



Recessions, institutions, and regional exploration

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ABSTRACT

This paper investigates how recessions affect regional exploration, defined as innovation in technologies that extend beyond a region's existing knowledge base. By analyzing USPTO patent data from 2002 to 2015 across the United States, we demonstrate that regional exploration is counter-cyclical. We further examine whether changes in regional institutions – specifically, public R&D, university R&D, and banking – partially mediate the effect of recessions on regional exploration. Our results indicate that only the increasing predominance of international banks in regional banking systems serves a partial mediator. These findings broaden our understanding of how business cycles impact innovation, suggesting that recessions may encourage the creation of new technological trajectories within regions. Furthermore, our study identifies which institutional factors during recessions support regional exploration, enhancing a region's potential for future growth and adaptability.

1. Introduction

Recessions are marked by significant economic contraction and substantial human costs. For instance, the 2008 Financial Crisis – “one of the most virulent recessions in decades” – led to significant unemployment, 4 % GDP contraction, and a decline in innovation expenditures across OECD economies and beyond (Filippetti and Archibugi, 2011; Paunov, 2012, p.24). Various institutional measures were taken to mitigate such effects of recessions (Brautzsch et al., 2015; Hud and Hussinger, 2015). However, several scholars argue that recessions may indeed positively impact technological development and economic growth (Field, 2003; Freeman and Perez, 1988; Kopytov et al., 2018; Manso et al., 2023; Mensch, 1978; Schumpeter, 1939). In this direction, our paper examines how recessions affect technological exploration within regions. We define ‘regional exploration’ as the process through which co-located inventors develop new technologies beyond the region's existing knowledge base (Lopez-Vega et al., 2016). Moreover, the paper further inspects whether recessions catalyze institutional changes that facilitate regional exploration. We focus on three key institutions that either conduct or finance innovation: public R&D institutions (Bloom et al., 2019; Brautzsch et al., 2015; Freeman and Perez, 1988), universities (Assimakopoulos et al., 2021; Youtie and Shapira, 2008), and banks (Aghion et al., 2012; Chava et al., 2013; Cornaggia et al., 2015).

The motivation for our research stems from a significant gap in

research on how business cycles impact innovation. While it is well-established that R&D investments and patent filings decline during recessions due to higher capital costs and lower returns on innovations (Barlevy, 2007; Fabrizio and Tsolmon, 2014; Ouyang, 2011), the effect of recessions on the nature of innovation — specifically, technological exploration — is less understood. Schumpeter, who experienced the Great Depression (1929–35), viewed recessions as periods of ‘creative destruction’, when obsolete practices are discarded, and entrepreneurs adopt effective innovations (Schumpeter, 1939, p. 148). This view is echoed by Mensch (1978) who documented how recessions historically led to “swarms of basic innovations” that catalyzed new market creation and industry transformation. Further studies support a trend towards exploration-based innovation during recessions (Archibugi et al., 2013; Laperche et al., 2011; Manso et al., 2023). However, the adverse economic conditions typical of recessions, such as banking distress (Nanda and Nicholas, 2014), credit constraints (Aghion et al., 2012) and a scarcity of risk capital (Menzel et al., 2017), may drive firms towards exploiting existing technologies. Freeman and Perez (1988) add a temporal dimension to this discussion arguing that while recessions may dampen innovation in the short term, the systemic and institutional changes they prompt likely facilitate the emergence of new technologies in the subsequent periods, increasing technological exploration in the long run.

This study advances the understanding of how recessions impact technological exploration by focusing on regional dynamics and the role

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of institutions. While existing studies on the effects of business cycles on innovation have mainly emphasized firm-level or environmental factors (Archibugi et al., 2013; Barlevy, 2007; Field, 2003; Kopytov et al., 2018; Laperche et al., 2011; Makridis and McGuire, 2023; Manso et al., 2023; Ouyang, 2011), they frequently neglect the spatial dynamics of innovation. Regions act as hubs of social connectivity, facilitating knowledge search and diffusion, and are essential for examining how institutions foster regional exploration during recessions (Cooke et al., 1998; Feldman, 2018; Fleming et al., 2007; Saxenian, 1996). Institutions sustain innovation, especially when private R&D investments wane, and support the development of new technological trajectories (Brautzsch et al., 2015; Freeman and Soete, 1997; Hud and Hussinger, 2015). However, empirical evidence directly linking institutional responses to regional innovation during recessions remains scarce. In this direction, our study develops hypotheses relating recessions to technological exploration within regions, illustrating the mediating role of different institutions which fund or conduct R&D.

We tested our hypotheses using patented innovations (USPTO) in the context of the United States metropolitan statistical areas (hereafter, MSAs) (Fusillo et al., 2022; Fleming et al., 2007) between 2002 and 2015, a period encompassing a full business cycle, including the Financial Crisis and Great Recession (2008–13) (Christiano et al., 2015). We measured regional exploration by tracking patents by local inventors in the US main technology patent classes (USPC) in which the region had not patented before (Rosenkopf and Nerkar, 2001; Lopez-Vega et al., 2016). We measured the intensity of the recession through changes in the Housing Price Index (hereafter, HPI) at the MSA level (Adelino et al., 2015; Sanders, 2008).

Our findings confirm that technological exploration within regions is counter-cyclical. Our mediation analyses suggest that although public R&D spending increases during recessions, it is not significantly associated with regional exploration. Conversely, university R&D spending exhibits a positive association with regional exploration but universities do not increase R&D spending during recessions. Interestingly, international banking institutions emerge as a critical mediator, suggesting that the effect of recessions on regional exploration may partly stem from the increasing predominance of international banks in the region.

These insights deepen our understanding of how recessions impact innovation (Barlevy, 2007; Freeman and Perez, 1988; Makridis and McGuire, 2023; Mensch, 1978; Ouyang, 2011; Schumpeter, 1939) by showing that recessions are associated with technological exploration at the regional level. Significantly, our findings suggest that the increase in regional exploration during the Financial Crisis was facilitated by the private sector, particularly international banking institutions, more than by increases in public or university R&D spending. These findings also contribute to the ongoing debate over the relative merits of public versus private funding in driving post-recession recovery and innovation.

These results are also highly relevant for economic geographers studying the evolutionary dynamics of regional specialization (Boschma, 2015). Specifically, they suggest that recessions can stimulate the emergence of new technological paths in regions (Martin and Sunley, 2006; Tanner, 2016; Zhu et al., 2017). It is important to emphasize that exploration marks only the beginning of a new technological path, which requires sustained innovation support, downstream product development efforts, and supportive regional institutions (Dawley, 2014; Freeman and Soete, 1997; Zhu et al., 2017). The creation of new paths, in turn, adds to a region's diversity and enhances its resilience against future shocks (Boschma, 2015; Martin, 2012; Martin and Sunley, 2015).

2. Hypotheses

2.1. Recessions and regional exploration

Innovations can be differentiated into exploitation and exploration. Exploitation entails innovation along pre-existing technological

trajectories, while exploration involves defining new problems or discovering new solutions outside of the established trajectories (Cyert and March, 1963; Rosenkopf and Nerkar, 2001). From a regional perspective, exploration introduces technologies that are not part of a region's pre-existing knowledge base (Lopez-Vega et al., 2016; Rigby, 2015). The latter comprises the cumulative set of knowledge, practices, and routines within the region, serving as a critical foundation for potential innovation through the recombination of existing knowledge elements (Fleming, 2001; Fleming et al., 2007).

A region's capacity for exploration is significantly influenced by its knowledge base. Regions with extensive and diverse knowledge bases are better positioned to develop new technologies, as regional specialization deepens the local pool of expertise and resources (Boschma, 2015; Fritsch and Slavtchev, 2010). Conversely, regions with limited technological infrastructure, such as rural or less developed areas, may lack the necessary elements for exploration. Despite these differences, all regions face significant funding and implementation constraints during recessions, prompting regional actors to engage in different types of innovation activities based on local conditions and incentives.

Recessions are characterized by declines in economic activities, aggregate demand, and investments (Beaudry et al., 2018). Innovation tends to be procyclical with respect to both investments and outputs – actors often delay R&D until economic expansion phases to maximize returns by capitalizing on high demand before imitators erode their rents (Barlevy, 2007; Fabrizio and Tsolmon, 2014). Additionally, banking failures, higher costs of capital, and constrained credit and venture capital funding significantly impede the innovation capacity of firms, particularly those dependent on external financing (Aghion et al., 2012; Brautzsch et al., 2015; Menzel et al., 2017; Nanda and Nicholas, 2014; Ouyang, 2011). Historical events such as the Great Depression and the dotcom bubble burst illustrate how financial distress and scarce venture capital can lead to more conservative innovation efforts (Nanda and Nicholas, 2014) and a shift to more exploitative tie formation logic (Menzel et al., 2017). Aghion et al. (2012) observed that while R&D investment can be countercyclical, firms under tight credit constraints tend to exhibit procyclical R&D investments. This trend is particularly evident in sectors that rely heavily on external finance or possess intangible assets, where R&D drops during recessions without fully rebounding in upturns.

However, recessions also encourage exploration through countervailing mechanisms. Recessions generate high uncertainty, which has growth options effects (Bloom, 2014; Bloom et al., 2018). Although high uncertainty increases risk premiums and leads actors to defer investments (Bloom, 2014; Lee et al., 2015), it simultaneously incentivizes them to generate growth options in emerging technologies. Under high uncertainty, a technology that offers potential for significant gains becomes attractive despite its long gestation period and low probabilities of success (Bloom, 2014, p. 201). Furthermore, adverse demand conditions in mature industries during recessions reduce actors' economic performance and the returns from exploitation, thus lowering the opportunity cost of exploration (Aghion et al., 2012; Aghion and Saint-Paul, 1998; Makridis and McGuire, 2023; Manso et al., 2023). In response to declining performance, actors intensify search efforts. When local search along existing trajectories fails to restore performance, they exhibit higher risk-tolerance and engage in distant search beyond a region's preexisting knowledge base (Cyert and March, 1963; Greve, 2003).

These considerations align with Mensch's observation that deep recessions force actors to innovate in technologies that seemed impossible or unattractive (Mensch, 1978). Studying patents of the US firms between 1958 and 2008, Manso et al. (2023) showed that firms intensified their exploratory efforts during recessions. Similarly, Laperche et al. (2011) provided qualitative evidence on how resourceful French firms pursued green technologies during the Financial Crisis, illustrating that recessions can stimulate exploratory search. Based on these arguments, we formulate the following hypothesis:

H1. *The greater the intensity of a recession in a region, the higher the rate of regional exploration.*

2.2. Institutions and regional exploration

Institutions shape the political, social and economic interactions in a society (North, 1991). They encompass formal organizations such as universities and public research institutions (hereafter, PRIs), banking and financial institutions, and administrative, legal, regulatory, and judicial institutions. These formal institutions include organizations that serve specific collective needs and establish the mechanisms for cooperation, coordination and governance. The critical role of institutions in driving innovation and new path creation in regions is well acknowledged (Cooke et al., 1998; Dawley, 2014; Gong et al., 2022; Menzel et al., 2017; Vallance, 2016; Youtie and Shapira, 2008). For instance, Menzel et al. (2017) demonstrated how venture capital boosted innovation in North Carolina's Research Triangle Park, primarily in the ICT sector during the mid-90s. Youtie and Shapira (2008) illustrated the contributions of Georgia Tech to the R&D industrialization of Georgia since the 80s, leveraging its institutional leadership and boundary-spanning role in the regional innovation ecosystem. Similarly, Dawley (2014) emphasized the importance of social and institutional agency and public policy in creating new paths in the offshore wind sector in North East England.

Given the consensus on the role of institutional actors in supporting innovation during recessions (Brautzsch et al., 2015; Freeman and Perez, 1988), we examine whether institutional responses to recessions partly mediate the increase in regional exploration during recessions. We specifically focus on three key institutions — public R&D, university R&D, and banking institutions — that directly finance or conduct regional innovation.

2.2.1. Public R&D

Public R&D investments are aimed at offsetting the suboptimal private investment that is often stifled by high uncertainty and imperfect appropriability of innovations. Information asymmetry between innovative firms and investors further restricts the ability of capital markets to finance innovation (Bloom et al., 2019; Freeman and Soete, 1997). To mitigate these challenges, governments provide subsidies and tax incentives to innovators and establish public research institutions (PRIs) to spearhead R&D and support innovation (e.g., Hud and Hussinger, 2015).

Public R&D investments significantly expand the technological scope and reach of regional innovations (Bloom et al., 2019; Graf and Henning, 2009; Wang, 2018). Nonetheless, it is unclear whether these investments predominantly encourage exploration or exploitation. While subsidies might incentivize R&D in nascent technologies due to their risk-bearing nature (Bronzini and Piselli, 2016), yet the pressure on inventors by subsidy-granting institutions to deliver time-bound results may favor exploiting existing knowledge (Ning et al., 2022). Similarly, R&D tax credits support both exploration and exploitation (Bloom et al., 2019; Wilson, 2009; Yang et al., 2012).

PRIs serve as knowledge hubs that enhance regional competitiveness within their specialization areas. Acting as anchor organizations, they significantly influence regional innovation and entrepreneurship (Assimakopoulos et al., 2021; Mulligan et al., 2022; Yang et al., 2009). PRIs support regions in developing critical technologies and help them catch up with more advanced economies (Mazzoleni and Nelson, 2007). However, their focus on specific technologies typically promotes exploitation through enhanced knowledge transfer and spillovers, thereby constraining exploration by increasing its opportunity cost (Assimakopoulos et al., 2021; Feldman, 2003; Hu, 2011). For instance, the Industrial Technology Research Institute (ITRI) in Taiwan has played a critical role in strengthening Hsinchu's specialization in semiconductors and electronics. By encouraging deep search in these areas, ITRI may have inadvertently sidelined broader exploratory innovations and promoted exploitation. Between 1980 and 2009, 340 new firms

were registered in Hsinchu, all within ITRI's six areas of specialization. Over 100 spinouts in Hsinchu originated from ITRI (Hu, 2011).

