

Political, economic and research disintegration: The impact of geopolitical uncertainty on cross-border R&D collaborations and innovation

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Political, economic and research disintegration: The impact of geopolitical uncertainty on cross-border R&D collaborations and innovation

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Abstract

Uncertainty regarding the policy environment could be particularly detrimental to innovation, as it requires high-risk investment and long-term commitments with scientists and research partners. This paper focuses on the effects of geopolitical uncertainty on cross-border R&D collaborations and patenting activity, exploiting the UK's exit from the EU as a quasi-natural experiment in a difference-in-differences (DiD) analysis. Our results reveal a significant disruption to the cross-border research collaborations of UK organisations after the Brexit referendum, as EU-based inventors were replaced by UK-based ones. Overall, this disruption has negatively affected the innovation output of UK-based organisations, reducing both the number of inventions patented overseas and their quality.

JEL Codes: F15; O30; O34; O36; D80.

Keywords: Economic Policy Uncertainty; Brexit; Innovation; Patents; International Research Collaborations.

Disclaimer: The views expressed are those of the authors and do not necessarily represent the official views of Eesti Pank or the Eurosystem.

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Non-technical summary

Innovation plays a central role in economic growth and long-term prosperity. New technologies and scientific advances are rarely produced in isolation. Instead, they often emerge from collaboration between firms, universities, research institutes, and inventors located in different countries. These international links help organisations combine knowledge, share risks, and develop better ideas. At the same time, such cooperation depends on a stable political and economic environment.

This paper examines how geopolitical uncertainty can affect innovation. It focuses on the United Kingdom's decision to leave the European Union, commonly known as Brexit, as a major political and economic shock. Brexit created uncertainty about future rules affecting trade, regulation, research funding, and the mobility of skilled workers. Because innovation relies heavily on long-term planning and cooperation, this kind of uncertainty may be especially damaging.

The study investigates how Brexit affected the patenting activity of UK-based organisations between 2012 and 2019. Patents are used as an indicator of innovation because they capture new inventions and provide information on where inventions are filed, who owns them, and who contributed to them. The analysis looks not only at the number of patents, but also at their quality, the extent of international collaboration behind them, and whether UK organisations changed the way they organised their research activity.

The results show that Brexit had a negative effect on innovation by UK organisations. After the referendum, the number of patents filed by UK-based organisations declined relative to comparable organisations in EU countries. The fall was especially clear for jointly owned patents and for patent applications filed at European patent offices, suggesting that cross-border innovation activity was particularly affected.

The paper also finds that the quality of innovation declined. Several measures indicate that patents produced during the Brexit period were, on average, less valuable or less influential than before. This suggests that the effects of uncertainty were not limited to reducing the number of inventions, but also weakened the strength of the innovations being produced.

A key reason for this decline appears to be the disruption of research collaboration between the UK and the EU. The evidence shows that UK organisations became less likely to work with EU-based inventors after the referendum. In many cases, EU inventors were replaced by inventors based in the UK. This points to a shift towards a more domestic and inward-looking model of innovation.

While this adjustment may reflect an attempt to reduce dependence on foreign partners, the findings suggest that it came at a cost. International research networks are important because they allow organisations to access specialised knowledge, pool expertise, and produce stronger innovations. When those links weaken, innovation performance suffers.

The paper shows that political and economic disintegration can have important consequences for science, technology, and innovation. In an increasingly uncertain and fragmented global environment, maintaining stable international research ties is likely to remain crucial for technological progress. The results, therefore, highlight the importance of policies that support cross-border collaboration, institutional stability, and trust between research partners.

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1 Introduction

Technological progress and innovation lie at the core of human development, long-term economic growth, and national competitiveness (Schumpeter, 1942; Solow, 1957). Innovation is not an isolated activity; it emerges from complex interactions among firms, universities, research institutes, and government bodies embedded in broader innovation ecosystems and global collaborative networks (Teece, 1986; Chesbrough, 2003; Cassiman and Veugelers, 2006). These interdependencies have become even more salient amid rising geopolitical tensions and growing fragmentation in the global political economy (Archibugi and Filippetti, 2015). In this context, many governments have adopted “technological sovereignty” strategies aimed at enhancing domestic innovation capacity and reducing reliance on foreign partners and cross-border research ties (Filippetti and Vezzani, 2022; Edler et al., 2023).

Yet, we still know relatively little about how innovation ecosystems respond to political crises, abrupt policy shifts, and sustained uncertainty over future institutional arrangements. This is a critical gap, given that innovation is shaped by the regulatory and economic context in which it occurs. Uncertainty in this environment can fundamentally alter the incentives, behaviours, and capabilities of firms and research institutions, with long-term consequences for innovation performance.

In this paper, we examine how mounting policy uncertainty and economic disintegration affect innovation and international R&D collaboration. Specifically, we study the effects of the UK’s withdrawal from the European Union (Brexit) on the patenting activity of UK-based organisations between 2012 and 2019. Brexit provides an ideal setting for such analysis for several reasons. The UK ranks among global innovation leaders, largely due to its research-intensive universities, which accounted for over 23% of national R&D investment in 2019, and its participation in a broad range of publicly funded collaborative research projects with partners worldwide (PolicyLinks, 2022).¹

Our analysis contributes to the literature on geopolitical uncertainty and innovation (Filippetti and Vezzani, 2022; Edler et al., 2023; Bloom, 2009) by conceptualising Brexit not merely as a political event, but as a prolonged episode of structural uncertainty—a disruption that alters the institutional rules, expectations, and incentives that govern cross-border innovation. We identify five interdependent dimensions along which this structural shift unfolded: regulatory alignment (Bhattacharya et al., 2017), research collaboration (Griffith et al., 2006), talent mobility (Teece, 1986), investment flows (Bloom et al., 2019a), and market access (Garas et al., 2019).

Drawing from innovation systems theory and the literature on global innovation networks (Lundvall et al., 1992; Chesbrough, 2003; Zanfei, 2000), we conceptualise the UK and EU as historically integrated innovation regimes within a wider European research ecosystem. Brexit represents a process of de-integration, whereby formal and informal institutional linkages are weakened or reconfigured—disrupting flows of knowledge, capital, and labour, and undermining coordination mechanisms that sustain collaborative innovation. We further draw on the literature on policy-induced strategic uncertainty (Dixit and Pindyck, 1994; Bloom and Van Reenen, 2002) to examine how firms and universities respond to institutional instability. Uncertainty increases risk aversion, delays

¹While the UK spent 1.74% of GDP on R&D in 2019, below the OECD average of 2.5%, the government has committed to increasing public R&D investment to £22 billion by 2026/27. The UK’s comparatively low business R&D contribution (around 55%) and the limited presence of globally leading firms in patenting and R&D further underscore the importance of public support (Office for National Statistics, 2021).

investment, and weakens incentives for long-term R&D, especially when the regulatory and funding environment is ill-defined or subject to change. Our theoretical framework therefore, integrates three complementary lenses: (1) innovation systems theory to analyse institutional interdependencies, (2) the policy uncertainty literature to understand behavioural responses, and (3) geopolitical disruption as a framing for systemic shocks to the governance of innovation. This approach enables a more nuanced understanding of how geopolitical fragmentation can undermine innovation ecosystems, and how innovation policy must adapt in response.

Our contribution to the literature is threefold. First, using firm-level patent data for the UK and EU countries, we conduct a micro-level analysis of how geopolitical uncertainty affects patenting and cross-border R&D, controlling for firm characteristics, macroeconomic trends, and country-specific effects. Second, we leverage detailed patent data to examine the mechanisms of impact, including changes in patent filing strategies, patent quality, collaboration patterns, and technological specialisation. Third, by treating Brexit as a quasi-natural experiment, we address key endogeneity concerns that limit existing studies, allowing us to identify the causal effect of geopolitical uncertainty on innovation outcomes.

Our results show that Brexit-induced uncertainty had a significant and negative effect on the number of patents filed by UK organisations, particularly those jointly owned with EU partners. The number of international patent filings, especially at European patent offices, also declined. We find robust evidence that patent quality deteriorated during the Brexit process, based on multiple indicators. These outcomes appear to be driven, in large part, by the disruption of cross-border collaboration. Inventor-level data reveal a clear shift in team composition, with the share of EU-based inventors on UK patents falling and being replaced by domestic inventors.

This pattern suggests that UK organisations adopted a more inward-looking innovation strategy in response to Brexit, withdrawing from European collaboration networks and reorganising innovation processes domestically. However, this shift toward a "technological sovereignty" model has come at a cost: both the quantity and quality of innovation declined, pointing to the damaging effects of growing scientific isolation.

The remainder of the paper is structured as follows. Section 2 situates Brexit within the broader theoretical framework of uncertainty and innovation. Section 3 outlines the empirical strategy, including data sources and econometric methods. Section 4 presents the main results. Section 5 discusses the policy implications, and Section 6 concludes.

2 Theoretical Framework

2.1 Brexit as a Process of Geopolitical Uncertainty

We examine Brexit as a period of heightened geopolitical and economic uncertainty, focusing on the process from the 2016 referendum to the ratification of the withdrawal agreement in January 2020. Brexit can be defined as a period of geopolitical uncertainty due to the major shift it caused in the political, economic, and regulatory landscape of Europe. It created substantial political tensions between the UK and the European Union, and started an abrupt, largely unanticipated, and long-lasting economic and geopolitical realignment between the two previously well-integrated parts.

The origins of Brexit trace back to the 2015 UK General Election, when Prime Minister David Cameron promised an EU membership referendum. Held on 23 June 2016, the

referendum resulted in a narrow 51.9% vote to leave the EU, contrary to most expectations (Graziano et al., 2020). Although the result was not legally binding, the UK government committed to implementing it. Cameron resigned shortly after, deepening political instability, and was succeeded by Theresa May, who initiated formal withdrawal proceedings by triggering Article 50 of the Lisbon Treaty in March 2017. This began a complex negotiation period, during which the UK and EU worked to define the terms of withdrawal and their future relationship.

This process was far from linear, marked by deep political divisions within the UK government and constitutional conflicts between Parliament and the executive. This created widespread uncertainty among businesses and the public about the UK's future relationship with the EU. Negotiations with the EU were delayed until June 2017 due to a snap general election called by Prime Minister Theresa May, which unexpectedly resulted in a minority government. Political instability intensified, particularly after Parliament repeatedly rejected the Withdrawal Agreement in early 2019, prompting multiple extensions to the Brexit deadline.

