms is in decline. The average age of first-time patenting firms is rising, pointing to growing barriers to entry, financial constraints, and the increasing complexity of cutting-edge technologies.

Finally, while innovating firms enjoy higher survival and acquisition rates, many struggle to sustain long-term innovation. This calls for policies that not only support firm entry but also help young and small firms scale their innovative efforts—through access to finance, R&D partnerships, and innovation ecosystems.

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