During recessions, such as those observed during the Financial Crisis in the US (Rehm, 2018; Yap, 2009) and Germany (Brautzsch et al., 2015; Hud and Hussinger, 2015), public R&D often increases to accelerate the economic recovery. However, the potentially ambivalent effects of public R&D on regional exploration versus exploitation underscore the importance of assessing whether an increase in public R&D during recessions mediates the impact of recessions on regional exploration:

H2. *The effect of recession intensity on regional exploration is partially mediated by an increase in public R&D.*

2.2.2. University R&D

Universities play a crucial role in science-based innovations, accounting for nearly half of all fundamental scientific research in the US (Bloom et al., 2019). Their contributions to basic science significantly influence new technology development (Freeman and Perez, 1988; Freeman and Soete, 1997) and strengthen regional innovation through spinouts and industry spillovers (Abramovsky and Simpson, 2011; Cowan and Zinovyeva, 2013; Youtie and Shapira, 2008). As entrepreneurial anchors, universities deeply influence a region's technological specialization (Assimakopoulos et al., 2021).

Due to the entrenched institutional norms of academic freedom, universities typically promote exploration through bottom-up problem-identification and search efforts (Youtie and Shapira, 2008). In the US, university researchers have significant autonomy to address technological challenges and commercialize inventions (Goldfarb and Henrekson, 2003). Collaborations with universities and the hiring of their doctoral graduates significantly enhance firms' capabilities for exploratory R&D, often leading to technological breakthroughs (Buenstorf and Heinisch, 2020; Wirsich et al., 2016). Their extensive networks further facilitate the diffusion of new technologies across regions (Plunket and de Waldemar, 2022).

However, during recessions, industry funding for university research may decline due to reduced liquidity, lower revenues, and project rationalization (Rehm, 2018). Enrolments may decline due to higher interest rates on student loans. Universities also face a significant decline in endowment value during such periods (Yap, 2009). Conversely, public policies aimed at enhancing human capital during recessions might boost universities' revenues, supporting their ability to undertake basic research and exploration. These opposing considerations indicate that the impact of recessions on regional exploration may be in part mediated by changes in university R&D, although the direction of this effect remains to be determined:

H3. *The effect of recession intensity on regional exploration is partially mediated by an increase in university R&D.*

2.2.3. Banking institutions

Banking institutions play a crucial role in supporting exploration and the development of new technologies. Public capital markets exhibit low risk tolerance and their regulatory demands may expose firms' sensitive information to competitors (Bernstein, 2015). Thus, it is advantageous for entrepreneurial firms engaged in exploratory R&D to remain private and rely on bank financing rather than going public (Aggarwal and Hsu, 2014; Ferreira et al., 2014; Maksimovic and Pichler, 2001). Evidence suggests that private firms financed by banking and financial institutions produce broader and more exploratory patents compared to publicly traded companies (Gao et al., 2018).

Banks are essential for supporting R&D activities and fostering technological and economic growth in regions. Banking development enhances the quantity and quality of regional innovation, particularly benefiting regional actors dependent on external capital (Amore et al., 2013; Chava et al., 2013). Entrepreneurs and firms rely on geographically proximate banks for credit to fund their R&D endeavors (Lee and Brown, 2017; Zhao and Jones-Evans, 2017). During recessions,

Table 1
Variables, operationalization, and data sources.

Variables	Operationalization	Data-sources
Regional exploration	Share of exploratory innovations (an exploratory patent is assigned a USPC main class in which the MSA had no patents in the last ten years)	USPTO
Recession: Housing Price Index (HPI)	Housing price index in the focal MSA (non-seasonally adjusted; average of all quarters). The lower the index, the higher the intensity of the crisis	Federal Housing Finance Agency
Regional network size (log)	The number of inventors that filed at least one patent in the MSA in the application year	USPTO
Outward orientation	The ratio of external collaboration ties over the total number of internal ties formed by inventors in the focal MSA	USPTO
Technological specialization	Herfindahl-Hirschman index (HHI) of patenting in the focal MSA by USPC technology main classes	USPTO
Hierarchy in region's innovation network	Degree centralization of the focal MSA's co-patenting network of inventors	USPTO
Size of region's high-tech sector (log)	Natural log of the number of employees in high-tech industries in the focal MSA	US Bureau of Economic Analysis
Quality of HC (human capital) in region's high-tech sector	Per capita annual payment in the high-tech sectors in the focal MSA	US Bureau of Economic Analysis
Public R&D*	Public spending on R&D	US Census Bureau: State and Local Government Finance
University R&D*	Spending on R&D by the universities and colleges located in the focal MSA	National Science Foundation - HERD surveys
Predominance of international banks*	Share of bank branches specializing in international banking in the focal MSA	FDIC

* Institutional variables (mediation mechanism).

however, a decline in banking finance typically leads to reduced R&D investments and a shift from exploration to exploitation. [Nanda and Nicholas \(2014\)](#) documented that firms located in counties affected by banking distress during the Great Depression saw a decline in both the quantity and quality of innovation.

However, international and local banks exhibit distinct capabilities and risk preferences, thereby favoring different types of innovation. Hence, the structure and composition of a region's banking sector significantly influence the nature of innovation activities. International banking institutions, defined as those operating in many countries through branches and subsidiaries and engaging in cross-border and cross-currency financial flows, are particularly well-positioned to support high-risk R&D in new technologies, thus positively affecting regional exploration ([Aliber, 1984](#); [McCauley et al., 2021](#)). Their higher risk-taking is afforded by lower cost of capital (arbitrage) and ability to diversify asset risks across countries ([Aliber, 1984](#); [Amore et al., 2013](#); [Goetz et al., 2016](#)). Local banks often lend conservatively to R&D in novel technologies due to moral hazard and adverse selection ([Holmström, 1979](#)). However, extensive global operations of the international banks provide them with deeper insights into emerging technologies. Thus, international banks are better able to mitigate moral hazard and adverse selection problems and finance exploratory innovation.

Besides directly financing high-risk projects, international banks support exploration by increasing access to financing in the region, including from the competing local banks. Increased competition in the banking sector and greater credit availability stimulate innovation and encourage firms to pursue riskier projects ([Clarke et al., 2006](#); [Giannetti and Ongena, 2009](#)). Young, private firms, which engage more in path-breaking, exploratory R&D, specifically benefit from the erosion of local banks' market power through competition – they innovate more, pursue more audacious projects, and become less susceptible to acquisition ([Chava et al., 2013](#); [Cornaggia et al., 2015](#)). The presence of international banks also boosts entrepreneurial entries ([Bermpei et al., 2019](#)).

During recessions smaller, localized banks, with concentrated assets, face greater vulnerability compared to larger, internationally diversified banks ([Calomiris and Mason, 2003](#); [Cole and White, 2012](#)). This is particularly true for crises that originated in the banking domain, such as the Financial Crisis ([Gertler and Gilchrist, 2018](#)). For example, during the Financial Crisis, FDIC deposit data show that banking branches with international specialization decreased by 1.51 % in 2008 but surged by 46.99 % in 2009. This suggests that international banks tend to become more predominant relative to local ones during recessions, thereby

positively impacting regional actors' capacity to conduct exploratory R&D. Thus, structural changes in a region's banking sector, and in particular, an increased predominance of international banks following a recession, can partly mediate the impact of recessions on regional exploration.

H4. *The effect of recession on regional exploration is partially mediated by an increase in the predominance of international banking institutions in the regional economy.*

3. Context, variables and empirical model

3.1. Context

Our study covers the period 2002–2015, encompassing a complete business cycle that includes the Financial Crisis and Great Recession (2008–2013). The crisis was largely exogenous to regional innovation ([Sanders, 2008](#)). It originated from home mortgage defaults and led to widespread financial instability and economic contraction, with the Dow Jones Industrial plummeting from 17,273.21 in October 2007 to 8623.84 by February 2009. Unemployment peaked at 10 % in October 2009. Real GDP in the US only grew by 0.1 % in 2007–08 and declined by 2.6 % in 2008–09, with the economy not fully recovering to pre-crisis levels until after 2012 ([Christiano et al., 2015](#)).

We tested our hypotheses by studying innovation in the US regions defined by Metropolitan Statistical Areas ([Fleming et al., 2007](#); [Fusillo et al., 2022](#)). To measure 'regional exploration', we relied on the PatentsView database, which includes all patents granted by the USPTO. PatentsView is well-known for its superior quality and continued improvements in inventor disambiguation. This database has been frequently used by innovation scholars (e.g., [Clayton et al., 2022](#); [Righi and Simcoe, 2019](#)). We associated patents with MSAs by matching the geographical locations of inventors to the CBSA-MSA database as delineated in 2003, assigning patents to any MSA with at least one inventor.¹

¹ We conducted supplementary analyses by constructing our dependent variable based on fractional counts. In this approach, we weighted the contribution of a patent to a region by the number of regional co-inventors relative to the total number of co-inventors. For example, if a patent had three co-inventors and only one was located in a given region, that region is credited with 0.33 of a patent. We then computed the share of regional exploratory patents based on these fractional counts. The results (Appendix, Table A2, Model 4) are consistent with those presented in the paper.

While patents are a widely recognized innovation metric, they capture only codifiable knowledge. Some innovations are never patented due to high costs, lengthy procedures, or strategic decisions to maintain trade secrets, especially in the case of process innovations where patent rights cannot easily be enforced (Arundel, 2001; Arundel and Kabla, 1998). Despite the challenges of using patent data, its structured nature makes it particularly suitable for regional innovation studies due to its comprehensive coverage, detailed classification systems, and localization information, as evidenced by numerous studies (Barbieri and Consoli, 2019; Breschi and Lenzi, 2015; Castaldi and Los, 2017; Coffano et al., 2017; Gallo and Plunket, 2020; Menzel et al., 2017; Operti and Kumar, 2023; Sleuwaegen and Boiardi, 2014; Tanner, 2016). We addressed the limitations of patent data by employing region and patent class fixed effects to account for time-invariant differences in patent propensity, year fixed effects, and specific control variables discussed in our method section. We also highlighted in the limitations section how future studies might employ alternative data sources to test this framework.

3.2. Data sources and variables

Dependent variable. Following prior studies (Rigby, 2015; Rosenkopf and Nerkar, 2001), we used US patent classification (USPC) to identify whether an innovation represented an instance of exploitation or exploration. We measured regional exploration by calculating the number of patent applications filed in a given year² in technological areas that do not belong to the MSA knowledge base, normalized by the total number of patents filed in the MSA in that year. The Knowledge Base ($KB_{i,t}$) of a region i at time t consists of all USPC main classes k where any inventor from the MSA has filed patents (Rigby, 2015) during the ten years³ up to $t - 1$.

$$KB_{i,t} = \{k | \text{at least one patent filed in the class } k \text{ by inventors from region } i \text{ between } (t - 10) \text{ and } (t - 1)\}$$

A technology class k is considered new to the region i in year t if it is not part of the region's Knowledge Base ($KB_{i,t}$):

$$New_{i,t} = \{k | k \notin KB_{i,t}\}$$

Our dependent variable 'Regional Exploration' for region i in year t is then defined as the share of patents filed in these new USPC technology classes relative to the total number of patents filed by inventors from that region in the same year:

$$RE_{i,t} = \frac{\sum_{k \in New_{i,t}} P_{i,k,t}}{\sum_k P_{i,k,t}}$$

² We computed all patent-based variables using the application year and not the grant year. E.g., if a patent was filed in 2004 but granted in 2010, we record it as a patent from 2004 (not 2010). This minimizes the distortions arising from the often lengthy and variable patent granting process.

³ Technologies evolve over time. A region's knowledge base in a specific technology area may become redundant unless the region is continuously generating new knowledge in that area (Helfat and Peteraf, 2003). A 10-year gap in patenting within a USPC main class indicates that a region's knowledge in that technology area has practically become non-existent or redundant. To measure knowledge obsolescence, some studies (Manso et al., 2023) use a five-year moving window. We use a more conservative approach and use a 10-year moving window (e.g., Miller et al., 2007). We also conducted additional analyses using a 5-year moving window (Appendix, Table A2, Model 3), with results in line with those presented in the paper.

where $P_{i,k,t}$ is the number of patents filed by inventors in region i in USPC class k in year t . This index quantifies the extent to which inventors in a region are devoting their total innovation efforts to technologies that are not part of the region's knowledge base, capturing the general propensity to explore new technological areas.⁴

Independent variable. We measured the intensity of the recession using the Housing Price Index (HPI) at the MSA level, an established measure frequently used in finance and economics to capture variation in the severity of recessions. HPI effectively correlates with shifts in consumer demand, employment growth, and wages at the county level (Adelino et al., 2015; Mian and Sufi, 2014). We obtained MSA-level quarterly HPI data from the Federal Housing Finance Agency, and we computed the annual mean for each MSA. A higher HPI in an MSA indicates economic expansion, while a lower HPI reflects recessions. This measure is particularly relevant especially during the Financial Crisis (Gertler and Gilchrist, 2018), which originated in the home mortgage sector. In our robustness analyses, we used alternative measures (*employment across all sectors* and *real GDP* per capita) to gauge the intensity of recession in a region (see Appendix, Table A2).

Institutional variables. We operationalized the institutional mediators as follows. Public R&D spending was measured using data from the US Census Bureau (Bronzini and Piselli, 2016). This variable encompasses all R&D expenditures by state governments and other non-federal entities. It includes both intramural R&D, conducted by employees within a state department or agency, and extramural R&D, carried out by academic institutions, companies, and individuals but funded by the state department or agency. University R&D spending was measured using data from the National Science's Higher Education Research and Development (NSF HERD) surveys, which capture the investments made by universities and colleges within an MSA (Anselin et al., 1997). The predominance of international banks in a region was operationalized by

their share of the total number of banking branches in the MSA,⁵ using data from the Federal Deposit Insurance Corporation (FDIC) (Chava et al., 2013).