Theresa May resigned in June 2019 and was succeeded by Boris Johnson, whose government negotiated a revised deal with the EU, including a new Northern Ireland Protocol. Following another extension, a general election was held in December 2019, where the Conservative Party won a large majority with the slogan "Get Brexit Done." This result enabled the UK Parliament to pass the revised Withdrawal Agreement, which became law in January 2020. The UK formally left the EU on 31 January 2020, entering a one-year transition period.

This period saw a sharp rise in geopolitical and economic uncertainty, as businesses, investors, and policymakers grappled with unclear regulatory and trade outcomes. The process ultimately led to the UK's departure from the EU single market, customs union, and key areas of policy alignment. Figure 1 provides a graphical timeline of the events, including key dates and the primary sources of uncertainty, showing how the level of uncertainty has dramatically increased following the Brexit referendum. This reverberated through the entire economy, affecting as well research-intensive organisations, as shown in Figure 2 presenting the trends in Google searches in the UK about combinations of Brexit and other innovation related keywords since 2015. Searches about the post-Brexit research and innovation ecosystem jumped in the immediate aftermath of the Brexit referendum outcome shock, including searches about the European Research Council (ERC), the EU Horizon 2020 funding scheme, research grants and the consequences of a "no-deal" scenario for innovation. These increased significantly again towards the end of 2018, when the UK Government struggled to secure a meaningful vote about the exit agreement with the EU, and had to reopen the negotiations at the very last moment in 2019.

[Figures 1 and 2 about here]

Brexit has been widely used in the literature as a quasi-natural experiment to analyse uncertainty, particularly in the Trade Policy Uncertainty (TPU) literature (Graziano et al., 2020; Crowley et al., 2020; Douch et al., 2022), given the unpredictable nature of the Brexit referendum outcome, and the fact that the consequences for the future typology of UK's EU membership remained largely uncertain for years after the referendum (Sampson, 2017). Many studies have evaluated the impact of the Brexit uncertainty and process on several aspects of the UK economy, including foreign direct investment (Breinlich et al., 2020), gross domestic product (Born et al., 2019), living standards (Dhingra et al., 2016; Breinlich et al., 2022), trade activity (Graziano et al., 2020; Crowley et al., 2020; Douch and

Edwards, 2021, 2022; Douch et al., 2022; Freeman et al., 2025), firm productivity (Bloom et al., 2019b), and labour market (Javorcik et al., 2019). Consistent empirical evidence has demonstrated that the heightened uncertainty associated with Brexit caused an approximate 11% contraction in investment and a decline in productivity ranging between 2% and 5% over the three-year period following the referendum (Bloom et al., 2019b). Taken together, these findings provide robust evidence of the adverse macroeconomic consequences of Brexit-induced uncertainty, particularly with regard to diminished investment activity, reduced productivity growth, and weaker overall economic performance, even prior to the United Kingdom’s formal withdrawal from the EU. Nevertheless, none of the previous studies looked at the impact of Brexit on R&D investment or on innovation. Studying this could provide novel evidence on the impact of geopolitical uncertainty on R&D, innovation, and patenting in particular.

2.2 Geopolitical Uncertainty and Innovation

The concept of geopolitical uncertainty has emerged as a critical dimension in understanding the reconfiguration of innovation systems under conditions of economic and political disruption (Padilla and Garrido, 2018; Di Cataldo, 2017). Geopolitical uncertainty introduces a set of structural constraints that significantly influence innovation systems. Unlike cyclical economic shocks or market volatility, geopolitical uncertainty stems from fundamental disruptions to the institutional, legal, and relational foundations on which innovation depends (Archibugi and Filippetti, 2018). Events such as wars, sanctions, trade disputes, or political and economic realignments such as Brexit, can destabilise established patterns of cooperation, alter the distribution of resources, and shift the incentives faced by firms, researchers, and governments engaged in technological development (Pertuze et al., 2019; Tajaddini and Gholipour, 2020).

From a theoretical standpoint, the innovation ecosystems literature emphasises the importance of stable institutional environments and cross-border linkages for the effective generation and diffusion of knowledge (Lundvall et al., 1992). Geopolitical uncertainty disrupts these systems by introducing ambiguity over regulatory stability, market access, and coordination mechanisms. Uncertainty regarding the policy environment is particularly important for innovation, as it requires especially long-term investment with significantly higher risks regarding the future outcomes generated (Bhattacharya et al., 2017; Liu and Ma, 2020). Following the real option theory, R&D investment is an input into the innovation process with not fully reversible sunk cost, which makes them particularly sensitive to heightened uncertainty (Dixit and Pindyck, 1994). The value of the option to wait is particularly important for these investments, given the exploratory nature of innovation, and the high uncertainty regarding future commercialisation and profitability of innovations (Holmstrom, 1989; Aghion and Tirole, 1994; Manso, 2011; Ferreira et al., 2014). In this sense, political shocks like Brexit may have incentivised the postponement or scale down of R&D activities, as economic agents became cautious and held back on investment in the face of uncertainty, increasing the value of the option to wait (Bernanke, 1983; Alesina and Perotti, 1996; Bloom, 2009, 2014; Coelli, 2022). In fact, investors were unsure about market access, regulatory stability, and the future of trade relationships with the EU.

Brexit introduced a wide range of uncertainties regarding future divergence in the regulatory framework concerning technology and innovation. Although the system of patent protection obtained through the UK Intellectual Property Office (UKIPO) or the European Patent Office has remained substantially unchanged, there was widespread uncertainty

about future divergence in the EU and UK intellectual property rights (IPR) framework.² For instance, a new European patent regime called the Unified Patent Court entered into force in 2023, enabling proprietors of inventions to apply for a single, pan-European Unitary Patent (UP) covering most of Europe, and with a single Unified Patent Court (UPC) to hear and determine patent disputes on a pan-European basis.³ As a result of Brexit, the UK is not part of the UPC system, contrary to the previous expectations, a decision which was taken only in February 2020.

In addition, uncertainty about the future of trade relationships between the EU and the UK has decreased the relevance of the EU single market for UK organisations, and discouraged foreign firms from investing in the UK. For a long period during the negotiations, it was not clear whether Brexit would have introduced new barriers to trade, such as potential tariffs, customs delays, and divergent licensing requirements between the EU and the UK, and on which specific industries in particular. Ultimately, exiting the Single Market has made UK products and services in the EU market less competitive, ending the automatic reciprocal recognition of product standards and certificates. Due to the combinations of these threats, tech startups and scaleups in the UK found it harder to raise capital during this period of peak uncertainty (Bosio et al., 2025). Also, multinational firms reconsidered locating or expanding operations in the UK due to access concerns (Breinlich and Magli, 2024). Delayed investment could have significantly hindered UK organisations' innovation, by disrupting the cumulative and time-sensitive nature of knowledge development (Griliches, 1998; Pichler and Pisera, 2024). As a consequence, UK organisations risk falling behind competitors, missing market opportunities, and weakening collaborative networks by reducing access to talent (Teece, 1986). Over time, this would lead to an increase in risk aversion in innovation strategies, resulting in fewer breakthrough innovations, and slower technological progress (Bloom et al., 2007).

Conversely, patenting might become a more attractive option to organisations under uncertainty, as they represent a form of innovation output that carries real option characteristics. In fact, patents confer the right, but not the obligation, to pursue the commercialisation of an innovation, effectively truncating the R&D investment from the commercialisation investment (Gunther McGrath and Nerkar, 2004). This means that under certain types of uncertainty, particularly when future policy regimes or market structures are unclear, organisations may actually increase patenting activity as a strategic hedge, as patents function as growth options, whose value increases when investments can be staged or delayed (Pertuze et al., 2019). Yet, the strategic use of patents under uncertainty depends heavily on the context (Weeds, 2002). For example, geopolitical uncertainty may influence patenting behaviour differently than technologically specific uncertainties. Brexit, as a case of geopolitical disruption, may not have directly deterred patent filings if firms viewed patents as instruments to secure competitive positioning or preserve optionality in the future (Kulatilaka and Perotti, 1998). Moreover, patents may be used strategically to block potential competitors or signal technological leadership, especially in uncertain regulatory or competitive environments (Bloom and Van Reenen, 2002).

This phenomenon is also significantly intertwined within the theories of open innovation (Chesbrough, 2003) and global innovation networks (Zanfei, 2000; Baldwin and Von Hippel, 2011), given the increasing reliance of organisations on external sources and international collaboration to drive innovation. In particular, cross-border R&D collaboration is widely

²The Law Society (2021): <https://www.lawsociety.org.uk/topics/brexit/intellectual-property-after-brexit>

³For more information, see: <https://www.nortonrosefulbright.com/en/knowledge/publications/01b81fec/impact-of-brexit-on-intellectual-property>

regarded as a key driver of innovation and technological development. This is supported by empirical evidence showing that innovative organisations benefit from increased productivity and operational efficiency through international engagement (Griffith et al., 2006). For instance, patents with global inventor teams account for an ever-increasing share of the observed overall growth in global inventive activity among advanced economies (Pekkala Kerr and Kerr, 2018). This is not only driven by multinational firms (Bilir and Morales, 2020; Chikis et al., 2025), but increasing international collaboration is also found in higher education and academic publications (Freeman et al., 2014). Tapping into wider global innovation networks makes it possible for patents produced by global teams to be of higher quality compared to domestic patents, promoting more rapid technological development and economic growth (Bircan et al., 2021).

In this context, geopolitical tensions can directly limit access to cross-border R&D collaborations, funding, knowledge exchange, or joint ventures, in particular for the most productive and research-intensive organisations (Bircan et al., 2024). Nowadays, innovation is increasingly shaped by complex, global networks of interdependence, where firms and institutions operate across multiple jurisdictions (Cortinovis and van Oort, 2022). When geopolitical events threaten these linkages, by imposing legal barriers, disrupting mobility, or eroding trust, they undermine the collective innovation capacity of a country, through the strategic decoupling of technological ecosystems, reducing cross-border knowledge flows and driving fragmentation in standards and platforms (Bhattacharya et al., 2017; Chen et al., 2023).

