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A Growth-Inducing EU Innovation Act

Unleashing Europe's Potential for Radical Innovation

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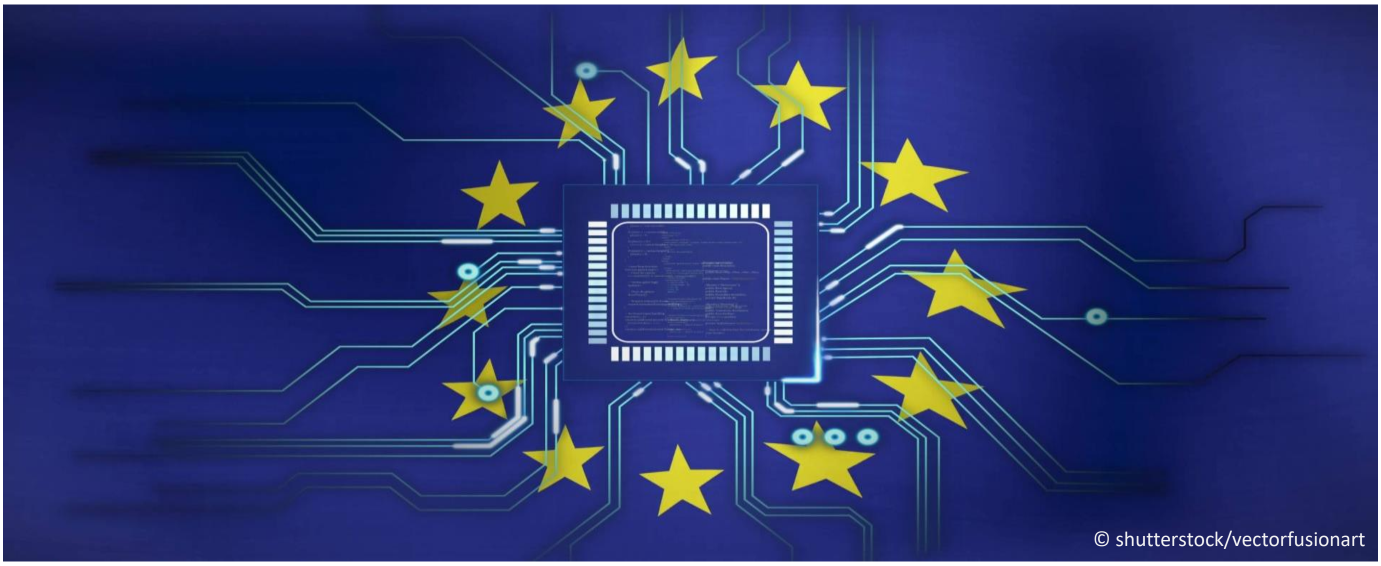

The EU's limited innovation capacity is one of its major weak spots in its struggle for technological sovereignty. This is not only due to a lack of inventions but also caused by barriers preventing the commercialization of inventions and the scaling up of business models. The Commission aims to address these issues with a dedicated European Innovation Act. This cepInput argues that, to be successful, an EU innovation strategy must go beyond supporting incremental innovation. It should focus on strengthening Europe's potential for radical innovation, defining new markets, and overcoming existing dependencies. Using a new measure of radicalness, it analyses past patterns of radical innovation activity inside and outside the EU in five critical technology fields. By identifying regional innovation hotspots, it demonstrates which location characteristics have proven successful in fostering radical innovation. From this, it derives recommendations for creating an innovation-friendly business environment in the EU.

- In global comparison, radical innovation activity is largely dominated by inventors based in the US. The EU is only on the periphery of global innovation networks and is close to be overtaken by China.
- Radical innovation activity within the EU is highly concentrated in a few hotspot regions, most of which overlap with traditional industrial centers. These regions share several characteristics, including a strong and dynamic local talent pool and extensive collaboration with external R&D partners.
- To unleash Europe's potential for radical innovation, a mixed policy strategy is required, combining improvements to the general framework conditions with the targeted development of regional innovation hubs.
- General EU measures should involve initiatives to overcome regulatory fragmentation between Member States, a stronger focus on risk-compensating instruments in public research support and upskilling programs to address EU-wide skill shortages.
- The promotion of regional innovation hubs should focus on supporting regional specialization and interregional and interdisciplinary knowledge networks. This requires investment in both physical research and testing infrastructure as well as joint institutions that facilitate knowledge exchange.

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1 Background

The exponentially growing data processing capacities suggest that future technological revolutions will be able to redefine global markets faster than ever before. For developed economies to secure competitiveness and prosperity, it will be crucial to take a leading role in technology development and dissemination. In this respect, Europe's fundamental weakness has received increased attention, at the latest, with Mario Draghi's report on the future of European competitiveness.[1] The report identifies low innovation capacity in key digital technologies as one of the main reasons for Europe's weaker long-term productivity growth compared to the United States. This lack of innovation is due to significant barriers at every stage of the innovation lifecycle, from research and development funding to commercializing inventions and scaling up new business models.

Against this backdrop, the European Commission has unveiled a series of supportive legislative initiatives for the 2024–2029 period. Most notably, these include a dedicated European Innovation Act (EIA), which is expected to be proposed in early 2026.[2] This will be supported by sector-specific innovation initiatives in strategic fields such as advanced materials and biotechnologies. The EIA is intended to address a variety of cross-sectoral innovation barriers throughout the entire innovation lifecycle, including access to testing infrastructure, public funding for the commercialization stage, and the harmonization of national intellectual property rights (IPR) and certification policies.

Such a comprehensive and multifaceted initiative risks failing due to a lack of regulatory focus. This concern is supported by the findings of the Draghi Report, which point not only to low overall activity, but also to insufficient focus on emerging sectors and key technologies as the reason for the malaise of European innovation. In particular, many recent studies have highlighted the importance of radical and disruptive innovation as drivers of long-term macroeconomic growth. These technologies represent fundamentally new forms of knowledge combination and serve as an impulse for shaping new business models and markets across many sectors of the economy. For the EU, an economic actor with persistent cost competitiveness issues, taking an active role in these disruptive processes is essential in order to offset high costs with first-mover margins. At the same time, the economic nature of radical innovation differs substantially from that of standard incremental innovations, requiring a tailor-made policy mix.

This cepInput uses the current discussion as an opportunity to advocate for an EU innovation strategy that promotes radical innovation in Europe. To this end, it begins by explaining the characteristics and economy-wide implications of radical innovation, drawing on recent research results. Through a detailed analysis of global patent statistics, it evaluates Europe's recent success in creating radical innovations in five key technology fields by applying its own 'radicalness score'. By analyzing the spatial distribution of inventors, the analysis identifies existing regional hotspots of radical innovation activity in the EU and links these spatial patterns to discrepancies in regional framework conditions. The results are then used to derive recommendations for an EU innovation strategy that plays a proactive role in shaping new markets. This includes establishing an innovation-stimulating regulatory framework and providing dedicated support to regional hubs of radical innovation in Europe.

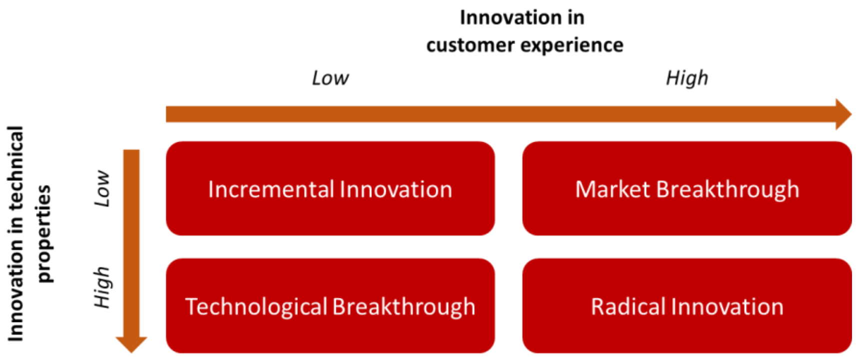
[1] Draghi, M. (2024). The future of European Competitiveness – Part A: A competitiveness strategy for Europe. Report.
[2] European Commission (2025a). Commission concludes public consultation on the European Innovation Act.

2 Causes and Consequences of Radical Innovation

2.1 Characteristics

In principle, the radicalness of an innovation can be judged based on either objective criteria, such as the technical novelty of a product or process, or subjective criteria, such as the degree to which its users perceive it as innovative. This means that the radicalness of an innovation is not necessarily decided at the invention stage, but is instead the result of intensive interaction between the inventors' ideas, their information networks, and the existing market environment. Consequently, the entire innovation process, including the commercialization strategies, must be aligned with the ambition of causing radical change. The complexity of this process has led to various definitions of radical innovation in economic literature, which sometimes overlap with related concepts such as breakthrough innovation. Chandry and Tellis (1998) propose a typology of four different forms of innovation, organized along two dimensions: technical novelty and value added for customers (see Figure 1).[3] Standard incremental innovation involves the technological improvement of existing products or processes, but only provides customers with a small amount of added value. Consequently, this type of innovation is unable to create new markets and associated monopoly profits. By contrast, a technological breakthrough offers fundamentally new technology, but does not address new forms of customer needs. HD television is an example of this. The opposite holds true for a market breakthrough. Radical innovation is defined as an innovation that is a game changer in both dimensions: it provides new technology and a fundamentally new customer experience. As a consequence, it not only directly creates new market segments through Schumpeterian creative destruction[4], but is also the origin of substantial follow-up innovation. The iPhone is a good example of this. This property makes radical innovation especially valuable from a wider economic perspective.

Figure 1: Types of innovation differentiated by two dimensions of radicalness



Source: Chandry and Tellis (1998); own adaption.

In order to understand how to increase the likelihood of radical innovation, it is first necessary to gain insight into its genesis. Radical innovation exhibits characteristic processes of market penetration. Traditionally, it is thought that the time path of adopting new products or processes follows an S-curve. In the early stage, adoption is slow due to high costs and limited customer knowledge. This is followed by a period of faster uptake, driven by reduced costs through economies of scale, extensive customer-to-customer marketing, and continuous technological improvements. This ends in a mature phase

3 Chandy, R. K., & Tellis, G. J. (1998). Organizing for radical product innovation: The overlooked role of willingness to cannibalize. Journal of Marketing Research, 35(4), 474-487.