⁴ We conducted additional analyses operationalizing the dependent variable as a ratio of exploratory to exploitative patents (Appendix, Table A2, Model 5). They results are in line with our hypotheses.

⁵ This operationalization assumes that between 2002 and 2015, firms and entrepreneurs secured R&D financing from bank branches located within their regions (MSAs). Ideally, a more precise operationalization would include data on the total R&D financing accessed by actors in each MSA and those accessed from international banking institutions specifically. However, such data were unavailable. We remain confident that this is a good proxy of our construct for two reasons. First, spatial proximity between bank branches and firms significantly affects financing outcomes. Research indicates that geographic distance increases transaction costs and diminishes the accuracy of soft information—such as the quality and motivation of entrepreneurs—which is crucial when hard information is lacking and information asymmetry is high (Agarwal and Hauswald, 2010; Bellucci et al., 2013; Degryse and Ongena, 2005). Economic geographers have shown that banks are less likely to extend credit to geographically distant innovators (Lee and Brown, 2017; Zhao and Jones-Evans, 2017). Second, online lending and lending from fintech firms were limited in the period we studied. Despite the potential for fintech firms to bridge geographical distance (Herpfer et al., 2023), their share of lending was relatively minor compared to the total industrial and commercial lending in the US (Gopal and Schnabl, 2022). FRED data also highlight a limited diffusion (until 2015) of secure internet servers, which are crucial for online banking transactions.

Table 2
Descriptive statistics.

Variables	Observations**	Mean	Std. Dev.	Min	Max
Regional exploration	5214	0.101	0.144	0	1
Housing Price Index	5214	169.404	36.900	86.714	364.25
Regional network size (log)	5214	4.686	1.765	0.693	9.709
Outward orientation	5214	6.221	11.183	0	229
Technological specialization	5214	0.082	0.141	0.007	1
Hierarchy in region's innovation network	5214	0.040	0.032	0.002	0.312
Size of region's high-tech sector (log)	5214	9.333	1.554	3.689	13.949
Quality of HC in region's high-tech sector	5214	51.715	15.173	13.975	165.953
Public R&D (in thousand)*	5211	9363.977	16,201.46	21	107,982
University R&D*	5214	108,614.4	245,867.6	0	2,803,423
Predominance of international banks*	5214	0.032	0.056	0	0.318

* Institutional variables (mediation mechanism).

** Observations from the main equation testing hypothesis 1.

Controls. We included several controls to account for factors that may influence regional exploration. Intellectual resources, proxied by the number of inventors residing in the MSA, may affect the level of technological exploration in a region (Breschi and Lenzi, 2015). Hence, we controlled for the size of the regional innovation network (log-transformed). We also controlled the external orientation of regional inventors, measured by the ratio of their collaboration ties outside to those within the region. External ties can bring new knowledge into a region, potentially boosting exploration (Perkmann, 2006). However, spatial distance often hinders communication and knowledge transfer, leading inventors in different regions to collaborate only when they share deep specialization in a technology. In such cases, external ties may reinforce the region's existing technological focus, promoting exploitation rather than exploration.

A region's technological specialization may influence innovation through an interplay of Marshallian and Jacobian externalities (Fritsch and Slavtchev, 2010). Specialization may cause lock-in effects, restricting regional exploration. We operationalized it using the Herfindahl-Hirschman Index (HHI) of patenting across USPC technology classes.⁶ We also controlled for the hierarchy of the regional innovation co-patenting network, as decentralization has been shown to promote diverse perspectives and parallel search processes necessary for exploration (Keum and See, 2017; Lazer and Friedman, 2007).

To capture the effect of technological competences on exploration, we used the size of high-tech industries and a proxy of the quality of human capital in each MSA (Fusillo et al., 2022; Sleuwaegen and Boiardi, 2014). Additionally, we included MSA(–state) and application year fixed effects, and dummies for the USPC main classes (up to 3 digits) in which the MSA had the largest number of patent applications (subsequently granted) in a year, to control for unobserved time-invariant differences at the region, year and technology levels.

Table 1 provides an overview of the key variables and controls, including their operationalization, and data sources. Table 2 presents descriptive statistics. On average, 10.14 % of a region's patents can be classified as technological exploration. The HPI, set to 100 for each MSA in the first quarter of 1995, dropped significantly during the Financial Crisis. Figs. 1 and 2 show the trends in mean technological exploration and mean HPI across US MSAs over time. Table 3 presents correlations between variables. The maximum mean VIF (variance inflation factor) for the models displayed in the tables was 3.12, below the threshold of 5.⁷ In our analyses, we standardized all variables to facilitate easier interpretation of the results.

⁶ In robustness analyses, we controlled distinct dimensions of region's technological profile and their interaction with recession (Appendix, Table A5).

⁷ We also did analyses omitting control variables with high VIF scores (regional network size, size of region's high-tech sector, and size of region's high-tech sector). The results were robust for each model.

3.3. Econometric model

The unit of analysis in this study is the MSA-state-year, given that some MSAs span multiple states and exhibit distinct values for certain variables derived from state-level data. To test the first hypothesis, we estimated a panel regression with MSA-state-and application year fixed effects:

$$\text{Regional exploration}_{i,t+1} = \beta_0 + \beta_1 \cdot \text{HPI}_{i,t-2} + \alpha Z_t + \varepsilon_{i,t+1} \quad (1)$$

We employed a two-year lag for the independent variable (HPI at $t - 2$) relative to the mediating institutional variables and controls, measured at time (t). The dependent variable (regional exploration) is measured at ($t + 1$). This lag structure accounts for the time required by economic and institutional actors to adapt to macroeconomic changes as well as the typical timeline from initiating an innovation project to filing the corresponding patents. Firms and inventors may also adjust their risk-taking and technology search strategies within their ongoing projects in response to changes in economic incentives. A two-year lag reflects the adjustment period to economic conditions, such as booms or recessions. Research indicates that while the duration from project conception to patent filing can vary across technologies, a one-year period is generally sufficient, given the strategic incentives for firms to file patent protection promptly (Baker and Mezzetti, 2005; Cappelli et al., 2023)⁸. Furthermore, the one-year lag between the dependent variable ($t + 1$) and the controls and institutional variables also mitigate concerns of reverse causality.

3.4. Testing partial mediation

We examined the potential indirect effect of recession on regional exploration, mediated through institutional variables, using mediation analysis—a method that explores a theoretical model forming a ‘causal chain’ from the independent variable to the outcome (Judd and Kenny, 1981a). Our model can be depicted as below (see Fig. 3).

According to Judd & Kenny (1981b, p. 605), three conditions must be met to establish mediation: (1) the independent variable must significantly affect the dependent variable (2) each variable in the ‘causal chain’ must significantly affect the next variable, and (3) the

⁸ In additional analyses (Appendix, Table A2), we used a two-year lag for MSA-employment (all sectors) and a one-year lag for MSA-GDP per capita, reflecting the delayed economic impact post-initial housing market crash. In another analysis, we used a three-year lag between the independent ($t - 3$), institutional ($t - 3$), and control variables ($t - 3$), and the dependent variable (t). The results align with our main analyses (Appendix, Table A7).

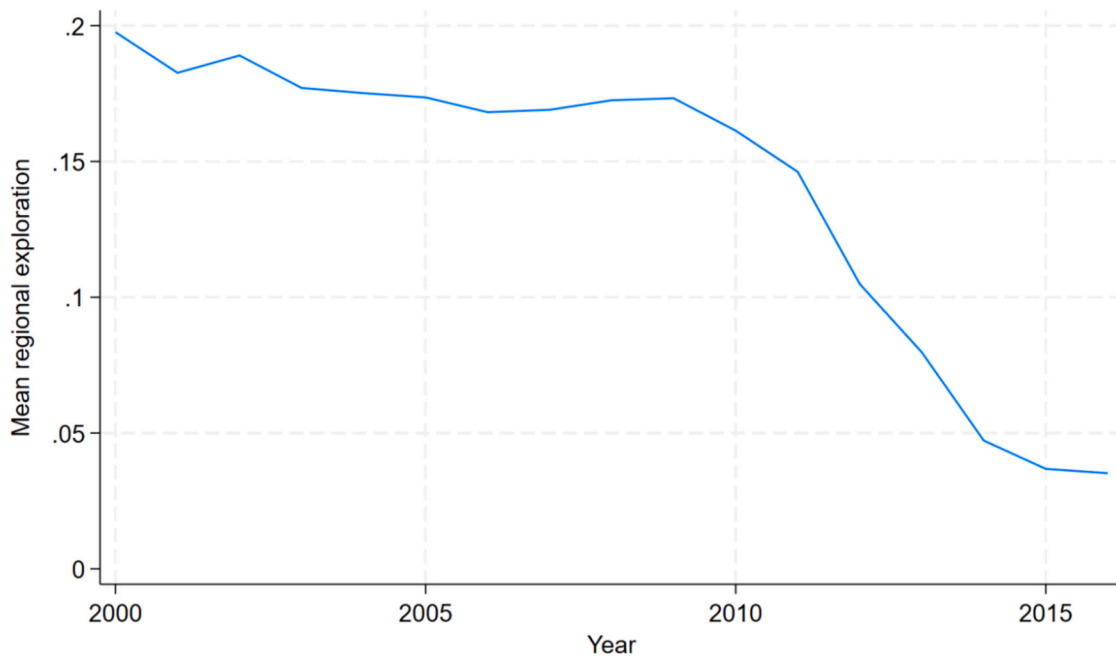


Fig. 1. Regional exploration (mean) over years in the US MSAs.

effect of the independent variable on the dependent variable must disappear when the mediating variable is controlled. However, the third condition is not necessary in partial mediation, which is more realistic in social science research (Baron and Kenny, 1986; MacKinnon et al., 2002). In partial mediation, the effect of the independent variable on the dependent variable is compared before (β_{yx}) and after controlling the mediating variable ($\beta_{yx.m}$). In full mediation, $\beta_{yx.m}$ becomes non-significant, whereas in partial mediation, $\beta_{yx.m}$ remains significant but with a reduced effect size (Cohen et al., 2013; Cummings and Kiesler, 2007; Døjbak Håkonsson et al., 2016; MacKinnon et al., 2002; Ndofor et al., 2011; Wood et al., 2008). We employ the Sobel (1982) Test, as recommended by Baron and Kenny (1986), to calculate the indirect (mediated) effect.

We first estimated the effect of recession (HPI) on each institutional variable. The equations are as follows:

$$\text{Public R\&D}_{i,t} = \beta_0 + \beta_1 \cdot \text{HPI}_{i,t-2} + \alpha Z_t + \varepsilon_{i,t} \quad (2)$$

$$\text{University R\&D}_{i,t} = \beta_0 + \beta_1 \cdot \text{HPI}_{i,t-2} + \alpha Z_t + \varepsilon_{i,t} \quad (3)$$

$$\text{International banks}_{i,t} = \beta_0 + \beta_1 \cdot \text{HPI}_{i,t-2} + \alpha Z_t + \varepsilon_{i,t} \quad (4)$$

Then, we assessed whether these institutional variables influenced regional exploration:

$$\text{Regional exploration}_{i,t+1} = \beta_0 + \beta_1 \cdot \text{Public R\&D}_t + \alpha Z_t + \varepsilon_{i,t+1} \quad (5)$$

$$\text{Regional exploration}_{i,t+1} = \beta_0 + \beta_1 \cdot \text{University R\&D}_t + \alpha Z_t + \varepsilon_{i,t+1} \quad (6)$$

$$\text{Regional exploration}_{i,t+1} = \beta_0 + \beta_1 \cdot \text{International bank}_t + \alpha Z_t + \varepsilon_{i,t+1} \quad (7)$$

If an institutional variable shows significant effects in both parts of the causal chain, this indicates mediation. To confirm partial mediation, we introduce each institutional variable in eq. [1] to observe whether the effect of HPI on regional exploration remains significant but is reduced in size ($\beta_{yx.m} < \beta_{yx}$).

$$\text{Regional exploration}_{i,t+1} = \beta_0 + \beta_1 \text{HPI}_{i,t-2} + \beta_2 \cdot \text{Public R\&D}_t + \alpha Z_t + \varepsilon_{i,t+1} \quad (8)$$

$$\text{Regional exploration}_{i,t+1} = \beta_0 + \beta_1 \text{HPI}_{i,t-2} + \beta_2 \cdot \text{University R\&D}_t + \alpha Z_t + \varepsilon_{i,t+1} \quad (9)$$

$$\text{Regional exploration}_{i,t+1} = \beta_0 + \beta_1 \text{HPI}_{i,t-2} + \beta_2 \cdot \text{International bank}_t + \alpha Z_t + \varepsilon_{i,t+1} \quad (10)$$

To compute the indirect effects mediated through each institutional variable, we used the STATA package *sgmediation*⁹, which performs Sobel-Goodman tests for statistical mediation in linear regression models (Choudhury and Haas, 2018; MacKinnon et al., 2002; Sobel, 1982). It is important to note that mediation tests do not establish causality but rather identify correlations between variables (Judd and Kenny, 1981b; Stone-Romero and Rosopa, 2008).

4. Results

4.1. The effect of recessions on regional exploration

4.1.1. Panel regression

Models 1 and 2 in Table 4 predict regional exploration using fixed effect panel regression. Model 1 included the control variables. Their effects were in line with our expectations. Size of the inventors' network in the MSA ($\beta = -0.388; p = 0.000$), technological specialization ($\beta = -0.139; p = 0.000$) and hierarchy within the region's innovation network ($\beta = -0.038; p = 0.009$) were negatively associated with regional exploration. Conversely, size of the region's high-tech sector ($\beta = 0.074; p = 0.005$) and quality of human capital in the MSA ($\beta = 0.077; p = 0.000$) were positively associated.

In Model 2, we introduced the independent variable (HPI), which had a negative effect on regional exploration ($\beta = -0.065; p = 0.000$). This finding supports our hypothesis 1, indicating that, similar to firm-level exploration (Manso et al., 2023), regional exploration is also counter-cyclical.