Brexit offers a distinct example of how geopolitical uncertainty affects innovation through the redefinition of established political and economic cross-border relationships. During the Brexit negotiation period, firms, universities, and research bodies were faced with uncertainty around regulatory alignment, talent mobility, and funding access, all critical enablers of innovation (Garas et al., 2019). The prospect of exiting the EU single market, with the consequent end of freedom of movement, has significantly constrained the mobility of high-skilled labour and researchers from the EU (Sampson, 2017). This has created uncertainty among both employers and prospective employees regarding future friction in hiring due to the introduction of post-Brexit visa requirements and more stringent immigration policy (Javorcik et al., 2019). This has overall diminished the UK’s attractiveness as a tech hub, also limiting access to investment from the EU, with large negative effects on the development of technology and its diffusion across the economy (RoyalSociety, 2019). In fact, Brexit unpredictability impaired long-term planning, disrupted collaborative networks, especially those linked to the EU Horizon 95.5 billion research and innovation fund, and created parallel regulatory regimes that increased compliance burdens, particularly in the knowledge-intensive services industries (Du et al., 2025). As a former net beneficiary of EU R&D funding, and an active participant in collaborative research networks, the UK found its role in European scientific cooperation temporarily suspended between 2021 and 2024. Prior uncertainty about the UK’s participation in Horizon has been one of the biggest issues in the fractious post-Brexit UK-EU relationship. The potential exclusion from the Horizon programme not only prevented UK research organisations from accessing an important source of funding, but also made it harder for them to recruit the best international scientists, and possibly reduced collaboration between UK and EU research organisations (Meyers and Springford, 2022).

The relationship between uncertainty and innovation is increasingly critical in today’s shifting geopolitical landscape (Archibugi and Filippetti, 2015). To sustain competitive advantage and drive economic growth, governments and firms must continually innovate—enhancing production efficiency, defending market share, and competing effectively

in global markets (Baldwin and Johnson, 1996; Martín-de Castro et al., 2013; Tidd and Bessant, 2020). This imperative has become even more pronounced amid rising international tensions and a trend toward political and economic fragmentation. In response, many governments have adopted “technological sovereignty” strategies aimed at strengthening domestic innovation capabilities and reducing reliance on foreign entities and international research collaborations (Filippetti and Vezzani, 2022; Edler et al., 2023).

Geopolitical uncertainty is increasingly reshaping how innovation systems function, particularly by reinforcing national strategies aimed at achieving technological sovereignty. As international tensions rise, governments and firms shift from globally integrated innovation models toward more domestically oriented, security-conditioned ecosystems. This trend marks a departure from traditional collaborative frameworks such as the Triple and Quadruple Helix, as states now assert themselves more actively as regulators, funders, and gatekeepers, often limiting international partnerships through export controls, investment screening, and strategic funding realignment (Edler and Fagerberg, 2017; Luo, 2021).

In this context, innovation is no longer viewed solely as an engine of economic growth, but increasingly as a lever of national power and resilience. The rise of sovereign innovation agendas, such as the EU’s Strategic Autonomy or the US CHIPS and Science Act, reflects a broader shift toward insulating technological capabilities from external risks (Filippetti and Vezzani, 2022; Edler et al., 2023). As a result, the logic of openness and knowledge sharing that once underpinned global innovation networks is being replaced by policies aimed at controlling and securing knowledge flows (Foray, 2014).

Moreover, geopolitical pressures also transform the temporal and institutional dynamics of innovation. In crisis settings like Brexit or the US–China tech conflict, governments may become more inward-looking, adopting industrial strategies focused on national security or technological sovereignty, or restructure funding priorities in ways that emphasise resilience over collaboration (Mazzucato, 2018; Edler and Fagerberg, 2017). Over time, such adaptations contribute to the emergence of sovereignty-aligned innovation ecosystems, where openness is traded off against strategic control, and the pathways of knowledge, talent, and capital are restructured by national priorities. While such shifts can foster innovation in strategic sectors, they may also lead to inefficiencies, duplication of efforts, and reduced global spillovers (Luo, 2021).

2.3 Hypothesis

In sum, the literature points mostly to a negative relationship between geopolitical uncertainty and innovation, primarily through reduced investment, weakened collaboration, and increased institutional complexity. However, IPR protection could increase during uncertainty periods under certain circumstances, in particular with a strategic use of patents to secure competitive positioning or preserve optionality in the future. Brexit exemplifies these dynamics in a high-income and innovation-intensive economy, and offers an ideal case study to analyse how geopolitical uncertainty affects the innovation system. Based on this theoretical framework, we develop the following testable hypothesis:

- **H1: Impact on Patent Filing**
 - **H1a:** Brexit-related geopolitical uncertainty has a negative effect on the number of patent filings by UK-based organisations, due to postponed or reduced R&D investments, and decreasing cross-border collaborations.

- **H1b:** Conversely, Brexit-related geopolitical uncertainty has a positive effect on patent filings when UK organisations use patents strategically to preserve the option to delay investment and commercialise innovations in the future.
- **H2: Geographic Distribution of Patent Filing**
 - **H2a:** The number of patents filed in EU-based offices by UK applicants decreased after Brexit, due to reduced market relevance and collaboration with EU partners.
 - **H2b:** The number of patents filed in the UKIPO or international (non-EU) offices increased as UK organisations sought to secure strategic protection and maintain autonomy in domestic and third-country markets.
- **H3: Patent Quality and Scope**
 - **H3a:** The average patent family size (as a proxy for international protection) increased post-Brexit, reflecting the UK organisations’ strategic effort to secure market positioning.
 - **H3b:** Other measures of patent quality decreased due to delayed investments and weakened cross-border collaborations.
- **H4: Cross-border Collaborations**
 - **H4:** Brexit and its associated geopolitical uncertainty led to a decline in international co-inventorship and co-applicant patents, particularly with EU-based partners, due to reduced mobility, funding, and institutional collaboration.
- **H5: Technological Focus**
 - **H5:** UK-based organisations increasingly concentrated their patenting activities in core or strategic technologies post-Brexit, driven by technological sovereignty agendas and constraints on global innovation networks.

3 Empirical Analysis

3.1 Data

This analysis makes use of the EPO PATSTAT Global database, which provides detailed bibliographical data relating to more than 100 million patent documents from most countries (Kang and Tarasconi, 2016). PATSTAT offers information regarding, among others, the patent’s filing date and patent office, name and address of owners and inventors, organisation type of owners, technological classifications, backward and forward citations, as well as information about the patent family⁴. We focus on patents families filed between January 2012 and December 2019 by organisations based either in the UK or in the EU, including universities, private firms, individuals, and other public or non-for-profit research

⁴A patent family denotes a group of patents which relate to similar or identical purposes or inventions. The families are constructed, typically automatically, by the patent offices. Applicants may re-patent the same innovation numerous times across several patent offices, which would then be recorded as separate patents. However, patent families account for this by bringing together all patents that pertain to the same invention (Martinez, 2010).

institutions.⁵ For our analysis, we aggregate the data at the applicant and quarter level, generating several variables describing the patenting activity of all EU and UK organizations filing a patent during this period. After cleaning the data and removing single patent observations, we are left with around 320,000 observations, including around 47,000 European and 5,000 UK applicants. Of these, the majority are private companies (38,000 ca.), followed in equal measures by universities and other public research institutions, and individual unaffiliated inventors (about 6,000 each).

3.2 Baseline Identification Strategy

To identify the impact of geopolitical uncertainty on innovation and cross-border R&D collaborations, we exploit the UK exit process from the European Union, commonly known as Brexit, from the referendum of June 2016 until the ratification of the withdrawal agreement in January 2020. Brexit has been used before as a quasi-natural experiment to analyse uncertainty, particularly in the Trade Policy Uncertainty (TPU) literature (Graziano et al., 2020; Crowley et al., 2020; Douch et al., 2022; Douch and Edwards, 2021, 2022; Freeman et al., 2025), given the unpredictable nature of the Brexit referendum outcome, and the fact that the consequences for the future typology of UK’s EU membership remained largely uncertain for years after the referendum, as discussed in the previous section.

In fact, preliminary evidence as those reported in Figure 3 shows how the patenting activity of UK and EU based organisations have changed over this period of high policy uncertainty. It is possible to notice that while EU-based organisations have shown a stable trend in terms of patent filing, quality and composition of inventors throughout the period of analysis, the patenting activity of UK-based organisations have rapidly changed starting from 2016, showing a slower rate of patent filing, in particular at EU patent offices, with a significant reduction in patent quality, and in the share of inventors based in the EU.

[Figure 3 about here]

The above statistics present however, only spurious evidence of a possible impact on innovation of the policy uncertainty induced by Brexit. In order to formally test this relationship we start by developing a two-way fixed effects (TWFE) difference-in-differences (DID) estimation to compare the effect of Brexit uncertainty between the group of UK (treated) and EU based (control) organisations on several measures of patenting activity before and after the beginning of the Brexit process in June 2016, as specified in the following model:

$$Y_{it} = \beta_0 + \beta_1 BXT_t \times UK_i + \beta_2 \overline{PS}_{it-1}^{t_0} + \eta_t + \theta_{iy} + \epsilon_{it} \quad (1)$$

Here, Y_{it} represents different outcome variables measuring the patenting activity of each organisation i in quarter t .⁶ The main coefficient of interest will be β_1 , estimating

⁵We limit our analysis to the end of 2019 for several reasons. First, patent data for subsequent years remains incomplete in PATSTAT. Second, we aim to exclude the period of disruption caused by the Covid-19 pandemic, which significantly affected patenting activity. Finally, 2019 marks the close of the Brexit uncertainty, culminating in the UK’s official departure from the European Union on 31 January 2020.

⁶All dependent variables in our models, except those representing shares, are logged ($\ln(y + 1)$). As a robustness test, we use a count Poisson model for the dependent variables with only integer values (e.g. count of patents), as generally done in the related literature given the presence of many 0 values in patent data. Results are robust and available in table A3 in the Appendix.

the effect of the post-Brexit referendum uncertainty for UK organisations with respect to EU-based ones, by interacting BXT_t , a dummy variable equal to 1 for quarters after 2016q2, and UK_i , a dummy variable equal to 1 for UK based organisations and 0 for EU ones. We include quarter η_t fixed-effects to control for quarter-specific macro shocks, and organisation-year θ_{iy} fixed-effects to consider any idiosyncratic organisation-specific time-variant characteristics which could predict their patenting activity. In addition, we control for the organisation overall innovativeness by considering their stock of patents until the previous quarter $\overline{PS}_{it-1}^{t_0}$. To minimise the endogeneity of this variable, we measure it as the total number of patent families filed by applicant i up to the first quarter t_0 in which applicant i appears in the PATSTAT data in the pre-treatment period Q1/2012-Q4/2015, multiplied by quarter t of observation.⁷

3.3 Patent Filing and Quality

We consider several measures of patenting activity by exploiting the richness of the PATSTAT data.⁸ First, we look at the total number of patent families filed by an applicant in each quarter. We also distinguish between patents filed with domestic or international partners, focusing in particular on patents filed in collaboration between UK and EU based partners, which we would expect to be the most affected by UK-EU geopolitical tensions.