4 Schumpeter, J. A. (2042). Capitalism, socialism and democracy. Harper, New York.

where growth slows down and the market reaches saturation.[5] In the case of radical innovation, the processes of technological improvement and market penetration are sometimes discontinuous. The fundamental novelty of the innovation requires trial-and-error tactics and substantial learning processes on the part of the innovators. This means that, in the early stages, technological improvements often do not happen at all, tempting competitors to believe that the innovation will never succeed in the market. Once fundamental technical problems have been solved, however, the technology's revolutionary nature is revealed and it takes off abruptly. In this way, niche markets can rapidly expand into mass markets, threatening existing technologies at a fast pace.[6] In other words, radical innovation often represents a discontinuity, challenging standard management concepts of market evolution.

In ex-ante view, this results in massive uncertainty on the actual radical nature of an innovation on the side of innovators, competitors and policymakers alike. O'Connor and Rice (2013) distinguish between four types of uncertainty: technical, market, organizational, and resource uncertainty.[7] From a company's perspective, radical innovation often requires considerable investment in research and development (R&D), with low chances of success but high long-term rewards if successful. For policymakers, providing tailor-made infrastructure services or direct monetary support to sectors or companies seen as candidates for generating radical innovation represents a fiscal risk.

Dealing with these forms of uncertainty requires an understanding of the specific factors and conditions that increase the likelihood of radical innovation. A significant body of economic literature has been devoted to identifying these determinants at a firm level. Initial investigations focused on the role of firm size. The traditional view is that large, established firms are best equipped to generate radical innovation.[8] They can access and manage the wide variety of information sources needed to develop fundamentally new technologies, and they have the necessary financial backing to cope with the uncertainty of long and unpredictable radical innovation processes. However, this has been challenged by approaches that emphasize the interplay between innovation processes and firm organization. Accordingly, radical innovation also requires a reorganization of thinking and the development of new organizational routines at a firm level.[9] Small firms, especially Start-ups, could be better in implementing such reorganization, due to less division-based thinking and a higher general degree of organizational flexibility. Empirical studies suggest that the overall impact of firm size is ambiguous. Instead, a significant determinant is the degree of inner-firm autonomy of innovation departments, which can be high or low in both large and small firms, depending on the organizational philosophy.[10]

Recent approaches have focused on the firm-external dimension of radical innovation processes. Innovation is seen as the outcome of interaction between internal and external stakeholders within innovation systems. This is summarized by the concept of open innovation. It assesses the innovation capability of a company or another form of institution based on its ability to leverage existing external

5 Rundi, A., & Voehl, F. (2016). S-Curve Model. The Innovation Tools Handbook, Volume 1: Organizational and Operational Tools, Methods, and Techniques that Every Innovator Must Know, 335.
6 Sood, A., & Tellis, G. J. (2005). Technological evolution and radical innovation. Journal of Marketing, 69(3), 152-168.
7 O'Connor, G. C., & Rice, M. P. (2013). A comprehensive model of uncertainty associated with radical innovation. Journal of Product Innovation Management, 30, 2-18.
8 Mansfield, E. (1963). Size of firm, market structure, and innovation. Journal of Political Economy, 71(6), 556-576.
9 Bessant, J., Öberg, C., & Trifilova, A. (2014). Framing problems in radical innovation. Industrial Marketing Management, 43(8), 1284-1292.
10 Olson, E. M., Walker Jr, O. C., & Ruekert, R. W. (1995). Organizing for effective new product development: The moderating role of product innovativeness. Journal of Marketing, 59(1), 48-62.

knowledge.[11] This reflects a general idea of knowledge generation as a search process for potential technology paths[12] This is especially relevant for radical innovation: its revolutionary nature requires access to a wide knowledge base from different technical disciplines, which is difficult and costly to accumulate within the boundaries of a single institution.

The ability to leverage external knowledge, in turn, depends on the institution's access to external sources and their internal absorptive capacity. To systematically exploit external information sources, a search strategy is required. According to Laursen and Saulter (2006), a successful search strategy requires both sufficient breadth (amount and variety of distinct sources) and depth (intensity and experience in dealing with a specific source).[13] The higher the general degree of innovation competition in an industry, the more extensive investments are needed in the search process. For radical innovation in particular, sufficient search depth is argued to be more important than search breadth, as the disruptive nature of radical innovation can make many information sources obsolete. [14] The internal absorptive capacity is generally assumed to depend on the existing stock of knowledge in the firm, i.e. its internal human capital.[15]

These learning-by-searching routines introduce extra uncertainty into the innovation process. Firms need to develop significant internal capacities specializing in learning from others. For instance, a survey of 183 high-tech firms in China shows that technical and administrative learning both facilitate the development of radical innovations.[16] However, learning requires getting acquainted with the different norms and forms of information coding used by other institutions. From an ex-ante perspective, it is often difficult to judge which external knowledge sources are the most promising and complementary. Unstructured search processes can result in over-searching, which can overload the absorptive capacity and lead to the most revolutionary ideas being overlooked.[17] As a consequence, Laursen and Saulter (2006) show that openness in innovation has positive returns, but these returns are decreasing with increasing search activity, indicating that there is a point where additional search becomes inefficient.[18]

This has stressed the need for formal cooperation arrangements between institutions as an element of knowledge search. Exchanging information within established, trustworthy networks subject to clear common rules reduces the uncertainties of search processes and creates continuity of information flows. This is especially relevant for industries with a complex and widely dispersed knowledge base.[19] Firms can engage in cooperation with their suppliers, lead users and even with their

[11] Flor, M. L., Cooper, S. Y., & Oltra, M. J. (2018). External knowledge search, absorptive capacity and radical innovation in high-technology firms. European Management Journal, 36(2), 183-194.
[12] Nelson, R. R., & Winter, S. G. (1985). An evolutionary theory of economic change. Harvard university press.
[13] Laursen, K., & Salter, A. (2006). Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. Strategic Management Journal, 27(2), 131-150.
[14] Christensen, C. M. (2015). The innovator's dilemma: when new technologies cause great firms to fail. Harvard Business Review Press.
[15] Cheng, C. C., Yang, C., & Sheu, C. (2016). Effects of open innovation and knowledge-based dynamic capabilities on radical innovation: An empirical study. Journal of Engineering and Technology Management, 41, 79-91.
[16] Bao, Y., Chen, X., & Zhou, K. Z. (2012). External learning, market dynamics, and radical innovation: Evidence from China's high-tech firms. Journal of Business Research, 65(8), 1226-1233.
[17] Koput, K. W. (1997). A chaotic model of innovative search: some answers, many questions. Organization science, 8(5), 528-542.
[18] See Laursen and Salter (2006).
[19] Powell, W. W., Koput, K. W., & Smith-Doerr, L. (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. Administrative science quarterly, 116-145.

competitors ("Co-opetition").[20] This can give rise to an efficiency-enhancing division of labor in search processes, e.g. with lead users specializing on the user-relevant properties of new technologies. Besides exchanging complementary knowledge, mutual benefits can lie in the joint pooling of capital. These include cost advantages from the sharing of fixed costs for R&D facilities and efficiency gains through the common exploitation of economies of scale and scope. Furthermore, in a long-term perspective, the sharing of the manifold risks (e.g. development of technologies and markets) involved in R&D activities contribute to a reduction in the financing costs of the participating companies.[21] At the same time, knowledge sharing within such arrangements is not without risk, especially with competitors. If not properly managed through contracts, accidental oversharing of exclusive knowledge can damage the ability of firms to reap the benefits from their own ideas. Ritala et al. (2018) demonstrate that uncontrolled leakage is particularly detrimental to the capacity for radical innovation.[22]

Cooperation of firms with academic institutions focused on basic research does not entail these risks and offers strong knowledge complementarity between theory and practice. This allows companies to outsource basic research activities, enabling them to specialize in later stages of the innovation process. In line with this idea, Hall et al. (2003) demonstrate that research partnerships involving universities specialize in new, groundbreaking research areas. However, these partnerships tend to be associated with greater difficulty and delay due to differences in organization and the typical length of discovery processes between commercial research and academia.[23]

2.2 Welfare Implications

With the seminal work of Schumpeter (1942), the role of visionary entrepreneurs as a revolutionary force behind economy-wide technological progress entered the spotlight of economic analysis. Their radical new solutions not only entail the creative destruction of existing business models, but can be seen as the root of persistent macroeconomic growth, as demonstrated by the growth theory of Nobel laureates Aghion and Howitt (1990).[24] In their view, the key mechanism behind radical innovation that drives growth is the incentive and ability of 'outsider entrepreneurs' to overthrow existing forms of market power by creating new markets dominated by their own qualitatively superior solutions, leapfrogging existing market leaders in the process. This form of innovation can create significant potential for follow-up innovation and positive knowledge externalities. From a welfare perspective, however, this can imply underinvestment in innovation activities, as entrepreneurs do not consider the benefits of providing an information base to subsequent innovators. However, Aghion and Howitt (1990) demonstrate that this could be offset by an opposing effect: by generating monopoly profits through their market-creating innovation, the private returns to innovators could exceed those to society, potentially resulting in 'too much' innovation from a societal perspective. This suggests that a naive view of the merits of radical innovation can neglect its implications for market structure.

The general policy prescription resulting from this perspective is a balanced mix of pro-competition and innovation policies. It is essential to closely monitor market competition in order to avoid the emergence of persistent monopoly rents. At the same time, radical innovators require sufficient

[20] Bengtsson, M., Eriksson, J., & Wincent, J. (2010). Co-opetition dynamics–an outline for further inquiry. Competitiveness review: An international business journal, 20(2), 194-214.

[21] Vonortas, N. S. (2012). Cooperation in research and development (Vol. 11). Springer Science & Business Media.

[22] Ritala, P., Husted, K., Olander, H., & Michailova, S. (2018). External knowledge sharing and radical innovation: the downsides of uncontrolled openness. Journal of Knowledge Management, 22(5), 1104-1123.