⁹ Recently, UCLA Statistical Consulting Group has discontinued this package. However, Trenton D. Mize (Purdue University) has updated it (*sgmediation2*).

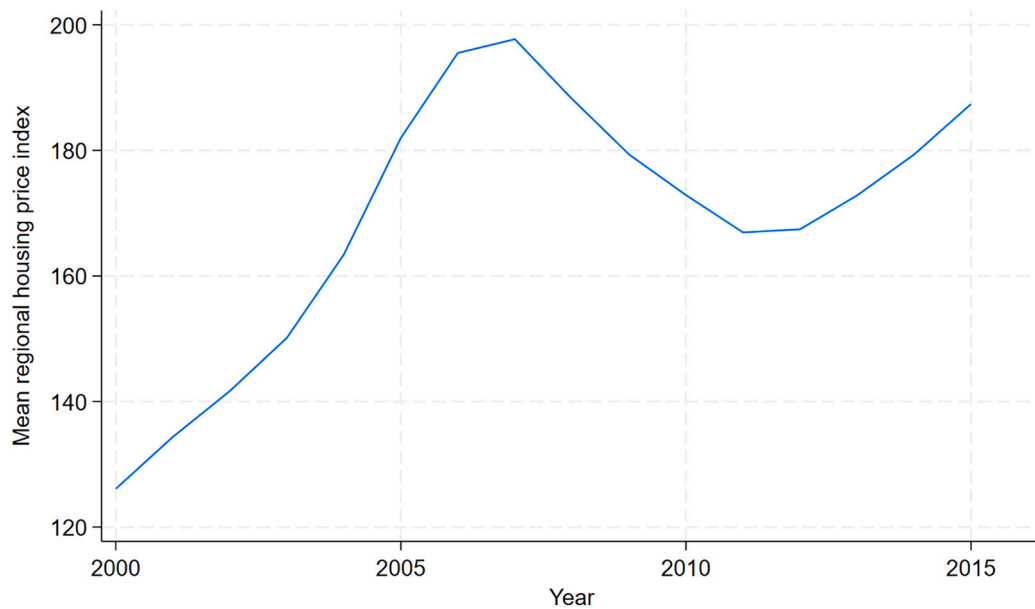


Fig. 2. Housing price index (mean) over years in the US MSAs.

Table 3
Correlation table.

Variables	1	2	3	4	5	6	7	8	9	10	11
1 Regional exploration	1.00										
2 Housing Price Index	−0.17	1.00									
3 Network size (log)	−0.61	0.25	1.00								
4 Outward orientation	0.11	0.03	−0.27	1.00							
5 Technological specialization	0.06	−0.03	−0.38	0.08	1.00						
6 Hierarchy in region's innovation network	0.40	−0.16	−0.59	−0.04	0.26	1.00					
7 Size of region's high-tech sector (log)	−0.49	0.28	0.87	−0.25	−0.28	−0.57	1.00				
8 Quality of HC in region's high-tech sector	−0.46	0.40	0.67	−0.12	−0.05	−0.43	0.69	1.00			
9 Public R&D	−0.10	0.19	0.12	0.10	−0.01	−0.15	0.08	0.19	1.00		
10 University R&D	−0.25	0.12	0.42	−0.14	−0.12	−0.27	0.35	0.34	0.05	1.00	
11 Predominance of international banks	−0.17	0.15	0.25	−0.01	−0.03	−0.15	0.25	0.29	0.35	0.08	1.00

4.1.2. Robustness: alternative estimation and controls

The Wooldridge and Cumby-Huizinga tests revealed the presence of autocorrelation in our panel data. Consequently, we performed robustness analyses using estimation methods that yield more reliable and less biased estimates in the context of temporal and cross-sectional autocorrelations (Table 4, Models 3–8). In Model 3, we controlled for the first and second lags of the dependent variable (Table 4, Model 3)¹⁰. The effect of HPI on regional exploration remained significant ($\beta = -0.059; p = 0.000$). Model 4 presents the results using autocorrelation-consistent Newey-West standard errors with a maximum lag of two (newey, lag(2)) (Newey and West, 1987). The

¹⁰ Combining lagged variables with individual FE violates the assumption of strict exogeneity, leading to biased estimates. However, since our panel is relatively long, the bias from including the lagged dependent variable diminishes and approaches zero asymptotically as the length of the panel (T) goes to infinity (Nickell, 1981). For first-order autoregressive models with reasonably large values of T , the 'Nickell' bias is approximately $\frac{(1+\rho)}{(T-1)}$. In our first-order autoregressive model, this bias is 0.009. We also initially used dynamic panel estimation using Arellano-Bond (xtabond) (Arellano and Bond, 1991) and System GMM (xtgdpdys) (Blundell and Bond, 2000) with two lags of dependent variable. Although the effect of HPI on regional exploration was consistent across these models ($\beta = -0.056; p = 0.002$ and $\beta = -0.058; p = 0.002$ respectively), the Sargan test indicated potential overidentification, leading us not to report these models in the main analysis.

Newey-West standard errors accounts for temporal dependence, correcting for correlations of error terms within each panel over time, and heteroskedasticity, addressing non-constant variance in error terms across observations. The findings remained consistent with our primary analysis ($\beta = -0.065; p = 0.000$). Model 5 reports the results of a fixed effects panel regression with Driscoll-Kraay standard errors (xtscc) (Driscoll and Kraay, 1998; Hoechle, 2007). Driscoll-Kraay standard errors accounts for heteroskedasticity, and both temporal and cross-sectional (i.e., correlations of error terms across panels at a given point of time) dependence. In Model 6, we included two lags of the dependent variable in the model. The effect of HPI remained negative and significant in both Model 5 ($\beta = -0.065; p = 0.015$) and Model 6 ($\beta = -0.059; p = 0.008$). Finally, we used a fixed effects panel regression with autoregressive errors (xtregar, fe) with Baltagi-Wu Locally Best Invariant (LBI) test to assess autocorrelation in the panel data model (Baltagi and Wu, 1999). For the LBI test, values close to 0, 2 and 4 respectively indicate very high autocorrelation, little to no autocorrelation, and very high negative autocorrelation. Our LBI test yielded a value of 1.939, indicating a minimal to no correlation in the residuals. The significant F-statistics for individual effects of the regions (panels) indicate that there are significant differences across these regions, justifying our choice of fixed-effects model. It helps mitigate the bias arising from omitted variables that are constant over time but vary between regions. In Model 7, the effect of HPI on regional exploration was negative and significant ($\beta = -0.076; p = 0.000$). In Model 8, which

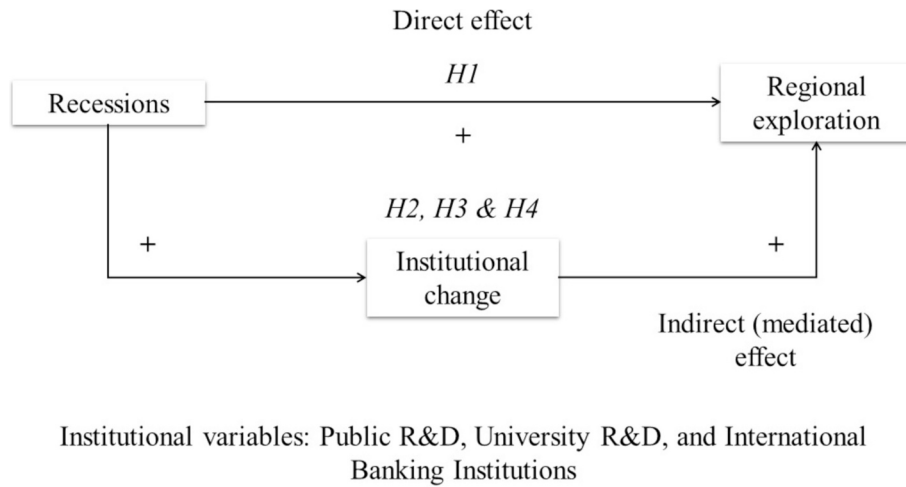


Fig. 3. Hypothesized relationships between recession, regional exploration, and institutional variables.

included two lags of the dependent variable in the model, HPI's effect remained aligned with our previous findings ($\beta = -0.081; p = 0.000$).

We also conducted a series of additional robustness checks to validate our main findings. First, we incorporated rejected patent applications in our sample. Given that the USPTO rejects a substantial number of patent applications but does not publish their data, we performed analyses using a database that included both granted and rejected patent applications (Appendix, Table A1). Second, we employed alternative operationalizations of the independent variable, such as per capita GDP at the MSA level and employment across all sectors at the state level (Appendix, Table A2, Models 1–2). We also used alternative operationalizations of the dependent variable, such as a measure based on a 5-year moving window to identify exploratory patents (A2, Model 3), fractional counts (A2, Model 4), the ratio of exploratory to exploitative patents (A2, Model 5), and winsorized dependent variables (A2, Model 6–7). Third, we controlled for dimensions of the region's technological base and assignee characteristics. To account for the effect of a region's technological base during a recession, we added additional control variables and examined their interactions with the HPI (Appendix, Table A5). Furthermore, we controlled for the concentration of patenting by assignees and the share of patenting by the four largest assignees to ensure that our results were not driven by a few large firms within the MSA (Appendix, Table A6). Our results remained robust across all these analyses.

4.1.3. Robustness analyses: quasi experimental design

To address potential endogeneity, we implemented several measures. In our main analyses, we employed a fixed effect panel regression (MSA-state) and included year fixed effects and USPC technology class dummies to account for unobserved, time-invariant differences that might influence both recession exposure and innovation activities in the region. Additionally, we applied an appropriate lag-structure to address potential simultaneity and reverse causality¹¹.

To further mitigate concerns about endogeneity from unobserved time-varying regional variables that might simultaneously affect a region's exposure to recessions and innovation activities, we also adopted a quasi-experimental design (Li and Branstetter, 2024; Pfister et al., 2021). This design estimates the effect of a treatment by comparing outcomes before and after the treatment, between treatment and control groups. To implement this design, we defined a *recession timeframe*

corresponding to the Financial Crisis and Great Recession (Christiano et al., 2015)¹². Following the lag-structure in the previous analyses ($t - 2$), we created a dummy variable (*recession timeframe* = 1) for the years 2010–15. We created a binary treatment variable *hit* by identifying regions severely affected by the Crisis compared to those less affected. We did so by computing the percentage decline in the HPI in each region between 2007, when the national average HPI was at its peak before the Financial Crisis, and 2011, when the average HPI was at its lowest post-Crisis. We coded the regions with a percentage decline in HPI greater than the median value in our sample as *hit* = 1, whereas we coded the remaining regions as *hit* = 0. Subsequently, we matched MSAs in the treatment (*hit* = 1) and the control (*hit* = 0) groups by population (decile), size of patent portfolio (decile), number of exploratory patents in the year preceding the Financial Crisis (decile), and state (same) [#Matching criteria 1], using coarsened exact matching (Blackwell et al., 2009)¹³. The unmatched MSAs were excluded from the analysis. We then compared regional exploration between the treatment (*hit* = 1) and the control (*hit* = 0) groups during the *recession timeframe*. We estimated the following equation:

$$\text{Regional exploration}_{i,t+1} = \beta_0 + \beta_1 \cdot \text{Hit} + \beta_2 \cdot \text{Recession timeframe}_{t-2} + \beta_3 \cdot (\text{Hit} \cdot \text{Recession timeframe}_{t-2}) + \alpha Z_t + \varepsilon_{t+1} \quad (11)$$

Table 5 presents the results of our analysis. Consistent with previous research indicating a decline in exploratory innovation over time (Arora et al., 2018; Manso et al., 2023), Model 1 reveals that regional exploration decreased during *recession timeframe* ($\beta = -0.516; p = 0.000$). Fig. 1 also illustrates this trend. The *hit* variable was omitted as it is time-invariant and hence collinear with MSA fixed effects. In Model 2, the interaction term between *recession timeframe* and *hit* had a positive and significant effect on regional exploration ($\beta = 0.221; p = 0.000$), indicating that MSAs severely struck by the recession experience a smaller decline in regional exploration in this timeframe compared to those not so severely struck. Fig. 4 illustrates that the difference in regional exploration between treatment (*hit* = 1) and control (*hit* = 0) MSAs remained fairly stable before the *recession timeframe* but narrowed

¹¹ We also tested for reverse causality by regressing regional exploration on HPI with lag structures of ($t + 1$), ($t + 2$), ($t + 3$), ($t + 4$), and ($t + 5$). The effect was non-significant in all analyses (Appendix, Section 9, Table A9), suggesting that the reverse-causality is not a concern within our sample period.

¹² In our dataset, HPI began declining in 2008 and only started a slow positive growth in 2012. Similarly, the US real GDP shrank to 0.1 % in 2008 and only returned to pre-crisis level in 2012, with many macroeconomic variables not recovering until 2013 (Christiano et al., 2015). Accordingly, the 2010–15 timeframe adequately captures the financial crisis and recession in the period 2008–13.

¹³ We used the *cem* command in STATA, using the option *k2k*.