[Table 1 about here]

Table 1 reports the results of this analysis. First of all, we can observe in column 1 a significant and sharp decrease in the number of patent families filed by UK organisations with respect to EU-based ones after the Brexit referendum. Over the post-referendum period, the number of patents filed by UK organisations have declined by around 3%.⁹ This effect seems to be entirely driven by inventions co-patented with international partners (column 3), and in particular for patents involving both UK and EU based partners (column 4), while there is no effect for patents with purely domestic teams. These findings provide some first evidence in favour of hypothesis H1a, as Brexit-related geopolitical seems to have caused the postponement and reduction of R&D investments vital in the production process of new knowledge (Bloom et al., 2019b).

We then consider where those patents have been filed in, distinguishing between the UK Intellectual Property Office (UK PTO), patents filed at the European Patent Office or in other EU countries' national patent offices (EU PTO), at the United States Patent and Trademark Office (USPTO), at the World Intellectual Property Organization (WIPO), or at any other national patent office in the rest of the world (ROW PTO). This could give us an indication of UK organisations' strategic decisions about how and where to protect their inventions under uncertainty, a signal of the importance of each specific market post Brexit, and of the growth option value of patents to hedge against geopolitical risks.

[Table 2 about here]

⁷Standard errors are estimated robustly to heteroskedasticity. Results are consistent if standard errors are clustered at the organisation and quarter level.

⁸Summary statistics and definition of the main patent variables considered in our analysis are reported in Tables A1 and A2 respectively in the Appendix.

⁹For logged dependent variables like in this case, the percentage change in Y in the post-referendum period is given by: $\% \Delta Y = (e^{\hat{\beta}} - 1) \times 100$.

The results, presented in Table 2, indicate that while there is no significant change in the number of patents filed at the UK Intellectual Property Office (UK IPO), a significant decline is observed in filings at overseas patent offices following the Brexit referendum—particularly at European offices, where filings dropped by approximately 4%. This evidence suggests that the growing uncertainty may have prompted UK-based organizations to reorient their patenting strategies toward domestic filings, reducing engagement with foreign patent systems, especially within Europe. This supports hypothesis H2a and goes against hypothesis H2b. Such a shift reflects a perceived decline in the importance of the EU single market for UK innovations or a deliberate move toward an isolationist strategy aimed at retaining intellectual property protection within national jurisdiction, speaking to hypothesis H5 (Hingley and Park, 2017). The broader decline in filings at non-European overseas offices may also point to a disruption in cross-border collaborations, which reduce the incentives for pursuing international patent protection, as predicted by hypothesis H4.

In addition, we consider several measures of patent quality, to understand if geopolitical uncertainty affects not only the extent of organisations’ patenting, but also the quality of the inventions protected. We start by looking at the number of patents actually granted by patent offices, a common measure of patent quality in the literature, as granted patents have passed an examination process, which includes checks for novelty, non-obviousness, and industrial applicability (Jaffe and Trajtenberg, 2002). In addition, we also consider the overall size of the patent family, counting in how many different offices the invention has been patented, and indication of commercial and technological value (Guellec and de la Potterie, 2000). Results reported in the first column of Table 3 show a decrease in the number of patents granted to UK organisations by almost 5.5%, a first indication of a reduction in the novelty of UK patents. We also find a reduction in the size of patent families in column 2, in line with the reduction in the number of patents filed at overseas offices as documented previously in Table 2 and against hypothesis H3a.

[Table 3 about here]

We then focus our attention on other measures of quality which are based on patents citations. We start with the simple number of citations received by each patent family, before counting the number of breakthrough patents, considered as the top 1% most cited patents in each year and International Patent Classification (IPC) technology class (Ahuja and Morris Lampert, 2001). Secondly, we consider two measures of patents *generality* and *originality* as developed by Hall and Trajtenberg (2004). In summary, generality represents how diverse a patent’s citations received are, derived by calculating the percentage of citations received that belong to the patent’s own technological field. Originality is calculated in the same manner, however, it relates to citations made by the patent, as opposed to citations received. Finally, we build measures of patent quality following Hall et al. (2001), measured as the relative number of citations by a patent with respect to all the other patents filed in the same quarter, and differentiating between the quality of patents filed at different patent offices.

Results reported in column 3 of Table 3 show that patents filed by UK organisations following the Brexit referendum are cited 7% less by other patents, a general indicator of their quality. There is also a significant decrease in the number of breakthrough patents filed by UK organisation (column 4), down by 3.5% in respect to EU peers post Brexit referendum. However, we do not observe any effect in terms of patents originality (column 5) and generality (column 6). Further results reported in columns 7-12 show that the

quality has decreased particularly for patents filed at European patent offices and other overseas offices, another indication that the uncertainty regarding the future UK-EU research and innovation relationships might have prevented UK organisations from patenting high-quality innovations in Europe. All these findings confirm thus hypothesis H3b, as UK organisations have suffered an overall decrease in patent quality as a consequence of Brexit uncertainty.

Since many of the patent quality indicators used rely on forward citations from other patents, our results may partly reflect a disruption in research networks. It is possible that patents from UK-based organisations receive fewer citations not because of a decline in the quality of the underlying invention, but due to weakened collaboration networks resulting from geopolitical uncertainty. In this case, the observed decline in citations would be more indicative of reduced international connectivity than of diminished inventive output. To test this hypothesis, we examine in Table A4 in the Appendix the heterogeneous impact of geopolitical uncertainty on the average number of citations received by patents from UK organisations, distinguishing by the composition of inventor and partner teams. The results show a decline in citations only from patents involving overseas collaborators, both in cases where inventors and partners are exclusively EU-based and where teams include both UK and EU-based individuals. In contrast, patents developed by purely domestic teams continue to cite UK patents at similar rates. This pattern provides further evidence supporting the hypothesis that geopolitical uncertainty has disrupted UK patenting activity by hindering in particular international research collaborations.

3.4 Patent Teams and Cross-Border Collaborations

Building on our previous findings, we now turn to the composition of inventors and partner teams associated with patents, in order to test our hypothesis H4 regarding the disruption of cross-border R&D collaborations resulting from Brexit-related uncertainty. We begin by examining the number and geographical distribution of inventors and co-applicants listed on each patent, distinguishing between those based in the UK, EU countries, other non-EU OECD countries, and the rest of the world (ROW). The results of this analysis are presented in Table 4.

Column (1) shows no significant change in the total number of inventors on patents filed by UK organisations. However, a notable shift in inventor composition emerges when comparing patents filed by UK organisations to those filed by EU-based applicants (columns 2–5). Following the Brexit referendum, patents from UK organisations experienced a significant decline in the share of EU-based inventors (-1.2%), accompanied by a corresponding increase in UK-based inventors (+1.4%), resulting in a roughly neutral net effect on the overall number of inventors.

Turning to patent co-applicants (columns 6–10), we observe a modest decline in the total number of partners involved in patents filed by UK organisations (-0.9%). However, when disaggregating by geographical location, the negative coefficients for EU and ROW co-applicants are not statistically significant, making it difficult to attribute the decline to a specific group.

These findings can be explained by two underlying mechanisms. First, the uncertainty surrounding UK–EU relations appears to have limited UK organisations’ access to the pool of EU-based inventors, a direct consequence of leaving the EU single market. Second, there may also be a broader, though less pronounced, disruption of institutional cross-border collaborations. Overall, the evidence supports hypothesis H4 and points to a more

inward-looking innovation strategy adopted by UK organisations in the aftermath of Brexit, marked by a weakening of collaborative ties with European inventors.

[Table 4 about here]

We then try to reconcile these results with the evidence previously provided on the impact of geopolitical uncertainty on patents quality (Table 3). In particular, we analyse the change in the productivity of patents' teams, looking at the number of patents including high-productivity inventors or partners, which we define as inventors/partners in the top 10th percentile of the distribution of patents filed following Moretti (2021), and at the average number of high-productivity inventors/partners in each patent. In fact, the uncertainty surrounding Brexit may have deterred the most talented inventors, particularly those with attractive job opportunities abroad, from remaining in or relocating to the UK. Similarly, highly productive foreign firms may have been discouraged from investing in the UK market due to the heightened levels of economic and political instability (Bloom et al., 2019b). The results in the top panel of Table 6 reveal a significant decline both in the number of patents involving highly productive partners (column 2) and in the average number of such partners per patent (column 4).

In contrast, we find no significant change in the involvement of highly productive inventors, suggesting that UK organisations have not compromised on inventor productivity when replacing EU-based inventors with domestic ones. However, the previously observed reduction in the number of co-applicants appears to be driven by the withdrawal of the most productive partners from UK patent filings—an effect that may, in turn, contribute to the observed decline in patent quality. These findings are reinforced by the results presented in Table A5 in the Appendix, where we examine the heterogeneous impact of geopolitical uncertainty on patenting activity by UK organisations, distinguishing between high- and low-productivity firms. The negative effects are entirely driven by the most productive organisations, who are also those most likely to engage in cross-border patenting collaborations.

In addition, we examine the heterogeneity of these effects across different types of organisations, distinguishing between private firms, universities and other public research institutions, and unaffiliated individuals. The results, reported in Table A6 in the Appendix, show that the overall decline in patenting activity is driven entirely by private companies. In contrast, we observe little to no significant impact for public research institutions or unaffiliated individuals. These findings can be explained by several factors. Private companies are more directly exposed to geopolitical uncertainty (Bloom et al., 2019b), which may have led them to reduce or delay patenting, particularly in technologies requiring international collaboration. These firms also tend to be more reliant on cross-border R&D networks (Laursen and Salter, 2006). In contrast, public research institutions are typically less reactive to short-term shocks, owing to more stable funding streams and longer-term research agendas. Moreover, universities often benefit from transitional arrangements or alternative funding sources, allowing them to maintain continuity in research activities (Pellens et al., 2024). Unaffiliated inventors, who are less integrated into international networks, are also less likely to be affected by geopolitical disruptions, which helps explain the absence of significant change in their patenting behaviour. Overall, this set of evidence seems to further prove hypothesis H1a, as in particular private firms might have deferred or reduced investments in R&D which are essential for patent outcomes. In addition, it is particularly concerning for the overall economic growth of the country, as highly productive organisations and private firms account for a disproportionately large

share of total patent output, especially in terms of high-quality and high-value patents.