[23] Katz, M. L. (1986). An analysis of cooperative research and development. The RAND Journal of Economics, 527-543.

[24] Aghion, P., & Howitt, P. (1990). A model of growth through creative destruction. NBER Working Paper, (w3223).

options to internalize the knowledge gains they generate in order to avoid underinvestment in R&D. In principle, this could be achieved through government subsidies, such as grants or R&D-related tax credits.[25]

In practice, however, a proactive innovation policy focused on stimulating radical innovation is subject to significant macroeconomic risk. Given the huge amount of diversified knowledge required for radical innovation, such a policy allocates a significant proportion of domestic intellectual resources towards long-term investments with a very uncertain outcome. Furthermore, when allocating public subsidies, regulators are often not well equipped to judge the economic potential of specific new industry segments and infant technologies. This can result in the misallocation of public resources, for example through an improper sectoral focus or inefficient lump-sum subsidies. At the same time, neglecting radical innovation as a policy target is risky as well. This could lead to foreign economic control of strategic technologies, not only exacerbating existing dependencies, but also endangering future access to the knowledge necessary for domestic innovation.

Therefore, a wise innovation policy should focus on eliminating the individual barriers that stakeholders capable of radical innovation face, rather than providing excessive fiscal stimulus. Firstly, this relates to barriers preventing engagement in external knowledge cooperation, which is essential for radical innovation (see Sub-section 2.1). Cooperation arrangements offer a partial solution to the issue of insufficient R&D activities by private firms, which is caused by positive externalities (knowledge spillovers). Even with strict patent and copyright laws in place, such spillovers cannot always be fully avoided because any protection of intellectual property is time-limited, restricted to codifiable knowledge, and subject to enforcement costs. By contrast, formalized research cooperation enables partners to exert greater control over the dissemination of information while facilitating the sharing of non-rival knowledge within the partnership. This contributes to more overall R&D activity, while not fully suppressing the welfare-enhancing channel of knowledge spillovers.[26] Unlike general R&D subsidies, the specific promotion of research partnerships helps reduce adoption costs by encouraging joint involvement in technology creation. Therefore, policies that provide fiscal incentives (e.g. tax breaks on R&D joint ventures or R&D vouchers) and/or collaborative infrastructure for research partnerships could improve welfare.

Secondly, stimulating radical innovation also requires targeted location policies at a local level. Recent empirical evidence suggests that specialized regional industry clusters can provide an environment conducive to radical innovation.[27] An important element in innovation policies is therefore the planning and maintenance of such clusters, as well as their interlinkages with stakeholders in other regions.

2.3 Location Requirements

Based on the general discussion above, specific requirements for locations aspiring to become hotspots for radical innovation can be established. In particular, local conditions should support innovative firms in increasing their capacity for knowledge creation and their ability to absorb external

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[25] Bryan, K A and H L Williams (2021), "Innovation: market failures and public policies", Handbook of Industrial Organization 5(1): 281-388.

[26] Hall, B. H., Link, A. N., & Scott, J. T. (2003). Universities as research partners. Review of Economics and Statistics, 85(2), 485-491.

[27] Grashof, N., Hesse, K., & Fornahl, D. (2021). Radical or not? The role of clusters in the emergence of radical innovations. In Rethinking Clusters (pp. 26-45). Routledge.

knowledge. Furthermore, they should facilitate external research cooperation with a wide range of institutions and knowledge disciplines.

Regarding internal innovation capacities, research points to the success of regions featuring a young local working population and a strong inter-firm worker mobility.[28] A young and mobile workforce can contribute to creativity and increase the learning capacity of local firms. In the medium term, it can also stimulate changes in corporate culture, such as greater flexibility in firm routines. These routines have been shown to be a key factor in differences in radical innovation activity at an international level.[29] Therefore, locational policies should provide the public infrastructure services necessary to attract young, qualified workers. In view of Europe's significant demographic challenges, such a strategy must also aim to raise the attractiveness of the region for young workers from third countries.

Moreover, training programs that stimulate the creativity of workers have been shown to successfully enable radical innovation. They help to exploit individual creative skills more effectively and reduce internal friction by creating a common language and understanding of innovation across different company departments. [30] However, not all firms can finance training activities at the necessary level of intensity to effectively raise innovation capacities. Therefore, public financial or infrastructure support for innovation-focused on-the-job training is an important tool in local innovation policies.

The opportunities for external knowledge cooperation depend on the type of cluster specialisation strategy chosen. Boschma et al. (2023) demonstrate that radical innovation in a technology field is positively correlated with the regional stock of related technologies (measured in patents with regional inventors). This highlights the well-researched role of local intra-industry agglomeration economies, such as the ability to exchange tacit knowledge via face-to-face communication.[31] At the same time, the literature shows that access to previously unrelated technology is essential for radical innovation as well.[32] In this regard, geographical proximity does not necessarily play an important role, as demonstrated by Shkolnykova and Kudic (2022) for Germany.[33] In fact, Hesse and Fornahl (2020) show that knowledge cooperation with actors outside a region can substitute for missing cluster-internal competencies in the creation of radical innovation.

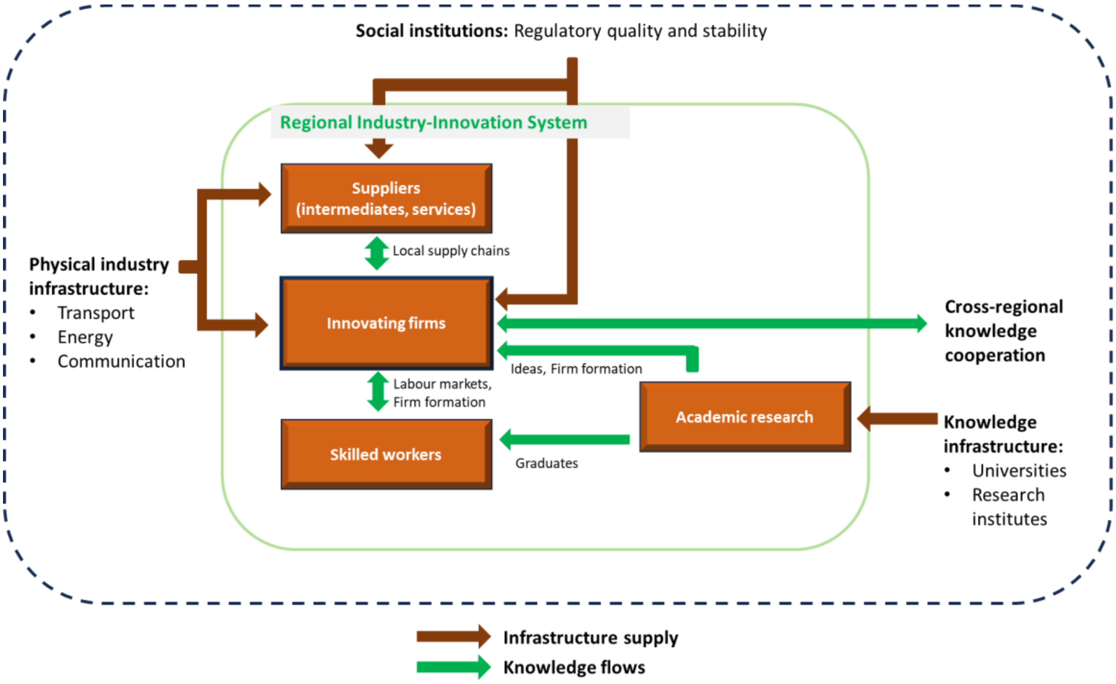
This suggests that an innovation-friendly cluster strategy is characterized by strong technology-specialization within clusters and strong cooperation linkages between clusters with complementary knowledge profiles. [34] This enables regions to reap the benefits of both cluster specialization and interregional knowledge cooperation. In addition to providing sector-specific infrastructure, support measures are required to overcome access barriers to external knowledge. For example, barriers for young firms, as well as for small and medium-sized enterprises (SMEs) in general, in accessing

[28] Gregory, T., & Patuelli, R. (2013). Regional age structure, human capital and innovation-is demographic ageing increasing regional disparities?. ZEW Discussion Papers, 13.
[29] Tellis, G. J., Prabhu, J. C., & Chandy, R. K. (2009). Radical innovation across nations: The preeminence of corporate culture. Journal of marketing, 73(1), 3-23.
[30] Rampa, R., & Agogué, M. (2021). Developing radical innovation capabilities: Exploring the effects of training employees for creativity and innovation. Creativity and Innovation Management, 30(1), 211-227.
[31] Van der Panne, G. (2004). Agglomeration externalities: Marshall versus Jacobs. Journal of evolutionary economics, 14, 593-604.
[32] Hesse, K., & Fornahl, D. (2020). Essential ingredients for radical innovations? The role of (un-) related variety and external linkages in Germany. Papers in Regional Science, 99(5), 1165-1184.
[33] Shkolnykova, M., & Kudic, M. (2022). Who benefits from SMEs' radical innovations? — empirical evidence from German biotechnology. Small Business Economics, 58(2), 1157-1185.
[34] Li, P. (2025). Cluster-based routines and paradigm-bound innovation. Research Policy, 54(3), 105192.

competitive interregional research and development (R&D) networks should be removed. Alongside creating open physical research infrastructure, such as joint innovation labs, this could take the form of R&D vouchers given to SMEs. Universities and large companies that enter into R&D partnerships with SMEs could redeem these vouchers and receive payment, thereby raising their incentives for knowledge cooperation with SMEs.[35]

Figure 2 summarizes the principles of a regional innovation system focused on promoting radical innovation activity. In the following, these principles are mirrored against the spatial distribution of radical innovation inside and outside Europe.