Table 4
Effects of recession on regional exploration.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
	DV: Regional exploration							
Variables	FE Panel regression (xtreg)		Newey-West SE (newey, lag(2))		FE panel regression with Driscoll-Kraay SE (xtscc)		FE panel regression with autoregressive errors (xtregar, fe)	
Housing Price Index		−0.065*** (0.012)	−0.059*** (0.012)	−0.065*** (0.012)	−0.065* (0.023)	−0.059** (0.019)	−0.076*** (0.017)	−0.081*** (0.019)
L1.regional exploration			0.109*** (0.017)			0.109 (0.076)		−0.246*** (0.018)
L2.regional exploration			0.120*** (0.016)			0.120† (0.065)		0.024 (0.017)
Network size (log)	−0.388*** (0.061)	−0.368*** (0.061)	−0.308*** (0.060)	−0.368*** (0.084)	−0.368** (0.093)	−0.308** (0.083)	−0.188** (0.064)	−0.141* (0.063)
Outward orientation	−0.001 (0.008)	0.000 (0.008)	0.003 (0.008)	0.000 (0.009)	0.000 (0.007)	0.003 (0.007)	0.006 (0.008)	0.004 (0.008)
Technological specialization	−0.139*** (0.011)	−0.134*** (0.011)	−0.091*** (0.012)	−0.134*** (0.020)	−0.134** (0.032)	−0.091† (0.047)	−0.059*** (0.012)	−0.068*** (0.012)
Hierarchy in region's innovation network	−0.038** (0.014)	−0.038** (0.014)	−0.032* (0.014)	−0.038† (0.020)	−0.038** (0.012)	−0.032* (0.014)	−0.009 (0.018)	−0.014 (0.018)
Size of region's high-tech sector (log)	0.074** (0.027)	0.073** (0.026)	0.069** (0.026)	0.073** (0.025)	0.073** (0.023)	0.069** (0.020)	0.065* (0.032)	0.050 (0.031)
Quality of HC in region's high-tech sector	0.077*** (0.019)	0.087*** (0.019)	0.077*** (0.019)	0.087*** (0.020)	0.087* (0.031)	0.077** (0.022)	0.060** (0.022)	0.048* (0.022)
MSA-state FE	YES	YES	YES	YES	YES	YES	YES	YES
Application Year FE	YES	YES	YES	YES	YES	YES	YES	YES
USPC Main class specialization FE	YES	YES	YES	YES	YES	YES	YES	YES
Constant	0.091** (0.033)	0.022 (0.036)	0.017 (0.035)	1.023* (0.465)	−0.392*** (0.084)	0.017 (0.034)	−0.820*** (0.131)	−1.031*** (0.100)
Observations	5214	5214	5213	5214	5214	5213	4780	4779
R-squared	0.408	0.411	0.418		0.411	0.423	0.011	0.017
Number of MSA-state	434	434	434	434	434	434	431	431

Standard errors in parentheses.

*** $p < 0.001$

** $p < 0.01$

* $p < 0.05$

† $p < 0.1$

significantly during it, suggesting that the observed trends are not merely time trends. Regions more severely affected by the crisis managed to narrow the gap in regional exploration compared to those less affected by the recession.

Using a similar approach, we categorized regions based on their pre-crisis exposure to housing mortgages before the Financial Crisis. We assigned a *high mortgage* treatment variable the value of 1 to MSAs above the median mortgage exposure. Since the Financial Crisis was driven by mortgage defaults, regions with higher mortgage exposure were more likely to experience severe effects. We estimated the following equation using the matched observations:

$$\text{Regional exploration}_{i,t+1} = \beta_0 + \beta_1 \cdot \text{Highmortgage} + \beta_2 \cdot \text{Recession timeframe}_{t-2} + \beta_3 \cdot (\text{Highmortgage} \cdot \text{Recession timeframe}_{t-2}) + \alpha Z_t + \varepsilon_{t+1} \quad (12)$$

Results (Table 5, Model 3) confirm that regions with high mortgage exposure (*high mortgage* = 1) exhibited more exploration than those with low mortgage exposure (*high mortgage* = 0) in the *ecession timeframe* ($\beta = 0.111; p = 0.042$).

To further validate the findings, we re-ran the analyses with different matching criteria, based on the size of high-tech sector (decile), quality of human capital (decile), and level of technological specialization (decile) [#Matching criteria 2]. Table 5 (Model 4) indicates that MSAs severely struck by the crisis (*hit* = 1) engaged in more exploration than those less affected (*hit* = 0) ($\beta = 0.075; p = 0.012$). Similarly, Model 5 confirms that MSAs with high mortgage exposure (*high mortgage* = 1) engaged in more regional exploration than those with low mortgage

exposure (*high mortgage* = 0) ($\beta = 0.112; p = 0.000$).

We then conducted additional analyses using the continuous version of the independent variable (HPI), restricting the sample to the matched observations. The effect of the HPI was negative and significant both in Model 1 ($\beta = -0.127; p = 0.002$) using #Matching criteria 1 and in Model 2 ($\beta = -0.034; p = 0.014$) using #Matching criteria 2. The results are presented in Appendix (Table A3).

4.2. The role of institutions: Partial mediation results

In this section, we present the results related to the test of H2, H3 and H4 as outlined in section 2.2. Table 6 examines the partial mediation by

public R&D spending. As expected, Model 1 shows that HPI was associated with a decrease in public R&D spending ($\beta = -0.091; p = 0.000$). However, Model 2 reveals that the effect of public R&D spending on regional exploration was not significant ($\beta = 0.017; p = 0.434$), indicating no mediation effect by public R&D spending. In Model 3, even when we controlled for public R&D spending ($\beta = -0.002; p = 0.933$), the direct effect of HPI on exploration remained unchanged ($\beta = -0.065; p = 0.000$). Table 7 presents the result of the Sobel-Goodman Test, which confirms the absence of a significant mediation effect of public R&D spending ($\beta = 0.000; p = 0.933$).

In Table 8, we tested the partial mediation by university R&D spending. Model 1 indicates that HPI was not significantly associated

Table 5

Quasi-experimental design: effects of recession on regional exploration.

	Model 1	Model 2	Model 3	Model 4	Model 5
	Dichotomous IV (quasi-experimental, matched)				
	Regional exploration				
Variables	#Matching criteria 1			#Matching criteria 2	
Recession-timeframe	−0.516*** (0.099)	−0.613*** (0.101)	−0.570*** (0.102)	−0.551*** (0.056)	−0.565*** (0.055)
Recession-timeframe*Hit		0.221*** (0.054)		0.075* (0.030)	
Recession-timeframe*High-mortgage region			0.111* (0.055)		0.112*** (0.029)
Network size (log)	−0.481*** (0.131)	−0.452*** (0.129)	−0.467*** (0.131)	−0.402*** (0.068)	−0.385*** (0.069)
Outward orientation	−0.033† (0.017)	−0.035* (0.017)	−0.034* (0.017)	0.005 (0.009)	0.004 (0.009)
Technological specialization	−0.074*** (0.022)	−0.071*** (0.021)	−0.072*** (0.022)	−0.132*** (0.013)	−0.132*** (0.013)
Hierarchy in region's innovation network	−0.052 (0.032)	−0.048 (0.032)	−0.052 (0.032)	−0.018 (0.016)	−0.020 (0.016)
Size of region's high-tech sector (log)	0.125* (0.054)	0.106* (0.053)	0.126* (0.054)	0.074* (0.029)	0.080** (0.029)
Quality of HC in region's high-tech sector	0.023 (0.050)	0.029 (0.049)	0.028 (0.050)	0.060** (0.023)	0.060** (0.023)
MSA-state FE	YES	YES	YES	YES	YES
Application Year FE	YES	YES	YES	YES	YES
USPC Main class specialization FE	YES	YES	YES	YES	YES
Constant	0.102 (0.072)	0.094 (0.071)	0.104 (0.072)	0.078* (0.036)	0.075* (0.036)
Observations	1111	1111	1111	3996	3996
R-squared	0.600	0.609	0.603	0.439	0.441
Number of MSA-states	112	112	112	424	424

Standard errors in parentheses.

#Matching criteria 1: population (decile), size of patent portfolio (decile), number of exploratory patents in the year preceding Financial Crisis (decile), and (same) state.

#Matching criteria 2: size of the high-tech sector (decile), quality of the human capital (decile), and the level of technological specialization (decile).

*** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$ † $p < 0.1$

with university R&D ($\beta = 0.002; p = 0.835$). Model 2 shows that university R&D was positively associated with regional exploration ($\beta = 0.132; p = 0.000$). The absence of a significant first leg of the 'causal link' also precludes a mediation effect in this case. In Model 3, when we controlled for university R&D spending ($\beta = 0.132; p = 0.000$), the effect of HPI on regional exploration equation remained unchanged ($\beta = -0.065; p = 0.000$). The Sobel-Goodman test, reported in Table 9, confirms the non-significant mediation effect of university R&D spending ($\beta = 0.000; p = 0.835$)¹⁴.

Table 10 examines whether the predominance of international banks partially mediated the effect of the recession on regional exploration. In Model 1, the HPI was negatively and significantly related to the predominance of international banks ($\beta = -0.220; p = 0.000$). Model 2 shows that the predominance of international banks within an MSA was positively associated with regional exploration ($\beta = 0.045; p = 0.000$). In Model 3, when controlling for the predominance international banks ($\beta = 0.034; p = 0.000$), the effect of the HPI on regional exploration decreased ($\beta = -0.057; p = 0.000$). Table 11 presents the results of the Sobel-Goodman Test, which indicates a statistically significant mediation effect of HPI on regional exploration through changes in the predominance of international banks ($\beta = -0.007; p = 0.004$). The test result suggests that 11.5 % of the total effect of HPI on regional

exploration was mediated through this institutional mechanism.

5. Discussion and conclusions

5.1. Discussion and contributions to theory

Building upon Schumpeterian and post-Schumpeterian research, this study explores how recessions shape the nature of innovation at the regional level (Freeman and Perez, 1988; Mensch, 1978; Schumpeter, 1939). Our findings indicate that recessions foster exploration, leading to innovations that extend beyond a region's existing technological knowledge base. These results align with prior research at the firm and industry levels (Archibugi et al., 2013; Field, 2003; Kopytov et al., 2018; Laperche et al., 2011; Manso et al., 2023; Mensch, 1978; Schumpeter, 1939), offering insights into technology search during recessions at the regional level.

These findings suggest that recessions modify actors' incentives and opportunity structures for innovation. High uncertainty during these periods encourages the development of growth options in emerging technologies (Bloom, 2014), while the reduced returns from exploitative innovation due to weakened demand lower the opportunity cost of exploration (Aghion et al., 2012; Aghion and Saint-Paul, 1998; Laperche et al., 2011; Manso et al., 2023). These dynamics drive regions towards exploration during recessions, even when access to risk capital is limited (Menzel et al., 2017).

By examining the link between business cycles and new technological path creation, our findings also contribute to evolutionary economic geography. We highlight that recessions can act as catalysts, pushing

¹⁴ In additional analyses (Appendix, Table A4), we used University Patents as an alternative measure of University R&D spending. The results confirm that university research does not mediate the effect of recessions on regional exploration.

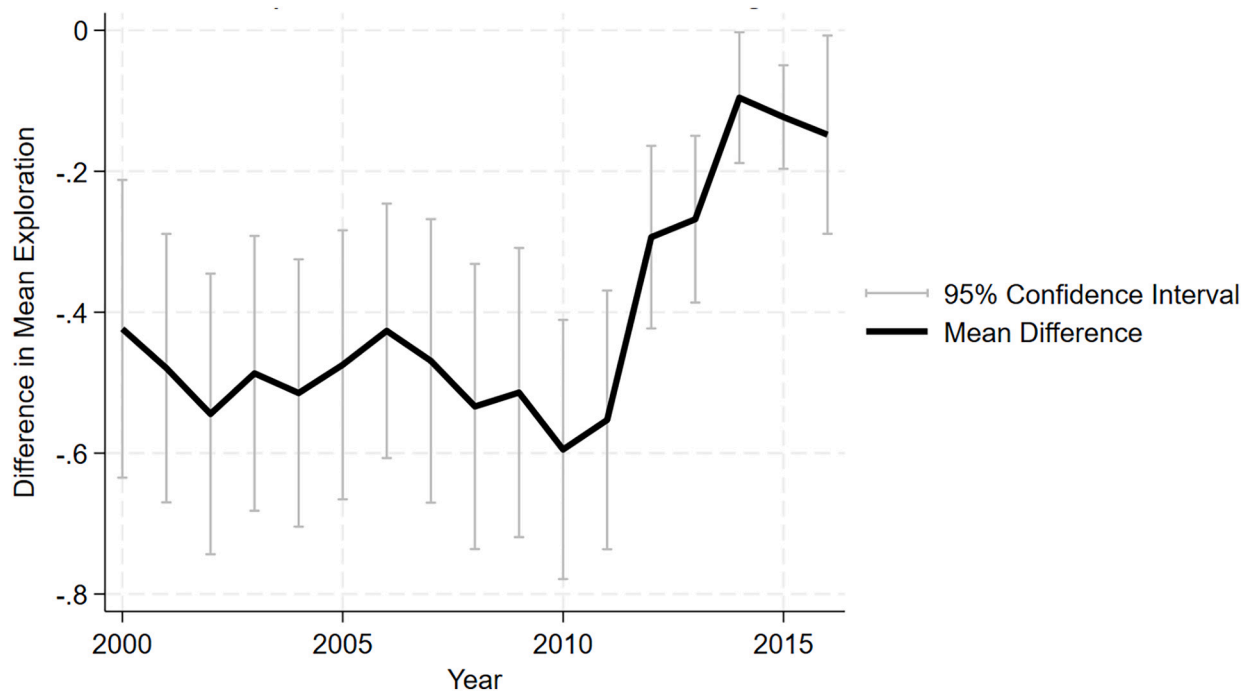


Fig. 4. Difference in exploration trends between 'Hit' and 'non-Hit' regions

Note: The recession time-frame is 2010–15 (instead of 2008–13) due to 2-year lag-structure between housing price index (HPI) and innovation.

Matching criteria: population (decile), size of patent portfolio (decile), number of exploratory patents in the year preceding Financial Crisis (decile), and (same) state.

Table 6
Partial mediation by public R&D.