To provide further evidence of the disruption to UK organisations’ cross-border R&D collaborations resulting from heightened geopolitical uncertainty, we also examine trends in international partnerships formed to secure research funding. Specifically, we analyse data from EU-funded Horizon 2020 projects alongside data on research projects funded by UK Research and Innovation (UKRI) over the period 2013–2019.¹⁰ We follow an econometric approach similar to what we developed in equation 1, analysing successful funding applications and categorising them according to whether they involve international collaborations or not:

$$IntCollab_{iy} = \beta_0 + \beta_1 BXT_y \times UK_i + \beta_2 X_{iy} + \eta_y + \theta_i + \epsilon_{iy} \quad (2)$$

where $IntCollab_{iy}$ is a dummy variable equal to 1 for successful funding applications involving a cross-border collaboration and equal to 0 otherwise. X_{iy} includes additional controls such as the funding scheme and the awarded amount of funds. η_y and θ_i represent year and organisation fixed-effect respectively.

[Table 5 about here]

The results of our analysis reported in Table 5 uncover a significant post-referendum decline in international collaboration involving UK organisations in Horizon 2020-funded projects, with the effect being especially pronounced among private firms. This suggests that Brexit disrupted long-standing cross-border research partnerships not only in patenting but also in research funding applications, particularly those grounded in institutional and inter-organisational ties (Georghiou et al., 2014; Hoekman et al., 2010). While universities remain central to R&D consortia, their participation declined less sharply, indicating that firms bore the brunt of the disruption also in this case. This is concerning given the well-established role of academic–industry collaborations in driving patentable innovation (Azoulay et al., 2019; Rodríguez-Pose and Crescenzi, 2008), especially through cumulative innovation and knowledge spillovers (Cohen et al., 1990; Cockburn and Henderson, 1998; Furman et al., 2002). The reduced ability of UK firms to access Horizon international consortia may therefore underlie some of the findings previously identified while analysing patenting activities, reflecting a weakening of the knowledge infrastructure supporting innovation.

In contrast, UKRI-funded projects show a small, statistically insignificant increase in international collaboration for UK organisations post-Brexit, driven mostly by businesses. However, this domestic substitution appears limited in both scale and institutional embeddedness. Unlike Horizon’s structured, multinational consortia, UK schemes lack comparable scope, alignment mechanisms, and reputational capital (Arora-Jonsson et al., 2023;

¹⁰We restrict our analysis to selected Horizon and UKRI funding schemes that are primarily focused on supporting highly innovative research and technological advancements in scientific fields excluding social sciences, arts and humanities, and are hence more likely to lead to patentable innovations. These include EU funded programs such as BBI-IA-DEMO, BBI-IA-FLAG, BBI-RIA, which drive innovation in bio-based industries, and the ERC grants (ADG, COG, STG, POC), which foster groundbreaking research by exceptional scientists. Other key schemes include EuroHPC-IA for high-performance computing, FCH2-RIA for fuel cell and hydrogen technologies, IMI2-RIA for biomedical innovations, and MSCA programs (IF, ITN) that promote researcher-driven innovation and training. Additionally, Shift2Rail-IA, Shift2Rail-RIA, and SESAR-RIA focus on innovative advancements in the rail and air traffic sectors. For UKRI funding we focus on the funding provided by BBSRC, EPSRC, ISCF, ISPF, MRC, NERC, STFC, and TMF Research Councils, and on funding specifically designed to support businesses provided by Innovate UK.

D’Este et al., 2013). The more limited engagement of universities with domestic alternatives further suggests that these schemes have not adequately replaced the collaborative functions lost through Brexit (Haskel and Wallis, 2013).

Overall, also these results point to a structural shift in the UK’s innovation system, with reduced cross-border collaboration as predicted in hypothesis H4. This is particularly pronounced for firms, potentially undermining their technological competitiveness and integration into global R&D networks (Veugelers, 2016; Bloom et al., 2019a).

[Table 6 about here]

Finally, to further investigate the mechanisms underlying our results, we examine the heterogeneity of patenting activity across IPC subsections along two dimensions. Our aim is to assess whether the period of uncertainty had a differential impact on specific technological areas. First, we compare the number of patents filed in IPC subsections characterised by a high versus low likelihood of cross-border collaboration.¹¹ This allows us to test whether uncertainty disproportionately affected technologies that typically rely on international cooperation. Columns 5 and 6 of Table 6 indicate that the overall effect is entirely driven by a decline in patent filings within technologies that exhibit a high propensity for international collaboration (-3.2%), such as mining, chemistry, medical technologies, ICT, and nanotechnology. In contrast, there is no significant effect in fields typically characterised by lower levels of international collaboration. This provides additional evidence supporting hypothesis H4 that geopolitical uncertainty has disrupted cross-border research partnerships.

Next, we examine patenting activity in technologies where UK applicants demonstrate a strong revealed comparative advantage (RCA), as defined by Balassa (1965), compared to those where they do not. This allows us to assess whether uncertainty prompts firms to concentrate on their technological strengths or instead to diversify into new areas. The results in columns 7 and 8 reveal a decline in patent filings in non-core technologies by UK organisations, such as metallurgy, textiles, shaping instruments, and construction. This may suggest a strategic refocusing on technological domains where the UK has historically held a comparative advantage. Alternatively, it could reflect an attempt by UK organisations to reinforce domestic capabilities in key sectors, in line with a broader “technological sovereignty” agenda (Edler et al., 2023). In both cases, these findings support our hypothesis H5.

3.5 Dynamic Effect

Building upon this baseline specification, we improve our analysis by modelling the Brexit-induced policy uncertainty as a dynamic process rather than as a single event. To do that, we conduct an event study analysis following the (Callaway and Sant’Anna, 2021) methodology as shown in the following equation 3:

$$Y_{it} = \beta_0 + \sum_q \beta_q UK_{i,t_0+q} + \beta_2 \overline{PS}_{it-1}^{t_0} + \theta_{iy} + \epsilon_{it} \quad (3)$$

where differently from 1 UK_{i,t_0+q} is a dummy variable that equals 1 for treated observations if organisation i is observed q periods away from the beginning of the Brexit

¹¹The classification of IPC technology subsections by revealed comparative advantage and international collaboration intensity is provided in Table A7 in the Appendix.

uncertainty at time t_0 and 0 otherwise, and β_q is the event-time coefficients capturing the dynamic treatment effects before and after Q2/2016. This setup serves two main purposes. First, it allows us to test the validity of the pre-treatment parallel trends assumption for $q < 0$. Second, it enables us to examine the dynamic evolution of the impact of geopolitical uncertainty on patenting activity, beginning with the Brexit referendum in the second quarter of 2016 ($q \geq 0$). This method combines elements of inverse probability weighting (IPW) and ordinary least squares (OLS), offering a powerful framework for estimating causal effects in DiD settings. This doubly robust approach minimises the risk of incorrect specification and offers more accurate estimates, particularly when considering a complex, evolving phenomenon like the impact of Brexit on innovation and cross-border R&D collaborations.

[Figure 4 about here]

Results presented in Figure 4 support our main findings through an event-study analysis following the methodology of Callaway and Sant’Anna (2021). Overall, there is no statistically significant difference in patenting outcomes between UK and EU organisations prior to the Brexit referendum, validating the parallel trends assumption.¹²

Panel (a) shows an immediate drop in the number of patents jointly owned by UK and EU organisations following the referendum, though the estimates are imprecise. This suggests a sudden pause in cross-border collaboration, even for ongoing joint research projects, potentially due to uncertainty around the referendum outcome and its implications for cross-border research.

Panel (b) reveals no initial change in the number of patents filed by UK organisations at European patent offices in the quarters immediately after the referendum. However, from 2019 onwards, filings decline sharply. This drop aligns with a spike in policy uncertainty, as shown in Figure 1, driven by renewed Brexit negotiations and the UK government’s announcements clarifying its intent to leave the Single Market. These developments likely reduced the strategic value of EU markets for UK firms.

Panels (c) and (d) examine the composition of inventor teams in UK patents post-referendum. They reveal a steady increase in the share of UK-based inventors, mirrored by a decline in EU-based inventors. This trend suggests a gradual substitution of EU talent with domestic researchers, pointing to Brexit-related barriers to talent mobility and a weakening of the UK’s position as a hub for international R&D.

Finally, panels (e) and (f) assess two measures of patent quality, both of which show a gradual and persistent decline post-referendum. This is consistent with reduced cross-border collaboration and declining R&D investment, both of which likely contributed to a deterioration in innovation quality.

As an alternative approach to investigate dynamic effects, we change our baseline model in equation 1 by replacing the BXT_t dummy variable with a continuous and time-varying variable measuring changes in policy uncertainty. In this case, we make use of the time-varying Bank of England Brexit Uncertainty Index (BUI_t) developed by Bloom et al. (2019c). This index is specifically designed to capture the Brexit-induced uncertainty affecting firms, as shown in Figure 1. It is based on the Decision Makers Panel survey of around 3,000 firms responding every month, and represents the share of firms which

¹²This assumption has been formally tested; results are available upon request.

rate Brexit as one of the three highest drivers of uncertainty for their business.¹³ The results presented in Table A8 in the Appendix confirm our main findings, indicating that the impact on UK organisations' patenting activity was particularly pronounced during periods of heightened Brexit-related uncertainty.

4 Discussion

Through our analysis, it becomes clear that the ramifications of Brexit have pronouncedly affected the landscape of research and innovation within the UK. The reduction in the number of co-inventors from EU countries in patents filed by UK companies suggests a fragmented collaborative environment. Such collaborations traditionally drive both the quantity and quality of outputs, indicating a disruption that could threaten the UK's standing as a global innovation economy, in line with existing studies highlighting the importance of international cooperation (Squicciarini and Voigtländer, 2015; Diodato et al., 2021).

The strategic shift towards more domestic-centric patent filings, as evidenced by diminished activities in EU and other international patent offices, likely represents a defensive move against uncertainties over intellectual property management post-Brexit. This inward-looking pivot, while protective, might reduce the exposure and influence of UK innovations in international markets (Hingley and Park, 2017). Moreover, such trends potentially signal a broader withdrawal from the collaborative and open innovation model that has characterised global research and development in recent decades, highlighting potential concerns about the UK's future role in the international innovation landscape (Chesbrough, 2003). And their disruption can greatly impact organisational output and strategic planning (Cassiman and Veugelers, 2006).

Furthermore, our findings regarding the technological shifts in patent filings post-Brexit highlight a specialisation of UK innovation towards domains perceived as more secure and controllable at a national level. This inclination towards "technological sovereignty" might be symptomatic of wider geopolitical shifts towards nationalism and has significant implications for policy (Edler et al., 2023). This recalibration, however, has unfolded alongside an evident decline in the quality of UK patents, particularly those filed in Europe. This degradation, as evidenced by fewer citations, suggests a diminishing recognition of UK innovations, which is problematic given the strong correlation between citation metrics and innovation impact (Hall and Trajtenberg, 2004). The decrease in patent quality and quantity following the Brexit referendum suggests a potential erosion of R&D productivity which could have long-lasting repercussions on economic growth and competitiveness (Schumpeter, 1942; Solow, 1957).