Figure 2: Success factors in regional industry-innovation systems



Source: own illustration

3 Empirical Analysis of Innovation Activity

3.1 Data and Methods

From an economic point of view, it makes sense to start measuring innovation at the point where the prospect of commercialization becomes evident through the registration of property rights. Patent data is therefore often the basis for output-based innovation indicators. Their limitations are well known.[36] They do not provide information about the actual subsequent market success of patented inventions and their general societal impact. They are also not perfect measures of innovation at the development stage, as many types of inventions are not patentable for technical or legal reasons. Nevertheless, main advantages are the high degree of international harmonization and the high level of technological detail in patent statistics, allowing for the identification of key technologies. The

[35] Sala, A., Landoni, P., & Verganti, R. (2016). Small and medium enterprises collaborations with knowledge intensive services: An explorative analysis of the impact of innovation vouchers. R&d Management, 46(S1), 291-302.

[36] Wydra, S. (2020). Measuring innovation in the bioeconomy–Conceptual discussion and empirical experiences. Technology in Society, 61, 101242.

International Patent Classification (IPC) system enables an extremely fine-grained subdivision according to fields of technology.[37] In addition, information on innovation networks via cross-referencing (citations) and supra-regional cooperation between institutions and inventors is available.

For our analysis of radical innovation, we use data from PATSTAT, the worldwide patent database of the European Patent Office (EPO).[38] It is one of the world's most comprehensive patent databases and a popular choice for innovation analyses. In identifying radical innovation, we focus on five key technology fields from the EU's list of critical technologies[39]: advanced materials, advanced semiconductor technologies, Artificial Intelligence (AI) technologies, connectivity technologies and energy technologies. To identify the IPC classes attached to the single fields, we draw upon work conducted by the ATI project.[40] In a series of publications, the ATI project analysed EU patenting activities in a range of advanced technologies, by applying lists of IPC codes established by the detailed technology expertise of the participating institutions.[41] Table A1 in the Appendix shows the assignment to IPC classes made. As a timeframe, the period 2011-2020 is considered, to make sure that enough time has passed for a meaningful comparison of citation counts.

To identify cases of radical innovation within this patent dataset, the economic literature has developed different statistical indicators, reflecting different theoretical concepts of radicalness. Their common understanding is that radicalness goes beyond the pure influence of a patent (e.g. measured in patent citation counts) and also involves the creation of linkages between different technology fields. These linkages are sometimes measured backward-looking, through indicators of the technological diversity of patents cited by the given patent (backward citations).[42] Other approaches favour a forward-looking approach by calculating the diversity of patents citing the given patent (forward citations).[43] For our purposes, we implement a simplified and intuitive measure of radicalness combining overall influence of a patent with the diversity of follow-up inventions. It consists of a metric score that links total forward citations of a patent with the number of IPC classes observed for the citing patents in a multiplicative fashion.[44] It thus perceives radicalness as a reflection of both sufficient depth and breadth of an innovation, a view that seems to be most in line with the innovation management literature discussed in Section 2. This radicalness score is computed for all patents from the five chosen fields. Based on this, radical patents are identified as those with radicalness scores belonging to the Top 1% within the whole global dataset, adopting a common pragmatic procedure for the identification of breakthrough inventions.[45]

The number of radical patents is then the basis of global country as well as regional comparisons (NUTS-2 level) within the EU, using addresses of the registered inventors as indicators for the geographical allocation of patents. For a country/region comparison, we must consider that often several people are registered as the inventors of a patent, who may be located in different countries or

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37 WIPO (2025). International Patent Classification (IPC). World Intellectual Property Organization.
38 EPO (2025). PATSTAT – Backbone dataset for statistical analysis. European Patent Office.
39 European Commission (2023). Commission Recommendation of 3.10.2023 on critical technology areas for the EU's economic security for further risk assessment with Member States.
40 European Commission (2024a). European Monitor of Industrial Ecosystems.
41 ATI (2021). Indicator framework and data calculations. September 2021.
42 Shane, S. (2001). Technological opportunities and new firm creation. Management science, 47(2), 205-220.
43 Dahlin, K. B., & Behrens, D. M. (2005). When is an invention really radical?: Defining and measuring technological radicalness. Research Policy, 34(5), 717-737.
44 Formula: Radicalness score = Total number of forward citations · log (1+Number of distinct IPC-Classes (6-Digit))
45 Ahuja, G., & Morris Lampert, C. (2001). Entrepreneurship in the large corporation: A longitudinal study of how established firms create breakthrough inventions. Strategic Management Journal, 22(6-7), 521-543.

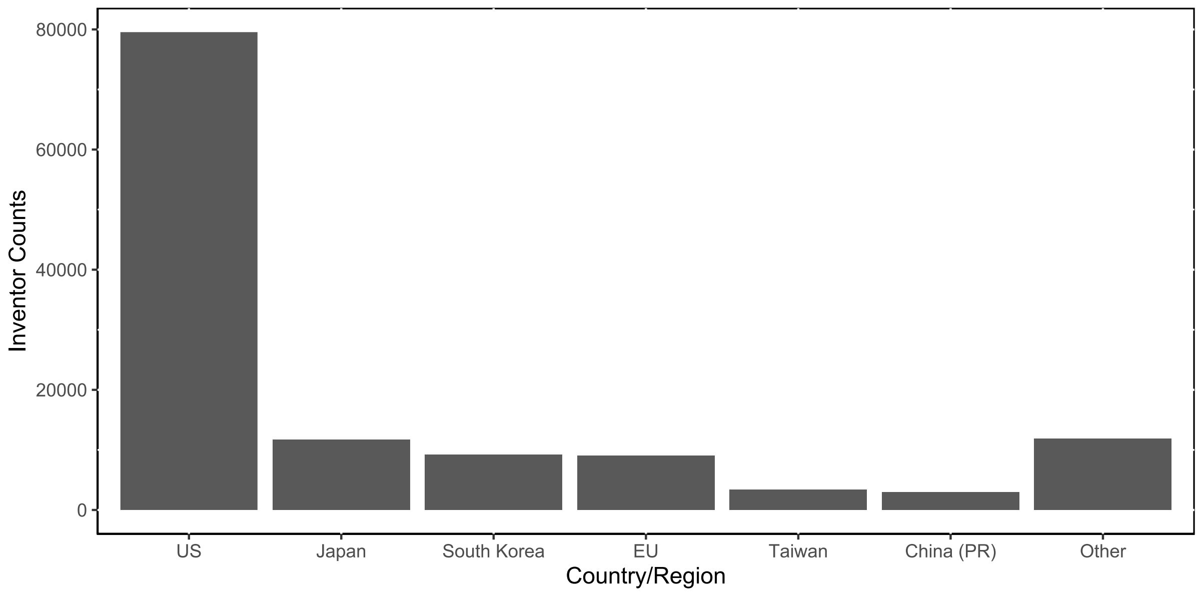
regions. As is common in the literature, we account for this by applying an equal share for each inventor as a weighting factor in calculating patent numbers. For instance, in the case of a patent with eight registered inventors, each inventor is assigned a share of 0.125. Then, we calculate the total radical innovation activity of a country/region as the sum of the shares of inventors residing in the respective country/region ("inventor counts").

3.2 Results

3.2.1 Global Activity

The most striking feature when focusing on the global distribution of radical innovation activity is the dominance of the US. Of the 127,640 radical patents in total, almost two thirds (79,548) are assigned to inventors residing in the US. This implies that the US exceeds Japan, the second most successful inventor nation, by a factor of seven (see Figure 3). Inventors residing in the EU were responsible for only around 7% of all radical patents during the investigated time period. Consequently, the EU ranks fourth in a global comparison, behind not only Japan but also the much less populous South Korea. The US's dominance extends to all five of the technology fields investigated (see Table 1). No other nation comes even remotely close to the US patent counts in any of the fields. US dominance is also evident in terms of the origin of the most radical patents. The first 20 of the patents with the highest radicalness scores in the sample either exclusively or predominantly feature US-based inventors. The relevance of the EU varies moderately across fields. The largest EU share of radical patents is observed in advanced materials (global share of 10%), and the smallest is observed in AI technologies (4.5%). There are no EU inventors in the global top 50 for patents measured by radicalness score. This suggests that the EU's comparative advantage lies not in producing spectacular single inventions, but in creating a wide range of moderately radical inventions.

Figure 3: Radical patent count by country/region of inventor during 2011-2020



Source: EPO (2025); own calculations

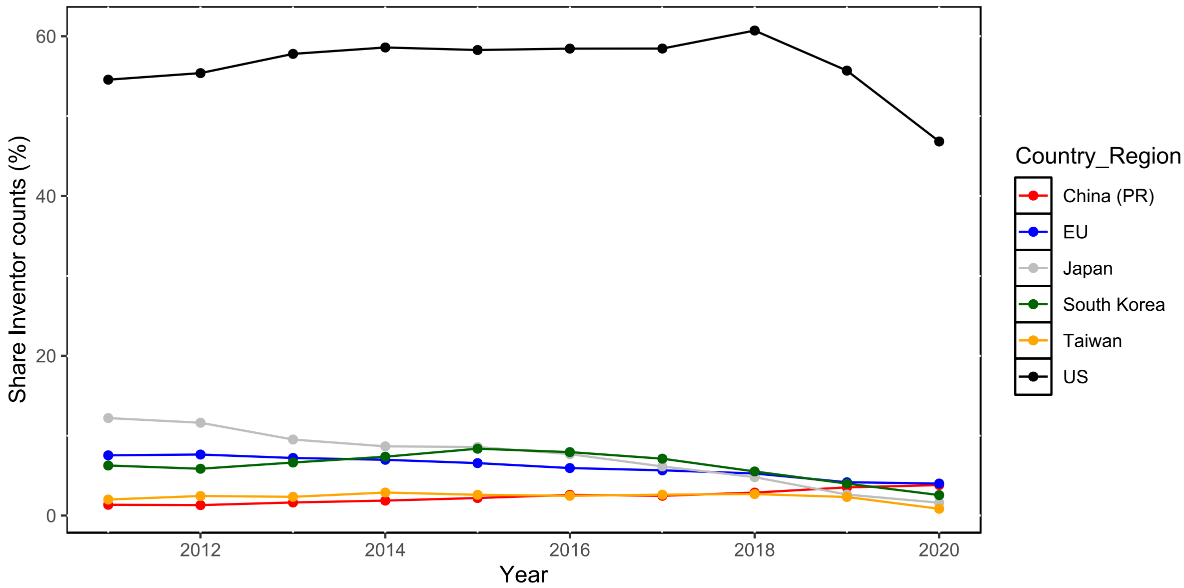
Table 1: Radical patent count by country/region of inverter and technology during 2011-2020