	Model 1	Model 2	Model 3
	FE Panel Regression		
Variables	Public R&D	Regional exploration	Regional exploration
Housing Price Index	−0.091*** (0.008)		−0.065*** (0.012)
Public R&D spending		0.017 (0.022)	−0.002 (0.022)
Network size (log)	0.138*** (0.041)	−0.388*** (0.061)	−0.366*** (0.061)
Outward orientation	0.005 (0.006)	−0.001 (0.008)	0.000 (0.008)
Technological specialization	−0.016* (0.007)	−0.139*** (0.011)	−0.134*** (0.011)
Hierarchy in region's innovation network	0.003 (0.010)	−0.039** (0.014)	−0.039** (0.014)
Size of region's high-tech sector (log)	−0.104*** (0.018)	0.076** (0.027)	0.073** (0.027)
Quality of HC in region's high-tech sector	0.068*** (0.013)	0.076*** (0.019)	0.087*** (0.019)
MSA-state FE	YES	YES	YES
Application Year FE	YES	YES	YES
USPC Main class specialization FE	YES	YES	YES
Constant	−0.278*** (0.024)	0.093** (0.034)	0.021 (0.036)
Observations	5211	5211	5211
R-squared	0.265	0.408	0.411
Number of MSA-states	434	434	434

Standard errors in parentheses.

*** $p < 0.001$

** $p < 0.01$

* $p < 0.05$

† $p < 0.1$

Table 7
Indirect effect mediated by public R&D (Sobel-Goodman Test).

	Coefficient	Std. error	Z	P > Z
Indirect effect	0.000	0.002	0.085	0.933
Direct effect	−0.065	0.012	−5.255	0.000
Total effect	−0.065	0.012	−5.314	0.000

Proportion of total effect that is mediated: −0.003.

Ratio of indirect to direct effect: −0.003.

regions to forge new technological paths, fostering specialization in nascent technologies, enhancing adaptability, and sustained economic growth (Martin and Sunley, 2006; Tanner, 2016; Zhu et al., 2017). These new trajectories, in turn, may also strengthen a region's resilience over the long term (Boschma, 2015; Martin and Sunley, 2015).

A distinctive aspect of our research is the examination of the role institutions play in catalyzing regional exploration during recessions (Brautzsch et al., 2015; Freeman and Perez, 1988; Freeman and Soete, 1997). Interestingly, the empirical evidence underscores the role of economic entities, particularly international banks, over traditional institutions like universities or PRIs in bolstering exploration during recessions. This observation enriches the ongoing debate on the relative merits of public versus private funding in post-crisis resurgence (Brautzsch et al., 2015; Martin, 2012; Nanda and Nicholas, 2014). While scholars have argued that banking development fosters regional innovation and economic growth (Menzel et al., 2017; Nanda and Nicholas, 2014), it seems counterintuitive that banks, which triggered the Financial Crisis, also contributed to an increase in exploration within regions. What we observe is a structural change in the regional banking structure, wherein small local players, specialized in mortgages and consumer lending, or overly exposed national credit players, are forced to close branches while the surviving international players consolidate and increase their operation across the US. Given international banks' ability to assess and diversify risks, and their propensity for risk-taking, such consolidation boosted regional exploration (Aliber, 1984; Amore et al., 2013; Bermpei et al., 2019; Chava et al., 2013; Chen et al., 2017;

Table 8
Partial mediation by university R&D.

	Model 1	Model 2	Model 3
	FE Panel Regression		
Variables	University R&D	Regional exploration	Regional exploration
Housing Price Index	0.002 (0.009)		−0.065*** (0.012)
University R&D		0.132*** (0.021)	0.132*** (0.021)
Network size (log)	0.077† (0.043)	−0.398*** (0.061)	−0.379*** (0.060)
Outward orientation	−0.006 (0.006)	−0.000 (0.008)	0.001 (0.008)
Technological specialization	−0.039*** (0.008)	−0.134*** (0.011)	−0.129*** (0.011)
Hierarchy in region's innovation network	−0.009 (0.010)	−0.037* (0.014)	−0.037* (0.014)
Size of region's high-tech sector (log)	0.065*** (0.019)	0.066* (0.026)	0.064* (0.026)
Quality of HC in region's high-tech sector	0.064*** (0.013)	0.069*** (0.019)	0.078*** (0.019)
MSA-state FE	YES	YES	YES
Application Year FE	YES	YES	YES
USPC Main class specialization FE	YES	YES	YES
Constant	−0.101*** (0.025)	0.104** (0.033)	0.036 (0.036)
Observations	5214	5214	5214
R-squared	0.170	0.413	0.417
Number of MSA-states	434	434	434

Standard errors in parentheses.

*** $p < 0.001$

** $p < 0.01$

* $p < 0.05$

† $p < 0.1$

Ge et al., 2022).

5.2. Limitations

A key limitation of this study is our reliance on archival data. For example, we used the number of bank branches in the MSA as a proxy for the predominance of international banks in a region, which may not fully capture their share in R&D financing, especially as online banking can decouple physical presence from financial activities. Nonetheless, evidence that the geographic proximity of firms and entrepreneurs significantly influences banks' financing decisions (Agarwal and Hauswald, 2010; Bellucci et al., 2013; Degryse and Ongena, 2005) and the marginal role of fintech and the limited diffusion of secure internet servers in the US during the observed period lend confidence to our operationalization. Future studies could address this limitation by using more granular data on bank transactions or leveraging technologies that accurately track digital lending patterns, potentially within a more narrowly defined geographic area where such data are available or can be systematically collected.

Table 9
Indirect effect mediated by university R&D (Sobel-Goodman Test).

	Coefficient	Std. error	Z	P > Z
Indirect effect	0.000	0.001	0.208	0.835
Direct effect	−0.065	0.012	−5.353	0.000
Total effect	−0.065	0.012	−5.311	0.000

Proportion of total effect that is mediated: −0.004.

Ratio of indirect to direct effect: −0.004.

Table 10
Partial mediation by predominance of international banks.

	Model 1	Model 2	Model 3
	FE Panel Regression		
Variables	Predominance of international banks	Regional exploration	Regional exploration
Housing Price Index	−0.220*** (0.016)		−0.057*** (0.012)
Predominance of international banks		0.045*** (0.011)	0.034** (0.012)
Network size (log)	0.240** (0.079)	−0.395*** (0.061)	−0.376*** (0.061)
Outward orientation	0.006 (0.011)	−0.001 (0.008)	0.000 (0.008)
Technological specialization	−0.052*** (0.014)	−0.136*** (0.011)	−0.132*** (0.011)
Hierarchy in region's innovation network	−0.017 (0.019)	−0.037** (0.014)	−0.037** (0.014)
Size of region's high-tech sector (log)	−0.181*** (0.034)	0.082** (0.027)	0.079** (0.026)
Quality of HC in region's high-tech sector	0.080** (0.025)	0.075*** (0.019)	0.084*** (0.019)
MSA-state FE	YES	YES	YES
Application Year FE	YES	YES	YES
USPC Main class specialization FE	YES	YES	YES
Constant	−0.720*** (0.046)	0.113*** (0.034)	0.047 (0.037)
Observations	5214	5214	5214
R-squared	0.370	0.410	0.413
Number of MSA-states	434	434	434

Standard errors in parentheses.

*** $p < 0.001$

** $p < 0.01$

* $p < 0.05$

† $p < 0.1$

Our sole reliance on granted patents to capture innovation is another important limitation. We lack data about innovations that were never patented or whose patent applications were rejected. Consequently, our data may not fully reflect the totality of innovation activities in the region, potentially underestimating the true scope of technological exploration (Arundel, 2001; Arundel and Kabla, 1998). This is a common challenge in patent-based studies. Scholars have also used alternative data-sources, such as community innovation surveys (Archibugi et al., 2013; Armand and Mendi, 2018), banking data (Aghion et al., 2012) and firms' financial reports (Amore, 2015) to measure innovation. However, these data are collected at the firm level and cannot be scaled to the regional level. Additionally, survey data can be subject to non-responder bias and are only as representative as their sampling criteria allow, whereas using firms' financial reports would omit smaller or privately-held firms. Future research could overcome these limitations through in-depth case studies of specific regions (e.g., Dawley, 2014; Menzel et al., 2017; Youtie and Shapira, 2008), which may

Table 11
Indirect effect mediated by predominance of international banks (Sobel-Goodman Test).

	Coefficient	Std. error	Z	P > Z
Indirect effect	−0.007	0.002	−2.849	0.004
Direct effect	−0.057	0.012	−4.604	0.000
Total effect	−0.065	0.012	−5.311	0.000

Proportion of total effect that is mediated: 0.115.

Ratio of indirect to direct effect: 0.130.

provide a more nuanced understanding of how recessions impact regional innovation.

Another limitation of our study is its focus on a specific recession triggered by the Financial Crisis. While this globally significant event offered valuable insights, it may not fully represent the dynamics of all recessions. Different recessions may have distinct origins and may influence regional exploration in varying ways. Since the Financial Crisis originated in the banking sector, it may have uniquely influenced the regional banking landscape. This potentially limits the generalizability of our findings to other recessions. Future research should explore the effects of multiple recessionary periods to gain a broader understanding of their impact on regional exploration, similar to what [Manso et al. \(2023\)](#) have examined at the firm level. Additionally, future research should explore how different dimensions of recessions, particularly demand shocks and financial constraints, affect regional innovation and exploration.

Caution is advised when interpreting our results due to potential sources of endogeneity. While research indicates that the Financial Crisis was exogenous to regional innovation ([Sanders, 2008](#)), the observed patterns may not solely reflect the direct impacts of recessions on regional exploration. To address potential time-invariant omitted factors, we employed region, technology and year fixed effects and included controls for the most important drivers of exploration. We also used models that give less biased estimates under cross-sectional and temporal autocorrelation and potential endogeneity. Moreover, our quasi-experimental design helped us better establish a connection between recession and exploration. Despite these efforts, the observed patterns and associations might be shaped not just by the direct impact of recessions on regional exploration but also by other latent time varying factors, such as strategic leadership and corporate interventions. Future research should continue to refine these approaches, focusing on exogenous shocks, such as natural disasters or pandemics, leading to recessions.

5.3. Policy implications

Recessions are typically viewed as negative events with significant human costs. However, our study underlines their potential positive impact on exploration and long-term regional development ([Field, 2003](#); [Kopytov et al., 2018](#); [Laperche et al., 2011](#); [Manso et al., 2023](#); [Mensch, 1978](#)). National and local policymakers could benefit from viewing recessions as opportunities to foster innovation, rather than merely as short-term economic crises. Strategic resource allocation during recessions can pave the way for new technological trajectories within regions, promoting sustained economic growth. For instance, following the Financial Crisis (2008), policy initiatives in Louisville, Kentucky, focused on promoting local entrepreneurship and strengthening sectors like healthcare and agritech. Similarly, Detroit, Michigan, used the crisis to tackle structural challenges, rejuvenating its downtown, attracting tech firms and diversifying its economy. However, policymakers must carefully tailor strategies to their specific regional contexts and economic conditions.

As recessions resolve technological stalemates and accelerate economic transitions to new technologies ([Field, 2003](#); [Kopytov et al., 2018](#); [Mensch, 1978](#)), understanding which actors engage in exploration and shape new regional trajectories is crucial for policy development. The limited role of institutional actors like universities or PRIs in driving regional exploration during recessions suggests a need for policymakers to reassess their investment strategies. These institutions often adhere to traditional funding metrics that may not promote the level of risk-taking required for exploration. To foster new technological trajectories, resource allocation criteria should be adjusted to support high-risk high-return projects. The goal should be to promote the development of new technologies by combining knowledge from different domains. In the aftermath of the 2008 Financial Crisis, several states funneled federal stimulus funds and R&D into “shovel-ready” infrastructure projects and

mature industries. While these projects undeniably created immediate jobs, many simply reinforced existing technological trajectories, with limited long-term impact. Policymakers should allocate resources only after carefully evaluating the potential risks and returns of both exploration and exploitation, rather than defaulting to investments in established technologies and actors.

As international banks tend to support regional exploration more effectively, one policy implication could be to consider liberalizing the banking sector and allowing for the predominance of such institutions. However, it is important to acknowledge that the financial behavior of many of these banks contributed to the 2007–08 Financial Crisis. Therefore, policy measures should aim to foster environments that support both local and international financial institutions with high integrity. At the same time, it is crucial to take judicious actions against less principled financial actors, whether local or international.

Ultimately, while our findings suggest the need for thoughtful policy responses to recessions that leverage opportunities for exploration, they also call for a cautious and context-sensitive approach. The long-term effects of such policies and the responses of institutional actors should be weighed against potential risks and immediate economic needs.

CRediT authorship contribution statement

Amit Kumar: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Elisa Operti:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Elisa Operti reports financial support was provided by French National Research Agency. Elisa Operti reports financial support was provided by CY Alliance. None. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.respol.2025.105189>.

Data availability

Data will be made available on request.

References

- Abramovsky, L., Simpson, H., 2011. Geographic proximity and firm-university innovation linkages: evidence from Great Britain. *J. Econ. Geogr.* 11, 949–977. <https://doi.org/10.1093/jeg/lbq052>.
- Adelino, M., Schoar, A., Severino, F., 2015. House prices, collateral, and self-employment. *J. Financ. Econ.* 117, 288–306.
- Agarwal, S., Hauswald, R., 2010. Distance and private information in lending. *Rev. Financ. Stud.* 23, 2757–2788. <https://doi.org/10.1093/rfs/hhq001>.