UK policymakers must respond to these challenges by crafting new strategies that promote domestic innovation and foster international collaboration. One approach could involve recalibrating existing innovation support instruments, such as HMRC's R&D tax credit and UKRI research funding, to incentivise partnerships beyond the EU. This would help offset the decline in EU collaborations by encouraging UK organisations to engage in new cross-border R&D projects with global innovation leaders. Targeting public funding toward highly productive organisations, especially those capable of producing joint breakthrough patents, could yield particularly high returns.

¹³Results available upon request are consistent when using alternative measures of uncertainty, as the more general Economic Policy Uncertainty (EPU) index developed by Baker et al. (2016).

Equally important is the need for policy clarity and stability to reduce uncertainty that may deter R&D investment. A policy environment characterised by consistency and strategic direction is known to boost investor confidence and encourage innovation activity (Bloom and Van Reenen, 2002; Coelli, 2022). In this context, a partial regulatory realignment with the EU, such as mutual recognition of standards or UK participation in the Unified Patent Court, would be strongly welcomed by UK innovators.

In parallel, the UK must adapt to emerging technological frontiers by strengthening collaboration between academia and industry, particularly in areas where the UK holds a comparative advantage. This would position the country for leadership in future-ready sectors and help maintain its global competitiveness.

Finally, restoring the UK’s attractiveness to European and international talent is critical. Rejoining the Erasmus+ programme is a step in the right direction, but further action, especially on migration policy, is needed to make the UK a compelling destination for students, researchers, and high-skilled professionals.

5 Conclusion

Uncertainty regarding the geopolitical environment could be particularly detrimental for innovation, as it requires high-risk investment, and long-term commitments with scientists and research partners scattered across different countries. This paper has focused on the effects of political and economic disintegration on cross-border patent collaborations and innovation, exploiting the UK exit from the EU as a quasi-natural experiment in a two-way fixed-effects difference-in-difference analysis. Our results reveal a disruption of cross-border research collaborations, as joint patents were badly affected and EU based inventors were replaced by UK ones in UK organisations’ patents. This has resulted in a significant decrease in the number and quality of patents applications after the Brexit referendum for UK organisations in respect to EU ones, affecting in particular applications at European patent offices.

The results from this study highlight the significant impact of geopolitical uncertainty on cross-border research collaborations and innovation. The analysis reveals that political and economic disintegration can disrupt international research networks, with adverse consequences for patenting activity and technological progress. This is evidence that the recent evolution of technological sovereignty and geopolitical tensions could have dire consequences for science and technology, as innovation is inherently global, requiring cross-border collaborations to pool resources, knowledge, and expertise (Verspagen et al., 2005; LaBelle et al., 2023). Our findings suggest that the disruption of these collaborations can significantly hinder the innovation capacity of organisations, especially in knowledge-intensive sectors that rely on international networks of scientists. This mirrors earlier studies on the impact of political instability on international R&D collaboration and the role of institutional stability in fostering innovation (Charpin et al., 2024).

Moreover, the shift in patenting activity and the decline in patent quality, as observed in this paper, reflects a broader phenomenon where uncertainty over geopolitical events increases the perceived risks associated with long-term innovation investments. As innovation involves significant upfront investment in research, often with uncertain and delayed returns, the disruption of stable institutional environments, whether through trade barriers, regulatory divergence, or political fragmentation, can reduce the incentive for organisations and researchers to engage in cross-border collaborations (Bloom, 2009, 2014). Policymakers must therefore be proactive in mitigating the risks associated with geopolitical instability

in an increasingly multipolar world, fostering cross-border collaborations and mutual trust to ensure continued technological progress.

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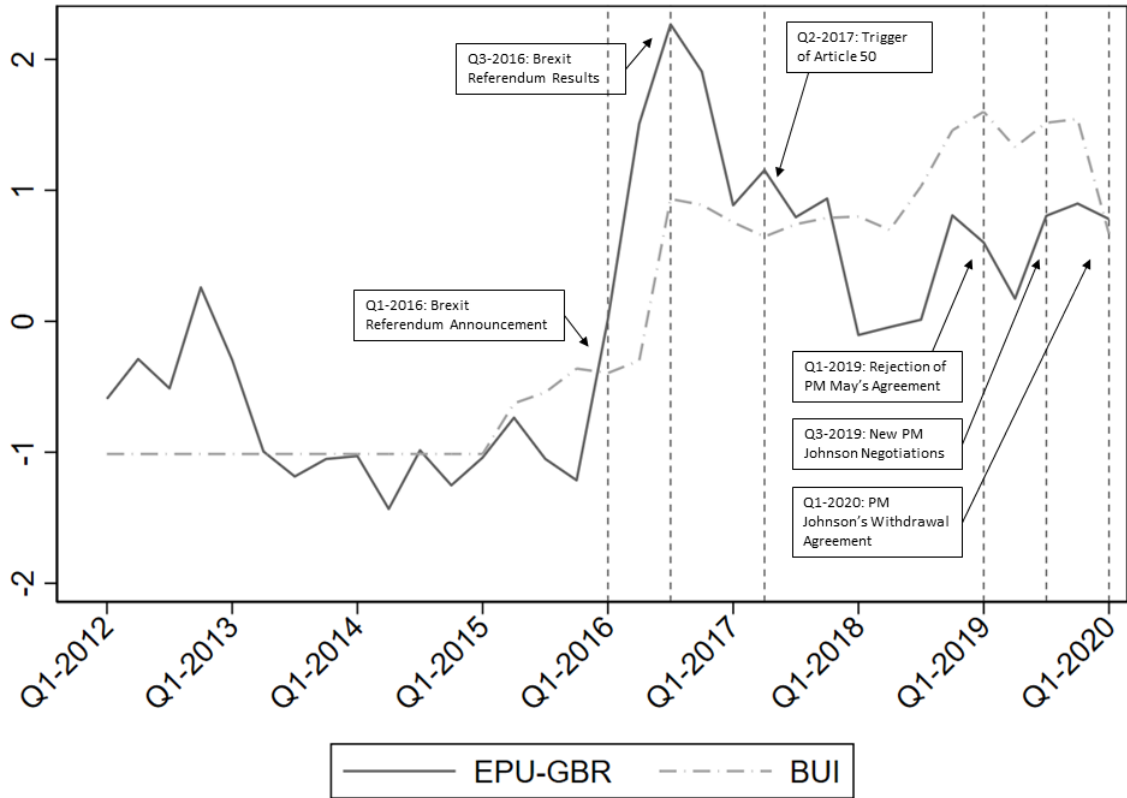
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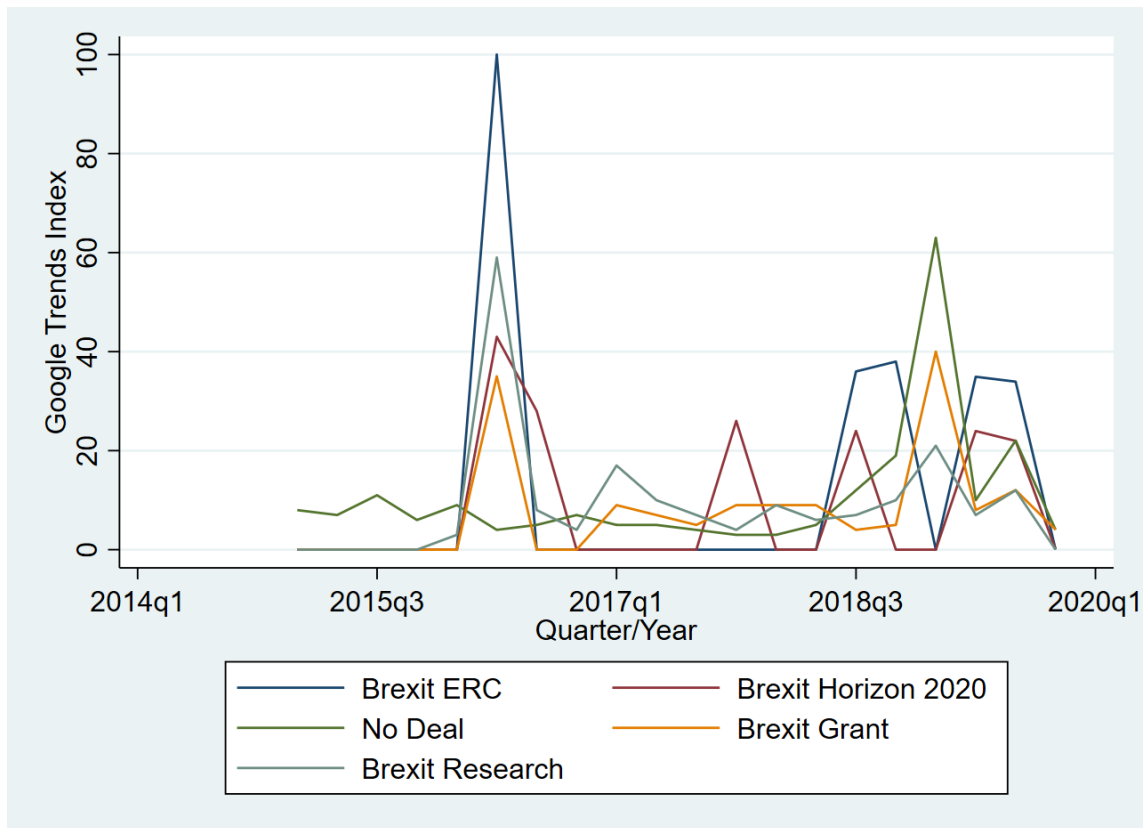
Tables and Figures

Figure 1: Brexit events timeline and quarterly changes in uncertainty indexes 2012-2020.