	Technology Field					
Country/Region	**AI**	**Connectivity**	**Energy**	**Adv. Materials**	**Semiconductors**	**Total**
China (PR)	258.60	734.56	220.18	301.94	1,420.71	2,936.00
EU	536.55	2,336.95	707.68	1,871.45	3,585.84	9,038.47
Japan	295.89	1,814.27	1,870.94	3,778.06	3,926.14	11,685.30
South Korea	482.50	2,796.43	1,452.02	1,569.51	2,927.58	9,228.04
Taiwan	56.05	392.47	817.20	1,036.18	1,079.96	3,381.86
US	8,863.21	27,501.51	4,187.35	7,848.54	31,146.94	79,547.55
Other	1,413.08	3,672.86	474.53	1,030.96	5,230.92	11,822.36

Source: EPO (2025); own calculations

Over the last decade, there have been no dramatic shifts in the time comparison (see Figure 4). Japan has consistently lost ground as a radical innovator compared to other major inventor countries. South Korea's influence began to wane in the second half of the decade. The US share declined at the end of the decade, and it remains to be seen whether this development will persist. Meanwhile, the People's Republic of China has increased its share of annually filed radical patents from 1.3% in 2011 to 3.8% in 2020. In this way, it could catch up with the EU, whose share has remained roughly stable, by the end of the decade.

Figure 4: Evolution of country/region shares in radical patents by filing year



Source: EPO (2025); own calculations

3.2.2 Patterns of Radical Innovation in Europe

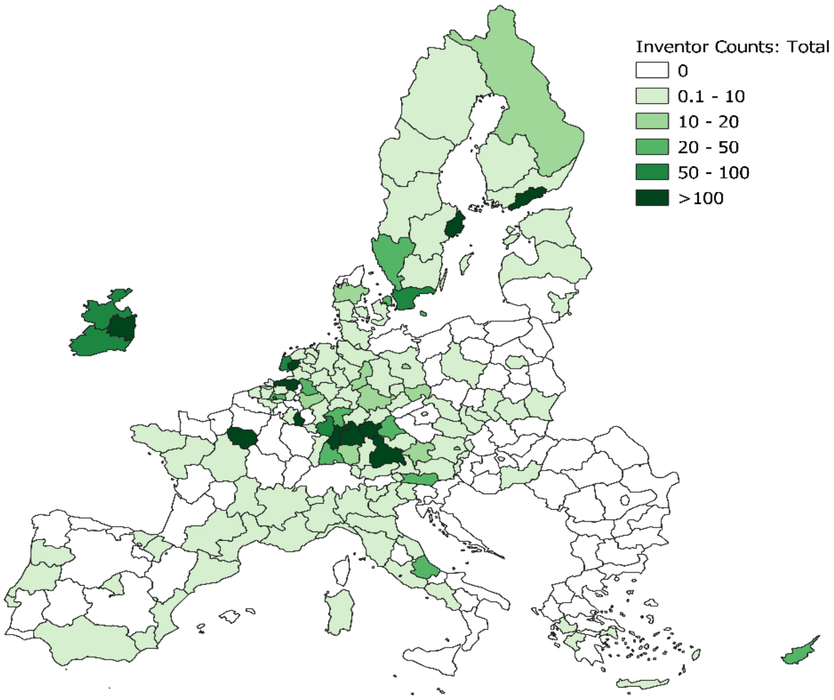
To obtain a picture on the regional distribution of radical innovation activity within the EU, the available information on the location of registered inventors in the PATSTAT Database is exploited. Regions are differentiated based on the standard NUTS-classification.[46] As the integrated NUTS-variable in PATSTAT is very incomplete and subject to inconsistencies, it is complemented by an own NUTS-assignment based on available information on the addresses of inventors. The analysis is undertaken

[46] Eurostat (2025a). Regional statistics by NUTS classification. Eurostat Database.

at the NUTS-2 level, representing basic regions with a population size mostly in the range between 800,000 and 3,000,000 people.

Figure 5 shows the total frequency distribution of inventor counts for the five analyzed technology fields. It reveals highly concentrated geographical activity patterns both within and across Member States. The majority of inventors reside in a small number of regions. The ten NUTS-2 regions with the highest inventor count accounted for more than two thirds of all radical patents in the EU during the analyzed time period. Macro-areas of especially intensive patenting activity include Belgium/the Netherlands, Ireland, southern Germany, southern Scandinavia and the Paris region. By contrast, almost half of all NUTS-2 regions did not contribute a single radical patent. The most striking discrepancy is between Western and Eastern Member States. Of the Member States that joined the EU in 2004 or later, only Cyprus exhibits above-average innovation performance. Further analysis reveals that this pattern is fairly consistent across technology fields (see Figure A1 in the Appendix). This suggests an important role of general regional framework conditions in stimulating innovation activity, as well as the importance of strong knowledge links between different fields.

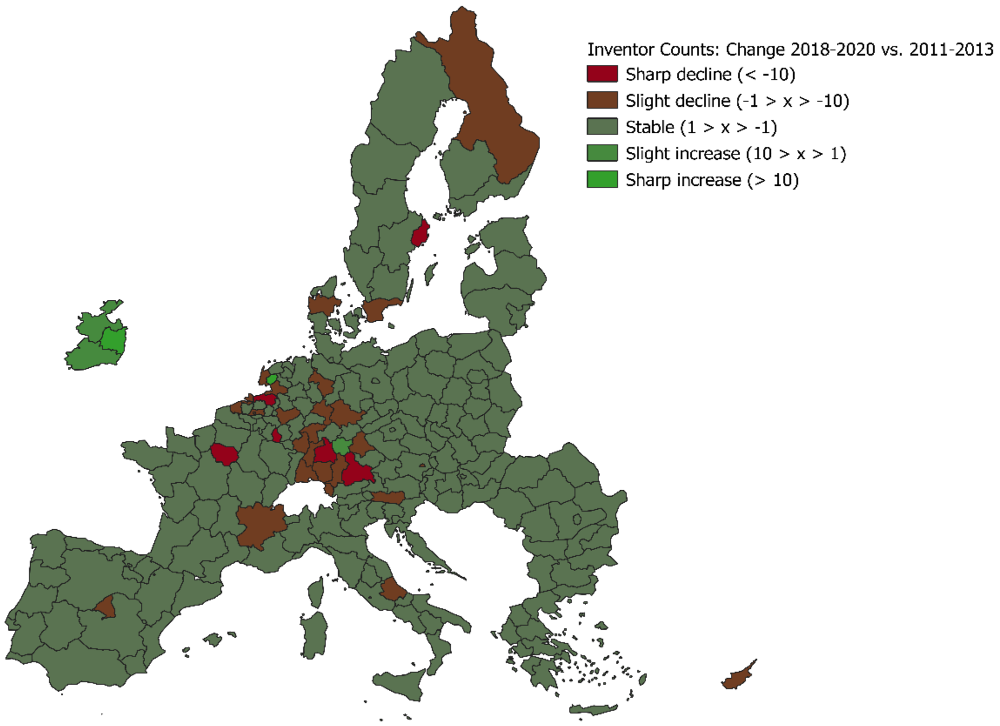
Figure 5: Distribution of radical innovation activity in EU regions (NUTS-2 level) in 2011-2020



Source: EPO (2025); own calculations

The length of the dataset also allows for an identification of regional trends over the last decade. Figure 6 compares inventor counts for the last three years with those for the first three years in the sample. Radical innovation activity has proven to be relatively stable in most regions. However, some regions in Central and Northern Europe, particularly southern Germany, have experienced a significant decline in the number of radical patents. Mittelfranken (DE25) is a positive exception in this respect. The sharpest decrease in inventor counts was measured in the Helsinki region (FI1B9), followed by Stockholm (SE11) and Paris (FR10). This was accompanied by a significant increase in patenting activity in all regions of Ireland. This demonstrates that well-established urban agglomeration zones in Europe cannot afford to rest on their traditional position as innovation hubs. Regional framework conditions are subject to change over time, requiring close monitoring of the main driving forces discussed in Section 2.

Figure 6: Changes in radical innovation activity in EU regions in 2018-2020 compared to 2011-2013



Source: EPO (2025); own calculations

3.2.3 Framework Conditions in EU Innovation Hotspots

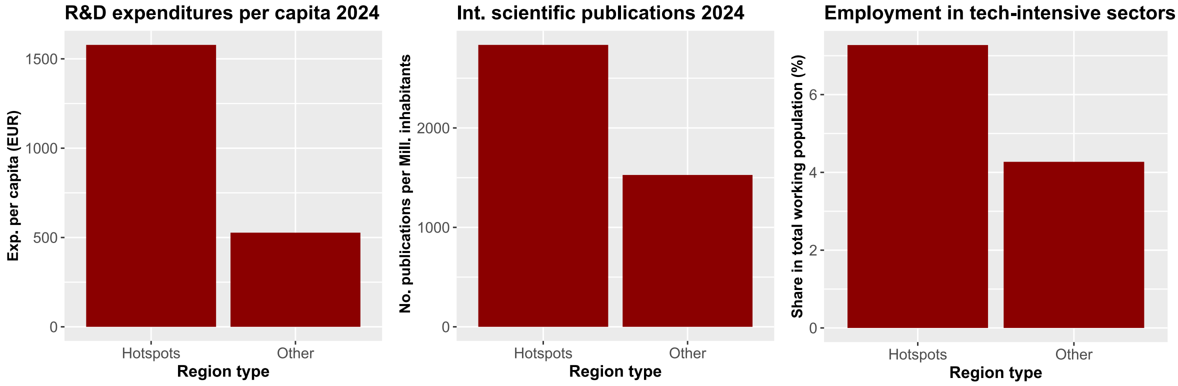
While identifying causal effects is beyond the scope of the existing dataset, descriptive analysis can still provide insight into the interplay between innovation and the regional business environment and specialization. To this end, this paper discusses the specific economic characteristics of the most successful innovation hotspots among the NUTS-2 regions, based on publicly available data. We consider the top 10% of regions in terms of inventor counts across all technology fields.