- Aggarwal, V.A., Hsu, D.H., 2014. Entrepreneurial exits and innovation. *Manag. Sci.* 60, 867–887. <https://doi.org/10.1287/mnsc.2013.1801>.
- Aghion, P., Askenazy, P., Berman, N., Cetté, G., Eymard, L., 2012. Credit constraints and the cyclical of R&D investment: evidence from France. *J. Eur. Econ. Assoc.* 10, 1001–1024. <https://doi.org/10.1111/j.1542-4774.2012.01093.x>.
- Aghion, P., Saint-Paul, G., 1998. Virtues of bad times: interaction between productivity growth and economic fluctuations. *Macroecon. Dyn.* 2, 322–344. <https://doi.org/10.1017/S1365100598008025>.
- Aliber, R.Z., 1984. International banking: a survey. *J. Money Credit Bank.* 16, 661–678. <https://doi.org/10.2307/1992100>.
- Amore, M.D., 2015. Companies learning to innovate in recessions. *Res. Policy* 44, 1574–1583. <https://doi.org/10.1016/j.respol.2015.05.006>.
- Amore, M.D., Schneider, C., Zaldokas, A., 2013. Credit supply and corporate innovation. *J. Financ. Econ.* 109, 835–855. <https://doi.org/10.1016/j.jfineco.2013.04.006>.
- Anselin, L., Varga, A., Acs, Z., 1997. Local geographic spillovers between university research and high technology innovations. *J. Urban Econ.* 42, 422–448. <https://doi.org/10.1006/juec.1997.2032>.
- Archibugi, D., Filippetti, A., Frenz, M., 2013. Economic crisis and innovation: is destruction prevailing over accumulation? *Res. Policy* 42, 303–314.
- Arellano, M., Bond, S., 1991. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Rev. Econ. Stud.* 58, 277–297.
- Armand, A., Mendi, P., 2018. Demand drops and innovation investments: evidence from the great recession in Spain. *Res. Policy* 47, 1321–1333. <https://doi.org/10.1016/j.respol.2018.04.015>.
- Arora, A., Belenzon, S., Pataconi, A., 2018. The decline of science in corporate R&D. *Strateg. Manag. J.* 39, 3–32. <https://doi.org/10.1002/smj.2693>.
- Arundel, A., 2001. The relative effectiveness of patents and secrecy for appropriation. *Res. Policy* 30, 611–624. [https://doi.org/10.1016/S0048-7333\(00\)00100-1](https://doi.org/10.1016/S0048-7333(00)00100-1).
- Arundel, A., Kabla, I., 1998. What percentage of innovations are patented? Empirical estimates for European firms. *Res. Policy* 27, 127–141.
- Assimakopoulos, D., Lawton Smith, H., Baines, N., Romeo, S., Tsouri, M., 2021. Oxford and Grenoble: multiple anchors, strong dyadic relationships and national policy in fostering cluster architectures. *Reg. Stud.* 56, 1–15. <https://doi.org/10.1080/00343404.2021.1998416>.
- Baker, S., Mezzetti, C., 2005. Disclosure as a strategy in the patent race. *J. Law Econ.* 48, 173–194. <https://doi.org/10.1086/426879>.
- Baltagi, B.H., Wu, P.X., 1999. Unequally spaced panel data regressions with AR (1) disturbances. *Economic Theory* 15, 814–823. <https://doi.org/10.1017/S0266466699156020>.
- Barbieri, N., Consoli, D., 2019. Regional diversification and green employment in US metropolitan areas. *Res. Policy* 48, 693–705. <https://doi.org/10.1016/j.respol.2018.11.001>.
- Barlevy, G., 2007. On the cyclical of research and development. *Am. Econ. Rev.* 97, 1131–1164. <https://doi.org/10.1257/aer.97.4.1131>.
- Baron, R.M., Kenny, D.A., 1986. The moderator–mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *J. Pers. Soc. Psychol.* 51, 1173–1182. <https://doi.org/10.1037/0022-3514.51.6.1173>.
- Beaudry, P., Galizia, D., Portier, F., 2018. Reconciling Hayek's and Keynes' views of recessions. *Rev. Econ. Stud.* 85, 119–156. <https://doi.org/10.1093/restud/rdx008>.
- Bellucci, A., Borisov, A., Zazzaro, A., 2013. Do banks price discriminate spatially? Evidence from small business lending in local credit markets. *J. Bank. Financ.* 37, 4183–4197. <https://doi.org/10.1016/j.jbankfin.2013.06.009>.
- Bermei, P., Kalyvas, A.N., Neri, L., Russo, A., 2019. Will strangers help you enter? The effect of foreign bank presence on new firm entry. *J. Financ. Serv. Res.* 56, 1–38. <https://doi.org/10.1007/s10693-017-0286-1>.
- Bernstein, S., 2015. Does going public affect innovation? *J. Financ.* 70, 1365–1403. <https://doi.org/10.1111/jofi.12275>.
- Blackwell, M., Iacus, S., King, G., Porro, G., 2009. Cem: coarsened exact matching in Stata. *Stata J.* 9, 524–546. <https://doi.org/10.1177/1536867X0900900402>.
- Bloom, N., 2014. Fluctuations in uncertainty. *J. Econ. Perspect.* 28, 153–176. <https://doi.org/10.1257/jep.28.2.153>.
- Bloom, N., Floetotto, M., Jaimovich, N., Saporta-Eksten, I., Terry, S.J., 2018. Really uncertain business cycles. *Econometrica* 86, 1031–1065. <https://doi.org/10.3982/ECTA10927>.
- Bloom, N., Van Reenen, J., Williams, H., 2019. A toolkit of policies to promote innovation. *J. Econ. Perspect.* 33, 163–184.
- Blundell, R., Bond, S., 2000. GMM estimation with persistent panel data: an application to production functions. *Econ. Rev.* 19, 321–340. <https://doi.org/10.1080/07474930008800475>.
- Boschma, R., 2015. Towards an evolutionary perspective on regional resilience. *Reg. Stud.* 49, 733–751. <https://doi.org/10.1080/00343404.2014.959481>.
- Brautzsch, H.-U., Günther, J., Loose, B., Ludwig, U., Nulsch, N., 2015. Can R&D subsidies counteract the economic crisis?—macroeconomic effects in Germany. *Res. Policy* 44, 623–633.
- Breschi, S., Lenzi, C., 2015. The role of external linkages and gatekeepers for the renewal and expansion of US cities' knowledge base, 1990–2004. *Reg. Stud.* 49, 782–797.
- Bronzini, R., Piselli, P., 2016. The impact of R&D subsidies on firm innovation. *Res. Policy* 45, 442–457. <https://doi.org/10.1016/j.respol.2015.10.008>.
- Buenstorf, G., Heinisch, D.P., 2020. When do firms get ideas from hiring PhDs? *Res. Policy* 49, 103913. <https://doi.org/10.1016/j.respol.2019.103913>.
- Calomiris, C.W., Mason, J.R., 2003. Fundamentals, panics, and bank distress during the depression. *Am. Econ. Rev.* 93, 1615–1647. <https://doi.org/10.1257/00028280322655473>.
- Cappelli, R., Corsino, M., Laursen, K., Torrisi, S., 2023. Technological competition and patent strategy: protecting innovation, preempting rivals and defending the freedom to operate. *Res. Policy* 52, 104785. <https://doi.org/10.1016/j.respol.2023.104785>.
- Castaldi, C., Los, B., 2017. Geographical patterns in US inventive activity 1977–1998: the “regional inversion” was underestimated. *Res. Policy* 46, 1187–1197. <https://doi.org/10.1016/j.respol.2017.04.005>.
- Chava, S., Oettl, A., Subramanian, A., Subramanian, K.V., 2013. Banking deregulation and innovation. *J. Financ. Econ.* 109, 759–774.
- Chen, M., Wu, J., Jeon, B.N., Wang, R., 2017. Do foreign banks take more risk? Evidence from emerging economies. *J. Bank. Financ.* 82, 20–39. <https://doi.org/10.1016/j.jbankfin.2017.05.004>.
- Choudhury, P., Haas, M.R., 2018. Scope versus speed: team diversity, leader experience, and patenting outcomes for firms. *Strateg. Manag. J.* 39, 977–1002. <https://doi.org/10.1002/smj.2753>.
- Christiano, L.J., Eichenbaum, M.S., Trabandt, M., 2015. Understanding the great recession. *Am. Econ. J. Macroecon.* 7, 110–167. <https://doi.org/10.1257/mac.20140104>.
- Clarke, G.R.G., Cull, R., Martínez Pería, M.S., 2006. Foreign bank participation and access to credit across firms in developing countries. *J. Comp. Econ.* 34, 774–795. <https://doi.org/10.1016/j.jce.2006.08.001>.
- Clayton, P., Lanahan, L., Nelson, A., 2022. Dissecting diffusion: tracing the plurality of factors that shape knowledge diffusion. *Res. Policy* 51, 104389. <https://doi.org/10.1016/j.respol.2021.104389>.
- Coffano, M., Foray, D., Pezzoni, M., 2017. Does inventor centrality foster regional innovation? The case of the Swiss medical devices sector. *Reg. Stud.* 51, 1206–1218.
- Cohen, J., Cohen, P., West, S.G., Aiken, L.S., 2013. *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*. Routledge.
- Cole, R.A., White, L.J., 2012. Déjà vu all over again: the causes of U.S. commercial bank failures this time around. *J. Financ. Serv. Res.* 42, 5–29. <https://doi.org/10.1007/s10693-011-0116-9>.
- Cooke, P., Uranga, M.G., Etxebarria, G., 1998. Regional systems of innovation: an evolutionary perspective. *Environ. Plan. A* 30, 1563–1584.
- Cornaggia, J., Mao, Y., Tian, X., Wolfe, B., 2015. Does banking competition affect innovation? *J. Financ. Econ.* 115, 189–209. <https://doi.org/10.1016/j.jfineco.2014.09.001>.
- Cowan, R., Zinovyeva, N., 2013. University effects on regional innovation. *Res. Policy* 42, 788–800. <https://doi.org/10.1016/j.respol.2012.10.001>.
- Cummings, J.N., Kiesler, S., 2007. Coordination costs and project outcomes in multi-university collaborations. *Res. Policy* 36, 1620–1634. <https://doi.org/10.1016/j.respol.2007.09.001>.
- Cyert, R.M., March, J.G., 1963. *A behavioral theory of the firm*. Englewood Cliffs, NJ 2, 169–187.
- Dawley, S., 2014. Creating new paths? Offshore wind, policy activism, and peripheral region development. *Econ. Geogr.* 90, 91–112. <https://doi.org/10.1111/ecge.12028>.
- Degryse, H., Ongena, S., 2005. Distance, lending relationships, and competition. *J. Financ.* 60, 231–266. <https://doi.org/10.1111/j.1540-6261.2005.00729.x>.
- Døjbak Håkonsen, D., Eskildsen, J.K., Argote, L., Mønster, D., Burton, R.M., Obel, B., 2016. Exploration versus exploitation: emotions and performance as antecedents and consequences of team decisions. *Strateg. Manag. J.* 37, 985–1001. <https://doi.org/10.1002/smj.2380>.
- Driscoll, J.C., Kraay, A.C., 1998. Consistent covariance matrix estimation with spatially dependent panel data. *Rev. Econ. Stat.* 80, 549–560. <https://doi.org/10.1162/003465398557825>.
- Fabrizio, K.R., Tsolmon, U., 2014. An empirical examination of the procyclicality of R&D investment and innovation. *Rev. Econ. Stat.* 96, 662–675.
- Feldman, M., 2003. The locational dynamics of the US biotech industry: knowledge externalities and the anchor hypothesis. *Ind. Innov.* 10, 311–329. <https://doi.org/10.1080/1366271032000141661>.
- Feldman, M., 2018. Geography of innovation. In: Augier, M., Teece, D.J. (Eds.), *The Palgrave Encyclopedia of Strategic Management*. Palgrave Macmillan, London, pp. 625–630. https://doi.org/10.1057/978-1-137-00772-8_537.
- Ferreira, D., Manso, G., Silva, A.C., 2014. Incentives to innovate and the decision to go public or private. *Rev. Financ. Stud.* 27, 256–300.
- Field, A.J., 2003. The most technologically progressive decade of the century. *Am. Econ. Rev.* 93, 1399–1413. <https://doi.org/10.1257/000282803769206377>.
- Filippetti, A., Archibugi, D., 2011. Innovation in times of crisis: National Systems of innovation, structure, and demand. *Res. Policy* 40, 179–192. <https://doi.org/10.1016/j.respol.2010.09.001>.
- Fleming, L., 2001. Recombinant uncertainty in technological search. *Manag. Sci.* 47, 117–132.
- Fleming, L., King III, C., Juda, A.I., 2007. Small worlds and regional innovation. *Organ. Sci.* 18, 938–954.
- Freeman, C., Soete, L., 1997. *The Economics of Industrial Innovation*. Psychology Press.
- Freeman, Christopher, Perez, C., 1988. Structural crises of adjustment, business cycles and investment behaviour. In: Freeman, Chris, Perez, C. (Eds.), *Technical Change and Economic Theory*. Pinter, Londres.
- Fritsch, M., Slavtchev, V., 2010. How does industry specialization affect the efficiency of regional innovation systems? *Ann. Reg. Sci.* 45, 87–108. <https://doi.org/10.1007/s00168-009-0292-9>.
- Fusillo, F., Consoli, D., Quatraro, F., 2022. Resilience, skill endowment, and diversity: Evidence from US metropolitan areas. *Econ. Geogr.* 98, 170–196. <https://doi.org/10.1080/0010030095.2021.2008797>.
- Gallo, J.L., Plunket, A., 2020. Regional gatekeepers, inventor networks and inventive performance: spatial and organizational channels. *Res. Policy* 49, 103981. <https://doi.org/10.1016/j.respol.2020.103981>.