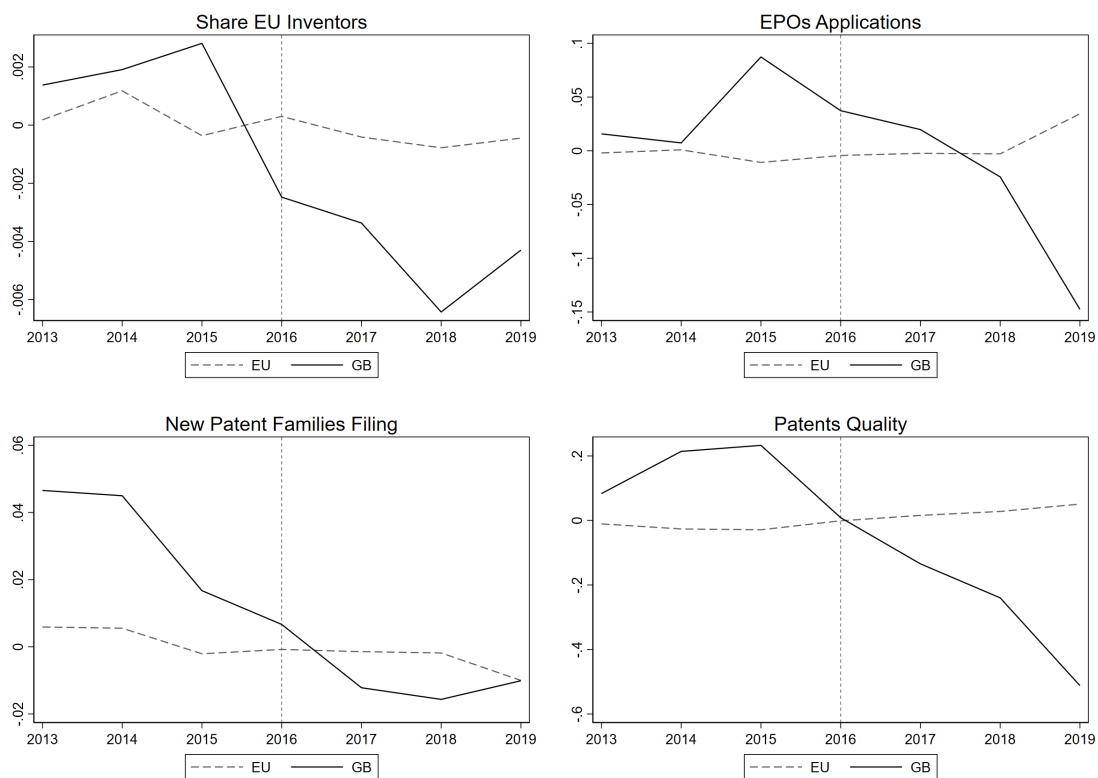
Note: Time series of the Bank of England Brexit Uncertainty Index (BUI) (Bloom et al., 2019c), and of the Economic Policy Uncertainty (EPU) index (Baker et al., 2016) for each quarter between 2012-Q1 and 2020-Q1. Key dates and events important to explain uncertainty indicated with reference lines.

Figure 2: Google searches in the UK about Brexit and other innovation related keywords.



Note: Time series of Google Trends indexes summarising Google searches in the UK about Brexit and other innovation related keywords since 2015.

Figure 3: Patenting activity of UK and EU based organisations over the period of analysis.



Note: Statistics using PATSTAT data over the period 2013-2019. Yearly mean values for UK and EU based organisations after controlling for quarter seasonality and country specific effects.

Table 1: Impact of policy uncertainty on UK organisations patenting activities.

	(1)	(2)	(3)	(4)
	No. Patents All	No. Patents Dom. Partners	No. Patents Int. Partners	No. Patents GB-EU Partners
$BXT_t \times UK_i$	-0.0297** (0.0140)	-0.0128 (0.0149)	-0.0374*** (0.0103)	-0.0110** (0.00583)
Observations	318,936	318,936	318,936	318,936
R-squared	0.829	0.830	0.781	0.775

Notes: Estimates from a panel two-way fixed effects (TWFE) difference-in-differences (DID) model using PATSTAT data at the applicant-quarter level for the period Q1/2012-Q4/2019. Organisation patent stock, quarter, and applicant-year fixed-effects included in all estimations. Robust standard errors reported in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2: Impact of policy uncertainty on UK organisations patent filing across patent offices.

	(1)	(2)	(3)	(4)	(5)
	UK PTO	EU PTO	US PTO	WIPO	ROW PTO
$BXT_t \times UK_i$	-0.00338 (0.0131)	-0.0392*** (0.0148)	-0.0302** (0.0152)	-0.0235* (0.0140)	-0.0296*** (0.0139)
Observations	318,936	318,936	318,936	318,936	318,936
R-squared	0.842	0.831	0.840	0.846	0.810

Notes: Estimates from a panel two-way fixed effects (TWFE) difference-in-differences (DID) model using PATSTAT data at the applicant-quarter level for the period Q1/2012-Q4/2019. Organisation patent stock, quarter, and applicant-year fixed-effects included in all estimations. Robust standard errors reported in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Impact of policy uncertainty on UK organisations patents quality.

	(1)	(2)	(3)	(4)	(5)	(6)
	Pat. Granted	Family Size	No. Citations	Breakthrough	Originality	Generality
$BXT_t \times UK_i$	-0.0565*** (0.0162)	-0.0233* (0.0128)	-0.0724*** (0.0231)	-0.0340*** (0.00836)	0.00778* (0.00457)	-0.00803 (0.00670)
Observations	318,936	318,936	318,936	318,936	293,264	190,660
R-squared	0.812	0.827	0.768	0.592	0.599	0.555
	(7)	(8)	(9)	(10)	(11)	(12)
	Pat. Quality	Quality UKPO	Quality EPO	Quality USPO	Quality WIPO	Quality ROWPO
$BXT_t \times UK_i$	-0.0609*** (0.0205)	-0.00676 (0.0549)	-0.0791*** (0.0241)	-0.0629*** (0.0241)	-0.0681*** (0.0247)	-0.0910*** (0.0339)
Observations	313,535	15,933	289,743	202,365	200,706	132,571
R-squared	0.664	0.671	0.662	0.632	0.653	0.638

Notes: Estimates from a panel two-way fixed effects (TWFE) difference-in-differences (DID) model using PATSTAT data at the applicant-quarter level for the period Q1/2012-Q4/2019. Organisation patent stock, quarter, and applicant-year fixed-effects included in all estimations. Robust standard errors reported in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Impact of policy uncertainty on UK organisations patents inventors and partners teams composition.

	(1)	(2)	(3)	(4)	(5)
	No. Inventors	Sh. GB Inv.	Sh. EU Inv.	Sh. OECD Inv.	Sh. ROW Inv.
$BXT_t \times UK_i$	0.0185 (0.0113)	0.0144** (0.00624)	-0.0119*** (0.00452)	0.00180 (0.00361)	-0.00422 (0.00476)
Observations	310,524	310,524	310,524	310,524	310,524
R-squared	0.696	0.939	0.881	0.737	0.762
	(6)	(7)	(8)	(9)	(10)
	No. Partners	Sh. GB Part.	Sh. EU Part.	Sh. OECD Part.	Sh. ROW Part.
$BXT_t \times UK_i$	-0.00931** (0.00362)	0.000832 (0.00281)	-0.00112 (0.00125)	0.000341 (0.00171)	-0.0005 (0.00214)
Observations	312,690	312,690	312,690	312,690	312,690
R-squared	0.821	0.993	0.982	0.895	0.863

Notes: Estimates from a panel two-way fixed effects (TWFE) difference-in-differences (DID) model using PATSTAT data at the applicant-quarter level for the period Q1/2012-Q4/2019. Organisation patent stock, quarter, and applicant-year fixed-effects included in all estimations. Robust standard errors reported in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Impact of policy uncertainty on cross-border collaboration for research funding

	EU Horizon		UKRI	
	(1) Int. Collab.	(2) Int. Collab.	(3) Int. Collab.	(4) Int. Collab.
$BXT_t \times UK_i$	-0.0714*** (0.0264)		0.00399 (0.00305)	
$BXT_t \times UK_i \times Firms$		-0.147*** (0.0278)		0.0104*** (0.00366)
$BXT_t \times UK_i \times Uni$		-0.0650** (0.0266)		0.00253 (0.00309)
Observations	15,722	15,722	130,758	130,758
R-squared	0.693	0.693	0.443	0.443

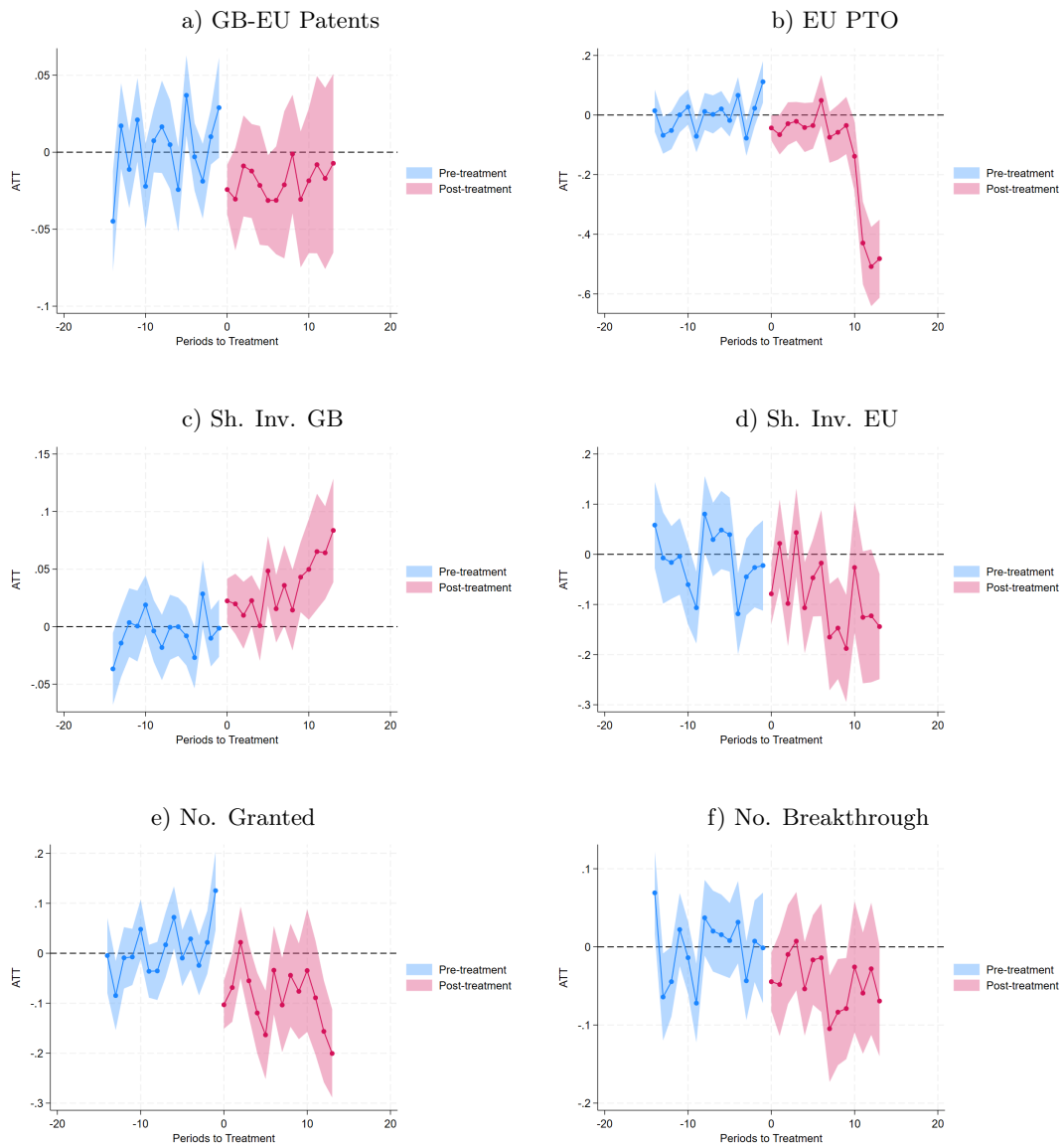
Notes: Estimates from a panel two-way fixed effects (TWFE) difference-in-differences (DID) model using UKRI Gateway to Research and EU Horizon funding data for the period 2012-2019. Year and applicant fixed-effects were included in all estimations. Additional controls include funding scheme and awarded amount. Robust standard errors reported in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Impact of policy uncertainty on UK organisations patents: teams productivity and IPCs heterogeneity.