As expected, hotspot regions stand out in terms of their local research capacities. In 2023, their average total R&D expenditure (i.e. R&D by public and private entities) per capita exceeded the average of the remaining NUTS-2 regions by a factor of three (see Figure 7). At the same time, the average share of R&D expenditure in the local gross domestic product (GDP) is twice as high in hotspot regions as in other regions.[47] This demonstrates that hotspot regions not only exhibit a generally higher level of economic development, but also stronger specialization in research investment. The significant research capacity of hotspot regions is also evident at the academic level. The number of international research publications per capita by scientists based in hotspot regions was almost twice as high as in the remaining regions.[48] The high knowledge intensity of the regional economy is further reflected in

[47] Eurostat (2025b). GERD by sector of performance and NUTS 2 region.
[48] European Commission (2025b). The European Higher Education Sector Observatory.

the patterns of sectoral regional specialization. On average, around 7% of workers in hotspot regions are employed in technology- and knowledge-intensive sectors, compared to 4% in other regions.[49]

Figure 7: Characteristics of regional hotspots for radical innovation in the EU



Sources: Eurostat (2025b;c); European Commission (2025b); own calculations

Notable discrepancies are also found in the human capital base. Firstly, hotspot regions employ on average almost twice as many people aged 15–34 (408,000) as other regions (223,000). The regional workforce is comparatively young in hotspot regions. Those aged 15–34 make up an average of 33% of the working population in hotspot regions, compared to 28% in other regions.[50] Furthermore, young workers in hotspot regions tend to have higher levels of academic qualification. On average, around half of workers aged 25–34 in hotspot regions possess a university degree. In the other regions, this figure is only 41%.[51] The notion of a strong human capital base in hotspot regions is further supported by the greater frequency of upskilling and reskilling activities. On average, 18% of those interviewed by the EU Labour Force Survey in 2024 recently participated in education or training programs. In the remaining regions, this figure was only 13% within the same age group.[52] This suggests a close interplay between regional research capacity, demographics, and skill endowment, which is consistent with the findings of the innovation literature (see Section 2). This interplay puts current hotspots in an ideal position to lead future waves of radical innovation.

Finally, the characteristics of current innovation hotspots align with the results of the literature on knowledge exchange. Hotspot regions feature a significantly higher academic research output in terms of scientific publications. The composition of authorship also reveals stronger international and inter-institutional knowledge networks. According to the European Higher Education Sector Observatory database, 59% of research publications in hotspot regions featured international co-authorships in 2023. In the remaining regions, less than half of the publications were international co-publications. Cooperation between the public and private sectors in research has also been more frequent in hotspot regions. On average, around 9% of scientific publications in hotspot regions in 2023 featured authors from both the public and private sectors, compared to just 6% in other regions.[53]

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49 Eurostat (2025c). Employed persons in technology and knowledge-intensive sectors by NACE Rev. 2 activity and NUTS 2 region.
50 Eurostat (2025d). Employed persons by NUTS 2 region.
51 Eurostat (2025e). Employed persons by educational attainment level and NUTS 2 region.
52 Eurostat (2025f). Participation rate in education and training (last 4 weeks) by NUTS 2 region.
53 European Commission (2025b). The European Higher Education Sector Observatory.

3.3 Discussion

The patent analysis shows that Europe currently lies on the periphery of global radical innovation activity in key technological fields. Given the cross-cutting nature of these technologies and their fundamental role in enabling the digital and green transitions, this represents an overlooked threat to Europe's long-term competitiveness. However, there are some successful hubs of radical innovation within Europe that can serve as role models. Their characteristics confirm the general findings of the literature. Most importantly, the success of these regions in innovation does not appear to be driven solely by physical or monetary research capacities, but is also the result of a strong skill base, dynamic regional labor markets, and a firm embedding of innovators in intra- and interregional knowledge networks.

At the same time, the fact that the spatial patterns of innovation activity in the EU coincide heavily with traditional economic centers suggests that it is very difficult to establish innovation hubs from scratch. New hubs outside existing cooperation structures must compete with the agglomeration forces of other regions while facing global competition. However, an EU innovation strategy that focuses solely on strengthening existing clusters of excellence would be unwise from both an economic and a political perspective. Economically, this would mean significant benefits of regional technology specialization remaining unexploited. The literature shows that the breadth and depth of the knowledge base required for radical innovation favors strong networks of innovation regions with complementary knowledge. Promoting emerging innovation hubs enables a more detailed division of labor through new forms of regional knowledge specialization. Politically, a strategy limited to strengthening existing innovation hubs risks further fragmenting the internal market by widening discrepancies in regional infrastructure and national regulatory frameworks. Given the persistently strong west–east divide in radical innovation activity (see Subsection 3.2.2), this would also risk exacerbating the current general rupture of the EU in major economic policy matters.

Promoting new innovation hubs specializing in developing new interdisciplinary expertise in growing cross-disciplinary fields such as AI technologies could stimulate regional economic development and, at the same time, increase the EU's responsiveness to future technological trends. Due to the unpredictable nature of future radical innovation waves, it is unlikely that successful new hubs will result from central planning processes. Instead, policymakers should focus on creating conditions that enable clusters to emerge from market-driven exploratory processes identifying a region's future comparative advantages within the EU internal market. EU-level coordination should take the form of intensive information exchange on regional development strategies between national and regional policymakers, in line with the traditional principle of subsidiarity. In this respect, EU regulation could define binding guidelines for the planning of new innovation zones and the application of regulatory sandboxes, as well as setting minimum quality requirements for local public administrative processes (e.g. the establishment of single points of entry for companies). Coupled with EU-wide fiscal support for Member States and information exchange, these coordination processes could help less economically advanced Member States catch up with the formation of competitive clusters.

A mixed strategy is required to support innovation across the board. This should combine measures that improve the general framework conditions for innovative companies in the EU, with measures that create favorable conditions for regional innovation hubs. Improving general framework conditions ensures that future R&D activity is less susceptible to the risks of technological lock-in and political planning errors. This should address barriers at all stages of the innovation cycle, including those related to the economic exploitation of generated knowledge. Supporting regional innovation hubs should focus on strengthening knowledge networks. Only by successfully channeling and maximizing the internal flow of knowledge can Europe compensate for structural disadvantages such as limited venture capital availability. The required infrastructure has both tangible (e.g. open labs, testing facilities and regional training centers) and intangible (e.g. coordinating institutions and talent attraction campaigns) elements. Based on these considerations, the following section proposes a set of priority measures for Europe's future innovation success.

4 Recommendations for an EU Innovation Strategy

4.1 Creating Innovation-Friendly Framework Conditions

- **Establish a simplified regulatory framework for revolutionary start-ups and SMEs:** The fragmentation of national rules in areas such as contract law, business formation, worker participation and cross-border mergers is a well-known barrier to market penetration for innovative products across borders between Member States. This primarily affects the growth potential of start-ups, given their limited resources for handling the administrative costs associated with different regulatory regimes.[54] To this end, the EU should offer innovative companies the option of operating under an alternative EU-wide set of rules. Furthermore, regulatory simplification should target technical product regulation. The necessity of detailed regulatory requirements, such as those defined by the EU Ecodesign Regulation, should be critically examined. High regulatory complexity increases the information and monitoring costs of innovation processes. It could also hinder the development of superior supply chain solutions. One example would be the development of groundbreaking materials that offer no immediate sustainability benefits but consequently provoke the establishment of completely new domestic supply chains. Rather than making detailed prescriptions on technical characteristics, regulation should support the further development of voluntary certification and labelling systems that make the environmental footprint of products transparent. Finally, the concept of regulatory sandboxes, which has already been tested in technology fields such as renewable hydrogen[55], should be applied more widely. It allows for a flexible testing of new regulatory conditions through try-and-error processes, thus reflecting the disruptive nature of radical innovation at the policy level.

- **Restructure public R&D funding towards more risk-compensating instruments:** The high technological complexity and demand uncertainty inherent in radical innovation give rise to a 'valley of death' in the innovation cycle, particularly between the proof-of-principle stage and industrial upscaling. Access to private venture capital is crucial for successful commercialisation, as highlighted by innovation literature. Rather than growing slowly and unevenly based on its own resources, a start-up commercialising a groundbreaking invention can accelerate its growth by receiving leverage from experienced investors, who often provide valuable industry knowledge and contacts. However, this key role of venture capitalists in driving the growth of innovative industries is still severely underutilised in Europe, especially compared to traditional centres of venture capital culture such as the US. According to OECD figures, only 3.2 billion USD of venture capital was invested in Germany and 2.2 billion USD in France in 2024, compared to 156 billion USD in the US.[56] This gap

[54] Drumm, S. (2025). Why fragmentation in Europe is holding back its startups — and how to fix it. Sifted Analysis.
[55] IRENA (2025). Regulatory sandboxes. International Renewable Energy Agency.
[56] OECD (2025). Venture capital investments (market statistics). OECD Entrepreneurship Financing Database.

concerns all business development stages from seed to later venture stage financing. Providing credit guarantees or temporary equity through the European Investment Bank (EIB) could significantly improve access to venture capital by partially covering return risks. In the long term, this will also help strengthen Europe's private venture capital culture. Currently, fiscal innovation support policies in the EU still focus on traditional instruments such as R&D grants and low-cost public loans. The EU should diversify its funding channels towards riskier financing instruments, drawing on the EIB's expertise and management experience. The recently announced Scaleup Europe Fund, a publicly-private co-financed initiative providing equity to deep tech companies, is a good starting point for this.[57] Additionally, Member States should consider introducing targeted tax incentives for venture capital within their national tax systems (e.g. how losses are carried forward in the event of a change of shareholder).