- Gao, H., Hsu, P.-H., Li, K., 2018. Innovation strategy of private firms. *J. Financ. Quant. Anal.* 53, 1–32. <https://doi.org/10.1017/S0022109017001119>.
- Ge, W., Kim, J.-B., Li, T., Zhang, J., 2022. Subsidiary operations in offshore financial centers and bank risk-taking: international evidence. *J. Int. Bus. Stud.* 53, 268–301. <https://doi.org/10.1057/s41267-021-00485-4>.
- Gertler, M., Gilchrist, S., 2018. What happened: financial factors in the great recession. *J. Econ. Perspect.* 32, 3–30. <https://doi.org/10.1257/jep.32.3.3>.
- Giannetti, M., Ongena, S., 2009. Financial integration and firm performance: evidence from foreign bank entry in emerging markets. *Review of Finance* 13, 181–223. <https://doi.org/10.1093/rof/rfm019>.
- Goetz, M.R., Laeven, L., Levine, R., 2016. Does the geographic expansion of banks reduce risk? *J. Financ. Econ.* 120, 346–362.
- Goldfarb, B., Henrekson, M., 2003. Bottom-up versus top-down policies towards the commercialization of university intellectual property. *Res. Policy* 32, 639–658. [https://doi.org/10.1016/S0048-7333\(02\)00034-3](https://doi.org/10.1016/S0048-7333(02)00034-3).
- Gong, H., Binz, C., Hassink, R., Trippel, M., 2022. Emerging industries: institutions, legitimacy and system-level agency. *Reg. Stud.* 56, 523–535. <https://doi.org/10.1080/00343404.2022.2033199>.
- Gopal, M., Schnabl, P., 2022. The rise of finance companies and FinTech lenders in small business lending. *Rev. Financ. Stud.* 35, 4859–4901. <https://doi.org/10.1093/rfs/hhac034>.
- Graf, H., Henning, T., 2009. Public research in regional networks of innovators: a comparative study of four east German regions. *Reg. Stud.* 43, 1349–1368. <https://doi.org/10.1080/00343400802251460>.
- Greve, H.R., 2003. A behavioral theory of R&D expenditures and innovations: evidence from shipbuilding. *AMJ* 46, 685–702. <https://doi.org/10.5465/30040661>.
- Helfat, C.E., Peteraf, M.A., 2003. The dynamic resource-based view: capability lifecycles. *Strateg. Manag. J.* 24, 997–1010. <https://doi.org/10.1002/smj.332>.
- Herpfer, C., Mjøs, A., Schmidt, C., 2023. The causal impact of distance on bank lending. *Manag. Sci.* 69, 723–740. <https://doi.org/10.1287/mnsc.2022.4346>.
- Hoeckle, D., 2007. Robust standard errors for panel regressions with cross-sectional dependence. *Stata J.* 7, 281–312. <https://doi.org/10.1177/1536867X0700700301>.
- Holmström, B., 1979. Moral hazard and observability. *Bell J. Econ.* 10, 74–91. <https://doi.org/10.2307/3003320>.
- Hu, M.-C., 2011. Evolution of knowledge creation and diffusion: the revisit of Taiwan's Hsinchu Science Park. *Scientometrics* 88, 949–977. <https://doi.org/10.1007/s11192-011-0427-5>.
- Hud, M., Hussinger, K., 2015. The impact of R&D subsidies during the crisis. *Res. Policy* 44, 1844–1855. <https://doi.org/10.1016/j.respol.2015.06.003>.
- Judd, C.M., Kenny, D.A., 1981a. Process analysis: estimating mediation in treatment evaluations. *Eval. Rev.* 5, 602–619. <https://doi.org/10.1177/0193841X8100500502>.
- Judd, C.M., Kenny, D.A., 1981b. *Estimating the Effects of Social Intervention*. Cambridge University Press, New York.
- Keum, D.D., See, K.E., 2017. The influence of hierarchy on idea generation and selection in the innovation process. *Organ. Sci.* 28, 653–669. <https://doi.org/10.1287/orsc.2017.1142>.
- Kopytov, A., Roussanov, N., Taschereau-Dumouchel, M., 2018. Short-run pain, long-run gain? Recessions and technological transformation. *J. Monet. Econ.* 97, 29–44. <https://doi.org/10.1016/j.jmoneco.2018.05.011>.
- Laperche, B., Lefebvre, G., Langlet, D., 2011. Innovation strategies of industrial groups in the global crisis: rationalization and new paths. *Technological Forecasting and Social Change*, Contains Special Section: Economic Hard Times: Impact on Innovation and Innovation Potential 78, 1319–1331. <https://doi.org/10.1016/j.techfore.2011.03.005>.
- Lazer, D., Friedman, A., 2007. The network structure of exploration and exploitation. *Adm. Sci. Q.* 52, 667–694.
- Lee, N., Brown, R., 2017. Innovation, SMEs and the liability of distance: the demand and supply of bank funding in UK peripheral regions. *J. Econ. Geogr.* 17, 233–260. <https://doi.org/10.1093/jeg/lbw011>.
- Lee, N., Sameen, H., Cowling, M., 2015. Access to finance for innovative SMEs since the financial crisis. *Res. Policy* 44, 370–380. <https://doi.org/10.1016/j.respol.2014.09.008>.
- Li, G., Branstetter, L.G., 2024. Does “made in China 2025” work for China? Evidence from Chinese listed firms. *Res. Policy* 53, 105009. <https://doi.org/10.1016/j.respol.2024.105009>.
- Lopez-Vega, H., Tell, F., Vanhaverbeke, W., 2016. Where and how to search? Search paths in open innovation. *Res. Policy* 45, 125–136. <https://doi.org/10.1016/j.respol.2015.08.003>.
- MacKinnon, D.P., Lockwood, C.M., Hoffman, J.M., West, S.G., Sheets, V., 2002. A comparison of methods to test mediation and other intervening variable effects. *Psychol. Methods* 7, 83.
- Makridakis, C.A., McGuire, E., 2023. The quality of innovation “Booms” during “Busts.” *Res. Policy* 52, 104657. <https://doi.org/10.1016/j.respol.2022.104657>.
- Maksimovic, V., Pichler, P., 2001. Technological innovation and initial public offerings. *Rev. Financ. Stud.* 14, 459–494. <https://doi.org/10.1093/rfs/14.2.459>.
- Manso, G., Balsmeier, B., Fleming, L., 2023. Heterogeneous innovation over the business cycle. *Rev. Econ. Stat.* 105, 1224–1236. https://doi.org/10.1162/rest_a_01104.
- Martin, R., 2012. Regional economic resilience, hysteresis and recessionary shocks. *J. Econ. Geogr.* 12, 1–32.
- Martin, R., Sunley, P., 2006. Path dependence and regional economic evolution. *J. Econ. Geogr.* 6, 395–437. <https://doi.org/10.1093/jeg/lbl012>.
- Martin, R., Sunley, P., 2015. On the notion of regional economic resilience: conceptualization and explanation. *J. Econ. Geogr.* 15, 1–42. <https://doi.org/10.1093/jeg/tbu015>.
- Mazzoleni, R., Nelson, R.R., 2007. Public research institutions and economic catch-up. *Res. Policy* 36, 1512–1528. <https://doi.org/10.1016/j.respol.2007.06.007>.
- McCauley, R., McGuire, P., Wooldridge, P., September 2021. Seven decades of international banking. *BIS. Q. Rev.* 61–75. https://www.bis.org/publ/qtrpdf/r_qt2109e.pdf.
- Mensch, G., 1978. *Stalemate in Technology: Innovations Overcome the Depression*. Ballinger Pub Co, Cambridge, Mass.
- Menzel, M.-P., Feldman, M.P., Broekel, T., 2017. Institutional change and network evolution: explorative and exploitative tie formations of co-inventors during the dot-com bubble in the research triangle region. *Reg. Stud.* 51, 1179–1191.
- Mian, A., Sufi, A., 2014. What explains the 2007–2009 drop in employment? *Econometrica* 82, 2197–2223.
- Miller, D.J., Fern, M.J., Cardinal, L.B., 2007. The use of knowledge for technological innovation within diversified firms. *AMJ* 50, 307–325. <https://doi.org/10.5465/amj.2007.24634437>.
- Mulligan, K., Lenihan, H., Doran, J., Roper, S., 2022. Harnessing the science base: results from a national programme using publicly-funded research centres to reshape firms' R&D. *Res. Policy* 51, 104468. <https://doi.org/10.1016/j.respol.2021.104468>.
- Nanda, R., Nicholas, T., 2014. Did bank distress stifle innovation during the great depression? *J. Financ. Econ.* 114, 273–292. <https://doi.org/10.1016/j.jfineco.2014.07.006>.
- Ndofo, H.A., Sirmon, D.G., He, X., 2011. Firm resources, competitive actions and performance: investigating a mediated model with evidence from the in-vitro diagnostics industry. *Strateg. Manag. J.* 32, 640–657. <https://doi.org/10.1002/smj.901>.
- Newey, W.K., West, K.D., 1987. A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica* 55, 703–708. <https://doi.org/10.2307/1913610>.
- Nickell, S., 1981. Biases in dynamic models with fixed effects. *Econometrica* 49, 1417–1426. <https://doi.org/10.2307/1911408>.
- Ning, L., Guo, R., Chen, K., 2022. R&D subsidies, novelty of firm innovation and industrial technological complexity: the knowledge recombinant view. *R&D Manag.* 52, 820–837.
- North, D.C., 1991. Institutions. *J. Econ. Perspect.* 5, 97–112. <https://doi.org/10.1257/jep.5.1.97>.
- Operti, E., Kumar, A., 2023. Too much of a good thing? Network brokerage within and between regions and innovation performance. *Reg. Stud.* 57, 300–316.
- Ouyang, M., 2011. On the cyclical of R&D. *Rev. Econ. Stat.* 93, 542–553. https://doi.org/10.1162/REST_a_00076.
- Paunov, C., 2012. The global crisis and firms' investments in innovation. *Res. Policy* 41, 24–35.
- Perkmann, M., 2006. Extraregional linkages and the territorial embeddedness of multinational branch plants: evidence from the South Tyrol region in Northeast Italy. *Econ. Geogr.* 82, 421–441. <https://doi.org/10.1111/j.1944-8287.2006.tb00324.x>.
- Pfister, C., Koomen, M., Harhoff, D., Backes-Gellner, U., 2021. Regional innovation effects of applied research institutions. *Res. Policy* 50, 104197. <https://doi.org/10.1016/j.respol.2021.104197>.
- Plunkett, A., de Waldemar, F.S., 2022. Regional recombinant novelty, related and unrelated technologies: a patent-level approach. *Reg. Stud.* <https://doi.org/10.1080/00343404.2022.2114595>.
- Rehm, J., 2018. Ten years after the economic crash, R&D funding is better than ever. *Nature*. <https://doi.org/10.1038/d41586-018-06634-4>.
- Rigby, D.L., 2015. Technological relatedness and knowledge space: entry and exit of US cities from patent classes. *Reg. Stud.* 49, 1922–1937. <https://doi.org/10.1080/00343404.2013.854878>.
- Righi, C., Simcoe, T., 2019. Patent examiner specialization. *Res. Policy* 48, 137–148. <https://doi.org/10.1016/j.respol.2018.08.003>.
- Rosenkopf, L., Nerkar, A., 2001. Beyond local search: boundary-spanning, exploration, and impact in the optical disk industry. *Strateg. Manag. J.* 22, 287–306.
- Sanders, A., 2008. The subprime crisis and its role in the financial crisis. *J. Hous. Econ.* 17, 254–261.
- Saxenian, A.L., 1996. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Harvard University Press, Cambridge, MA.
- Schumpeter, J.A., 1939. *Business Cycles*. McGraw-Hill New York.
- Sleuwaegen, L., Boiardi, P., 2014. Creativity and regional innovation: Evidence from EU regions. *Res. Policy* 43, 1508–1522. <https://doi.org/10.1016/j.respol.2014.03.014>.
- Sobel, M.E., 1982. Asymptotic confidence intervals for indirect effects in structural equation models. *Sociol. Methodol.* 13, 290–312. <https://doi.org/10.2307/270723>.
- Stone-Romero, E.F., Rosopa, P.J., 2008. The relative validity of inferences about mediation as a function of research design characteristics. *Organ. Res. Methods* 11, 326–352. <https://doi.org/10.1177/1094428107300342>.
- Tanner, A.N., 2016. The emergence of new technology-based industries: the case of fuel cells and its technological relatedness to regional knowledge bases. *J. Econ. Geogr.* 16, 611–635. <https://doi.org/10.1093/jeg/lbv011>.

- Vallance, P., 2016. Universities, public research, and evolutionary economic geography. *Econ. Geogr.* 92, 355–377. <https://doi.org/10.1080/00130095.2016.1146076>.
- Wang, J., 2018. Innovation and government intervention: a comparison of Singapore and Hong Kong. *Res. Policy* 47, 399–412. <https://doi.org/10.1016/j.respol.2017.12.008>.
- Wilson, D.J., 2009. Beggar thy neighbor? The in-state, out-of-state, and aggregate effects of R&D tax credits. *Rev. Econ. Stat.* 91, 431–436. <https://doi.org/10.1162/rest.91.2.431>.
- Wirsich, A., Kock, A., Strumann, C., Schultz, C., 2016. Effects of university-industry collaboration on technological newness of firms. *J. Prod. Innov. Manag.* 33, 708–725. <https://doi.org/10.1111/jpim.12342>.
- Wood, R.E., Goodman, J.S., Beckmann, N., Cook, A., 2008. Mediation testing in management research. *Organ. Res. Methods* 11, 270–295. <https://doi.org/10.1177/1094428106297811>.
- Yang, C.-H., Huang, C.-H., Hou, T.C.-T., 2012. Tax incentives and R&D activity: firm-level evidence from Taiwan. *Res. Policy* 41, 1578–1588. <https://doi.org/10.1016/j.respol.2012.04.006>.
- Yang, C.-H., Motohashi, K., Chen, J.-R., 2009. Are new technology-based firms located on science parks really more innovative?: evidence from Taiwan. *Res. Policy* 38, 77–85. <https://doi.org/10.1016/j.respol.2008.09.001>.
- Yap, E.-L., 2009. *Economics and the Sciences: Effects of the Recession*. Yale Scientific.
- Youtie, J., Shapira, P., 2008. Building an innovation hub: a case study of the transformation of university roles in regional technological and economic development. *Res. Policy* 37, 1188–1204. <https://doi.org/10.1016/j.respol.2008.04.012>.
- Zhao, T., Jones-Evans, D., 2017. SMEs, banks and the spatial differentiation of access to finance. *J. Econ. Geogr.* 17, 791–824. <https://doi.org/10.1093/jeg/lbw029>.
- Zhu, S., He, C., Zhou, Y., 2017. How to jump further and catch up? Path-breaking in an uneven industry space. *J. Econ. Geogr.* 17, 521–545. <https://doi.org/10.1093/jeg/lbw047>.