- **Address skill shortages through interdisciplinary talent campaigns:** The shortage of young talent and experienced professionals in European high-tech manufacturing must be addressed.[58] An important step is to expand university study programmes that are closely tailored to the needs of a research-based industry. Specialised master's degree programmes involving intensive collaboration with local manufacturing companies can lay the foundation for regional 'talent factories', overcoming the challenges of finding suitable matches in local labour markets and providing companies with a steady stream of highly qualified workers. At the same time, support for upskilling and reskilling the existing workforce should be increased. To recruit skilled workers from non-EU countries, global recruitment campaigns are needed, including common support programmes to facilitate relocation to Europe. To this end, the EU should rapidly implement its recent pact for skills.[59]

4.2 Supporting Regional Innovation Hubs

- **Strengthen knowledge exchange and human capital mobility within agglomeration regions:** Exploiting the benefits from regional knowledge and skill networks is an important prerequisite for industrial agglomeration regions to remain competitive through persistent innovation. Radical innovation, in particular, usually requires intensive knowledge flows along supply chains and across research disciplines. Insights from basic research in various fields must be combined with business information from suppliers, customers, and occasionally, competitors. Policies can contribute to denser local information networks in various ways. This involves public support to the establishment of institutions for knowledge sharing and joint training activities. For example, these could take the form of training centres for the transfer of specialised or interdisciplinary skills. These centres could be organised as public–private partnerships to mitigate the risk of underinvestment on the company side (generation of positive externalities). As well as providing skill upgrades, such institutions can indirectly contribute to knowledge exchange by expanding the local labour pool and building trust among local stakeholders.

- **Improve access of Start-ups and SMEs to knowledge networks and research infrastructure:** Barriers preventing young innovative firms, as well as SMEs in general, from accessing competitive R&D networks should be removed. Firstly, many small firms cannot finance adequate physical testing infrastructure for innovative solutions on their own. To address this issue, the EU has introduced

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[57] European Commission (2025c). Commission partners with private investors to set up multi-billion Scaleup Europe Fund. Press Release October 28th, 2025.

[58] Business Europe (2023). Analysis of labor and skill shortages: Overcoming bottlenecks to productivity and growth.

[59] European Commission (2024b). Pact for skills.

the concept of Open Innovation Test Beds (OITBs).[60] These are EU-funded clusters of laboratories, testing facilities, and innovation service providers that cooperate through a Single Point of Entry. Studies show that access to open innovation labs contributes to the innovation success of SMEs.[61] In addition, dedicated financial support could help SMEs join existing knowledge networks. The EU should apply clear preference rules for projects integrating SMEs in its research funding through the Horizon program. Furthermore, SMEs could be awarded R&D vouchers. Large companies or research institutions entering into R&D partnerships with SMEs could redeem these vouchers and receive payment. This would make SMEs more attractive as partners for established R&D networks, without the need for direct state interference in private research programs.

- **Enhance European coordination of industrial ecosystems and cluster policies:** The findings of the empirical literature (see Section 2) suggest that strengthening regional core competencies while simultaneously extending linkages to regions with complementary knowledge profiles is an effective way to increase a region's ability to generate radical innovation. From a European perspective, this indicates the potential for efficiency gains through a coordinated division of competencies between different industry and research clusters across Europe. The European Cluster Collaboration Platform (ECCP) provides a useful forum for intensifying the cooperation of national and regional policymakers.[62] In order to contribute effectively to Europe's overall innovation capacity, policy dialogue must be more closely linked to overarching strategic goals at the EU level, such as open strategic autonomy and technological sovereignty. This is motivated by the fact that resilience to global competition and supply risks is in the interest of all industry clusters in Europe. Further support for coordination could come from directly integrating frameworks for cluster development and management into EU regulation. The Net-Zero Industry Act, with its planning framework for Net-Zero Acceleration Valleys, could serve as a role model here.[63]

- **Scale up public support for interregional and interdisciplinary research cooperation:** Given the breadth and depth of knowledge required for radical innovation, regional innovation hotspots benefit greatly from R&D cooperation across regional, national and research disciplinary boundaries. This is confirmed by both the empirical literature (see Section 2) and the strong integration of current European frontrunner regions within supra-regional research networks (see Section 3). Therefore, an important task for EU R&D policies should be to further stimulate research cooperation at all levels. The targeted promotion of problem-oriented, interdisciplinary and international research via the EU's Horizon Europe research framework programme is the right approach. In future, however, the program should be more closely aligned with the EU's strategic goal of technological sovereignty, particularly with regard to the technologies required for its green and digital transformation, and its defence capabilities. Furthermore, to monitor resource efficiency, evaluation measures should play an even stronger role. These should not be limited to immediate research outcomes (e.g. patenting measures), but should also cover all stages of the innovation chain, from R&D projects to the successful scaling up of new business solutions.

[60] European Commission/European Health and Digital Executive Agency (2023). Open innovation test beds – Improving access to knowledge to accelerate European innovation. Publications Office of the European Union, 2023.

[61] Gryszkiewicz, L., Lykourentzou, I., & Toivonen, T. H. I. (2016). Innovation labs: leveraging openness for radical innovation?. Journal of Innovation Management, 4(4), 68-97.

[62] ECCP (2025). The European online hub for industry clusters.

[63] Wolf, A. (2024a). Net-zero industry valleys in Europe. cepInput No.5/2024.

- **Integrate innovation hubs into global technology partnership strategies:** IIn recent years, attempts to encourage R&D cooperation within the EU have been accompanied by increased engagement with third countries. The EU has signed dedicated partnership agreements on technology cooperation with countries like Australia, Canada and South Korea. These agreements include joint initiatives on research funding in key areas such as semiconductors, as well as the integration of partner countries into the EU's Horizon program.[64] As well as extending the funding base for radical innovation, the EU should strengthen these ties further by initiating direct cooperation between regional innovation clusters in the EU and those in partner countries, for example through discussion platforms. European regions could benefit from regular knowledge exchange with local policymakers and cluster representatives in partner countries when devising their cluster strategies. Such cooperation could also boost the diversification of supply chains by facilitating the creation of new business ties.

5 Conclusion

In its current preoccupation with the competitiveness of traditional industry branches, the economic policy debate in Europe risks neglecting a crucial factor for long-term prosperity: Europe's capacity for generating radical innovation. In contrast to incremental innovation, radical innovation creates new markets through the introduction of entirely new technological characteristics and forms of consumer experience. With global information flows becoming ever faster, it is reasonable to predict that future waves of radical innovation will become more frequent and more disruptive for established business models, the balance of economic power and, consequently, concepts of society. Recent research indicates that while the timing of radical innovation cannot be predicted ex-ante, its likelihood is significantly influenced by local economic framework conditions. In particular, the presence of dense knowledge networks linking stakeholders across institutions, regions and skill areas is shown to provide a favorable environment for radical innovation.

This cepInput applies a citation-based radicalness score to global patent data to show that the EU has recently played only a minor role in radical innovation activity in five key technology fields for the digital and green transformation. Much of the global innovation output remains centered in the US, while China has managed to catch up with Europe. This jeopardizes Europe’s ability to define the playing field in future global markets, which is indispensable for a high-cost region like the EU to thrive.

Radical innovation activity within the EU is highly concentrated in a few hotspots, which mostly overlap with traditional industrial centers. These regions show further commonalities, such as a strong and dynamic local human capital base, and intensive R&D collaboration between businesses and academic institutions. It is difficult to replicate these historically grown framework conditions in other parts of Europe, given the persistence of agglomeration forces and the strong competitive pressure that new innovation hubs are exposed to. However, an EU innovation strategy that focused solely on strengthening the few existing hubs would overlook the potential for regional knowledge specialization and cross-regional collaboration. Politically, it could lead to the Union becoming even more divided.

For policymakers, the response must lie in a mixed strategy. Firstly, the general framework conditions in the EU for the market penetration of innovative technologies must be improved by overcoming barriers at all stages of the innovation cycle, including regulatory fragmentation, access to venture

[64] Wolf, A. (2024b). The future of global technology cooperation. cepStudy No.7/2024.

capital, and skill shortages. Secondly, these general measures should be combined with new regional development strategies for innovation hubs focused on radical innovation and guided by intensive co-ordination and information exchange at EU level. These strategies should adopt a network-centered approach, focusing on providing the physical and institutional infrastructure necessary for knowledge networks to flourish. As part of a coordination process, the EU should actively support Member States and regions in hub development. Furthermore, the EU should integrate the role of regional innovation hubs as an asset into its external economic policies, particularly the bilateral technology and research partnerships it is currently developing.

The upcoming EU Innovation Act cannot address all of these aspects. Rather, its primary function should be to establish a firm foundation for a new long-term policy perspective that prioritizes readiness for disruptive innovation waves over safeguarding traditional branches of the economy.

6 Appendix

6.1 Definition of Technology Fields

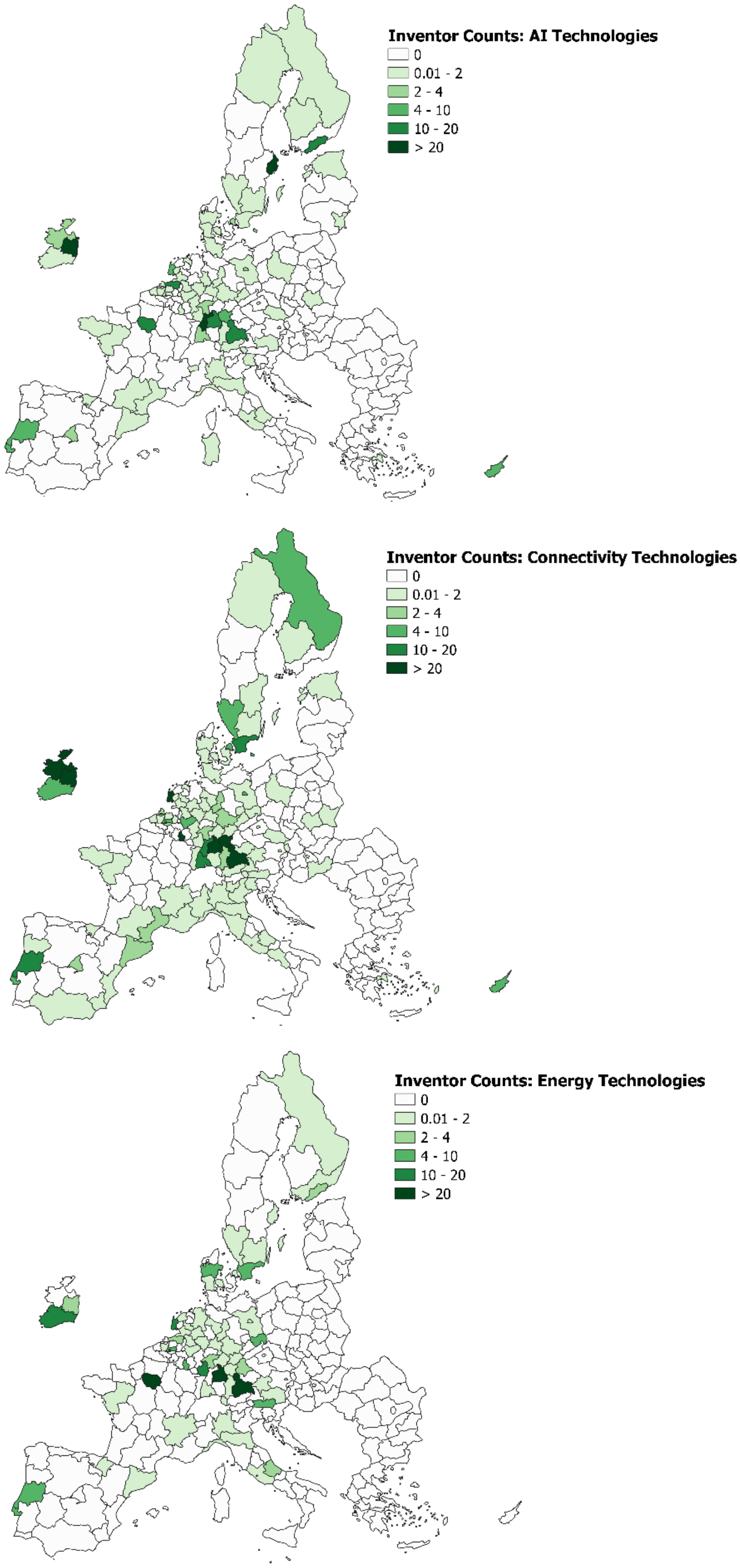
Table A1: Assignment of IPC codes to technology fields

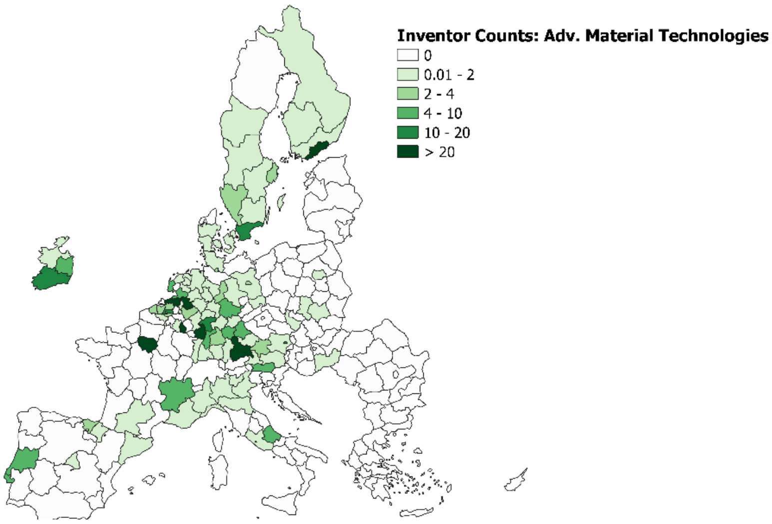
Critical technology (EU definition)	Source	Abbreviation	Assigned IPC codes
Artifical intelligence technologies	ATI (2021): Artificial intelligence	**AI**	G06F 15/18, G06F 17/20-17/28, G06F 17/30∗#, G06F 17/50∗#, G06F 19/10∗#, G06K 9, G06N∗#, G06Q 30/02∗#, G06T 7, G10L 13/027, G10L 15, G10L 17, G10L 25/63, G10L 25/66
Advanced connectivity, navigation and digital technologies Advanced sensing technologies	ATI (2021): Internet of Things, IT for mobility, Security	**Connectivity**	A61B 1/00%, A61B 5/00%, A61B 5/02%, A61B 5/04%, A61B 5/05%, A61B 5/103, G01C 11, G01C 19, G01C 21, G01S, G01V 3/17%, G01V 15/00%, G05D 1/03%, G06F12/14, G06F 17/00, G06F 19/00, G06F21, G06K19, G08B 5/22%, G08B 6/00%, G08B 13/14%, G08B 13/24%, G08B 21/00%, G08B 25/10%, G08B 29/00%, G08C 17/% , G08G, G09F 3/00%, G09C, G09F 3/03%, G11C8/20, H01Q 7/00%, H01Q 9/04%, H02J 17/00%, H04B 1/48%, H04B 1/59%, H04B 5/00%, H04B 7/00%, H04B 7/08%, H04B 7/185, H04B 10/105, H04K, H04L9, H04M1/66, H04M1/67, H04M1/68, H04M1/70, H04M1/727, H04N7/167, H04N7/169, H04N7/171, H04Q 5/22%, H04Q 7/00%, H04Q 9/00%, H04W12
Energy technologies	Own keyword search	**Energy**	C10L 5/40 (Biofuels), C25B 1/02(Water electrolysis), F03D (Wind motors), F24S (Solar heat collectors), F25B 30/00 (Heat pumps), G21B (Fusion reactors), H01L 31/04-31/05 (PV modules), H01M (Batteries, Fuel cells)
Advanced materials, manufacturing and recycling technologies	ATI (2021): Advanced materials	**Adv. materials**	B32B 9, B32B 15, B32B 17, B32B 18, B32B 19, B32B 25, B32B 27, B82Y 30, C01B 31, C01D 15, C01D 17, C01F 13, C01F 15, C01F 17, C03C, C04B 35, C08F, C08J 5, C08L, C22C, C23C, D21H 17, G02B 1, H01B 3, H01F 1/0, H01F 1/12, H01F 1/34, H01F 1/42, H01F 1/44, H01L 51/30, H01L 51/46, H01L 51/54
Advanced semiconductor technologies	ATI (2021): Micro- and Nano-electronics, Photonics	**Semiconductors**	B82Y 25, F21K, F21V, F21Y, G01D 5/26, G01D 5/58, G01D 15/14, G01G 23/32, G01J, G01L 1/24, G01L 3/08, G01L 11/02, G01L 23/06, G01M 11, G01P 3/36, G01P 3/38, G01P 3/68, G01P 5/26, G01Q 20/02, G01Q 30/02, G01Q 60/06, G01Q 60/18, G01R 15/22, G01R 15/24, G01R 23/17, G01R 31/26, G01R 31/27 , G01R 31/28 , G01R 31/303 , G01R 31/304,G01R 31/308, G01R 31/317, G01R 31/327, G01R 33/032, G01R 33/26, G01S 7/481, G01V 8, G02B 5, G02B 6 (excl. subclasses 1, 3, 6/36, 6/38, 6/40, 6/44, 6/46), G02B 13/14, G03B 42, G03G 21/08, G06E, G06F 3/042, G06K 9/58, G06K 9/74, G06N 3/067, G08B 13/186, G08C 19/36, G08C 23/04, G08C 23/06, G08G 1/04, G09G 3/14, G09G 3/32, G11B 7/12, G11B 7/125, G11B 7/13, G11B 7/135, G11B 11/03, G11B 11/12, G11B 11/18, G11C 11/42, G11C 13/04, G11C 19/30, H01F 10/193, H01G 9/028, H01G 9/032, H01H 47/32, H01H 57, H01J 3, H01J 5/16, H01J 29/46, H01J 29/82, H01J 29/89, H01J 31/50, H01J 37/04, H01J 37/05, H01J 49/04, H01J 49/06, H01L 31/052, H01L 31/055, H01L 31/10, H01L 33/06, H01L 33/08, H01L 33/10, H01L 33/18, H01L 51/50, H01L 51/52, H01S 3, H01S 5, H02N 6, H03B 5/32, H03C 3/22, H03F 3/04, H03F 3/06, H03F 3/08, H03F 3/10, H03F 3/12, H03F 3/14, H03F 3/16, H03F 3/183, H03F 3/21, H03F 3/343, H03F 3/387, H03F 3/55, H03K 17/72, H05B 33, H05K 1

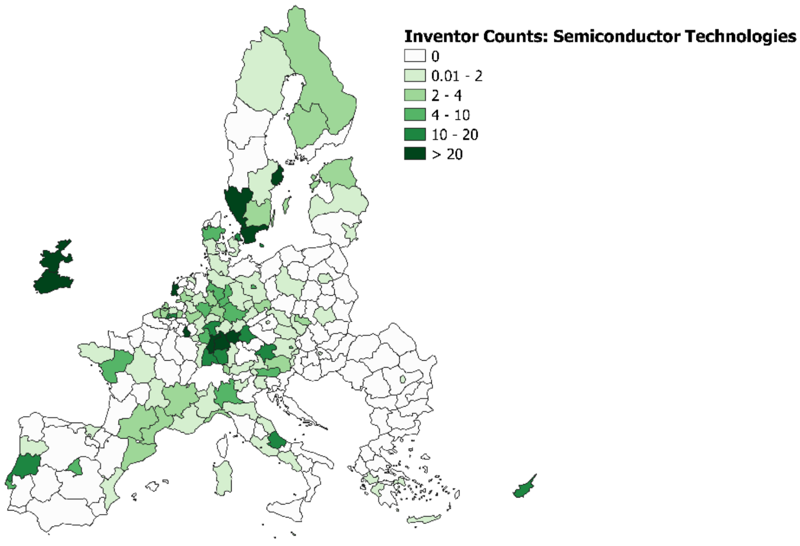
Source: ATI (2021); own representation

6.2 Results for Technology Fields

Figure A1: Distribution of radical innovation activity in EU regions by technology field







Source: EPO (2025); own calculations

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