	Teams Productivity			
	(1) No. Patents High-Prod. Inv.	(2) No. Patents High-Prod. Part.	(3) Av. No. High-Prod. Inv.	(4) Av. No. High-Prod. Part.
$BXT_t \times UK_i$	-0.0165 (0.0166)	-0.0290** (0.0140)	0.00392 (0.0135)	-0.00937*** (0.00340)
Observations	318,936	318,936	301,309	314,428
R-squared	0.805	0.843	0.688	0.842
	IPCs Heterogeneity			
	(5) No. Patents High Int. Collab.	(6) No. Patents Low Int. Collab.	(7) No. Patents High RCA	(8) No. Patents Low RCA
$BXT_t \times UK_i$	-0.0327** (0.0146)	-0.00903 (0.0123)	-0.0158 (0.0152)	-0.0330** (0.0152)
Observations	318,936	318,936	318,936	318,936
R-squared	0.843	0.838	0.838	0.814

Notes: Estimates from a panel two-way fixed effects (TWFE) difference-in-differences (DID) model using PATSTAT data at the applicant-quarter level for the period Q1/2012-Q4/2019. Organisation patent stock, quarter, and applicant-year fixed-effects included in all estimations. Robust standard errors reported in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Figure 4: Dynamic impact of policy uncertainty on UK organisations patenting activities.



Note: Estimates from an event study analysis using PATSTAT data at the applicant-quarter level for the period 2012-2019. Quarter and applicant-year fixed-effects included in all estimations. Robust standard errors clustered at the applicant-quarter level reported in parenthesis. Confidence intervals at the 95% significance level reported.

A Appendix

Table A1: Summary statistics of key variables by organisation type.

Variable	Firms	Unis	Indiv	Variable	Firms	Unis	Indiv
Unique obs.	38,724	5,625	5,845	No. Inventors	2.675468	3.954093	2.345099
Total obs.	248,272	43,865	18,137	Sh. GB Inv.	0.0781481	0.0796088	0.0550087
Av. Spell	8.79	10.22	5.01	Sh. EU Inv.	0.7636815	0.8338613	0.8552099
No. Patents	5.040697	3.496888	1.60644	Sh. OECD Inv.	0.059774	0.0183977	0.0218265
Init. Patent Stock	4.049482	2.636749	1.577328	Sh. ROW Inv.	0.0983964	0.0681322	0.0679549
No. Pat. Dom. Part.	4.707446	3.285307	0.8633732	No. Partners	1.110247	1.943432	1.270259
No. Pat. Int. Part.	0.3330057	0.2114898	0.2645421	Sh. GB Part.	0.0844021	0.0849031	0.0257893
No. Pat. GB-EU Part.	0.0492283	0.0230936	0.0183603	Sh. GB Part.	0.9021568	0.8953524	0.7899118
UK PTO	0.1852525	0.0566967	0.0360037	Sh. OECD Part.	0.010774	0.014314	0.1234616
EU PTO	4.474246	3.254964	1.199316	Sh. ROW Part.	0.0026671	0.0054306	0.0608373
US PTO	3.068151	1.935963	0.5376303	No. Pat. High-Prod Inv.	3.837763	2.593298	1.35287
WIPO	2.973883	2.352536	0.5459006	No. Pat. High-Prod Part.	5.025726	3.49283	0.9699509
ROW PTO	1.692196	0.9124587	0.1976071	Av. No. High-Prod Inv.	1.542601	1.420312	1.700131
Pat. Granted	3.172166	2.17971	0.9548988	Av. No. High-Prod Part.	1.107298	1.858864	0.9173299
Family Size	5.647601	4.633105	2.945921	High-Prod. Applicant	0.9689655	0.9777271	0.3386448
No. Citations	3.152823	2.228375	2.593072	No. Pat. High Int. Collab.	3.005949	3.073749	0.8684457
Breakthrough	0.0953591	0.0265132	0.0148867	No. Pat. Low Int. Collab.	2.034748	0.4231392	0.7379942
Originality	0.3892803	0.3980476	0.3237025	No. Pat. High RCA	2.603713	2.333387	0.7172079
Generality	0.2942829	0.3321974	0.2550334	No. Pat. Low RCA	2.436984	1.163502	0.889232
Pat. Quality	1.740035	1.0855	1.098911	Citing Pat. w\GB Inv.	0.119933	0.0589764	0.0264101
Quality UKPO	2.028319	1.502968	1.154415	Citing Pat. w\GB Part.	0.1613875	0.0942665	0.0082704
Quality EPO	1.753115	1.116819	0.9626995	Citing Pat. w\EU Inv.	2.492863	1.502246	0.6305894
Quality USPO	2.253272	1.582946	2.144495	Citing Pat. w\EU Part.	3.852561	2.041491	0.4875117
Quality WIPO	1.94904	1.293445	1.653769	Citing Pat. w\GB-EU Inv.	3.701183	2.181762	0.8139714
Quality ROW	2.339907	1.920663	2.164007	Citing Pat. w\GB-EU Part.	4.112651	2.189696	0.5198214

Notes: Summary statistics based on observations included in baseline regression using PATSTAT data at the applicant-quarter level for the period Q1/2012-Q4/2019.

Table A2: Patent variables definitions.

Variable	Definition
No. Patents	Number of new patent families filed in quarter t by applicant i .
Patents Stock	Total number of patent families filed by applicant i up to the first quarter t_0 in which applicant i appears in the PATSTAT data in the period Q1./2012-Q4./2015, multiplied by quarter t of observation.
No. Patents Dom. Partners	Number of new patent families filed in quarter t by applicant i including only partners from the same country.
No. Patents Int. Partners	Number of new patent families filed in quarter t by applicant i including cross-border partners.
No. Patents GB-EU Partners	Number of new patent families filed in quarter t by applicant i including both GB and EU based partners.
UK PTO	Number of patents filed at the UK Patent Office in quarter t by applicant i .
EU PTO	Number of patents filed at the EPO and other EU countries national patent offices in quarter t by applicant i .
US PTO	Number of patents filed at the US Patent Office in quarter t by applicant i .
WIPO	Number of patents filed at the International Patent Office in quarter t by applicant i .
ROW PTO	Number of patents filed at other countries' Patent Offices in quarter t by applicant i .
Pat. Granted	Number of new patent families granted in quarter t to applicant i .
Family Size	Average number of applications made by applicant i to different patent offices for inventions part of the same patent families filed in quarter t .
No. Citations	Average number of citations for patent families filed in quarter t by applicant i .
Breakthrough	Number of new patent families filed in quarter t by applicant i in the top 1st percentile of the distribution of citations received by patents filed in the same year and IPC class.
Originality	Average originality measure estimated following Hall and Trajtenberg (2004) for patent families filed in quarter t by applicant i .
Generality	Average generality measure estimated following Hall and Trajtenberg (2004) for patent families filed in quarter t by applicant i .
Pat. Quality	Average quality based on relative number of citations in respect to other patents filed in the same quarter for patent families filed in quarter t by applicant i .
Quality UKPO	Average quality of patent families filed in quarter t by applicant i at the UK patent office.
Quality EPO	Average quality of patent families filed in quarter t by applicant i at European patent offices.
Quality USPO	Average quality of patent families filed in quarter t by applicant i at the US patent office.
Quality WIPO	Average quality of patent families filed in quarter t by applicant i at the international patent office.
Quality ROWPO	Average quality of patent families filed in quarter t by applicant i at patent offices in the ROW.
No. Inventors	Average number of inventors listed in patents filed by applicant i in quarter t .
Sh. GB Inv.	Share of UK based inventors listed in patents filed by applicant i in quarter t .
Sh. EU Inv.	Share of EU based inventors listed in patents filed by applicant i in quarter t .
Sh. OECD Inv.	Share of inventors based in other non-European OECD countries listed in patents filed by applicant i in quarter t .
Sh. ROW Inv.	Share of inventors based in the rest of the world listed in patents filed by applicant i in quarter t .
No. Partners	Average number of co-applicants listed in patents filed by applicant i in quarter t .
Sh. GB Part.	Share of UK based co-applicants listed in patents filed by applicant i in quarter t .
Sh. EU Part.	Share of EU based co-applicants listed in patents filed by applicant i in quarter t .
Sh. OECD Part.	Share of co-applicants based in other non-European OECD countries listed in patents filed by applicant i in quarter t .
Sh. ROW Part.	Share of co-applicants based in the rest of the world listed in patents filed by applicant i in quarter t .
No. Patents High-Prod. Inv.	Number of patents filed by applicant i in quarter t including high-productivity inventors, defined as inventors in the top 10th percentile of the distribution of patents filed (Moretti, 2021).
No. Patents High-Prod. Part.	Number of patents filed by applicant i in quarter t including high-productivity partners, defined as applicants in the top 10th percentile of the distribution of patents filed (Moretti, 2021).
Av. No. High-Prod. Inv.	Average number of high-productivity inventors, defined as inventors in the top 10th percentile of the distribution of patents filed (Moretti, 2021), in patents filed by applicant i in quarter t .
Av. No. High-Prod. Part.	Average number of high-productivity partners, defined as applicants in the top 10th percentile of the distribution of patents filed (Moretti, 2021), in patents filed by applicant i in quarter t .
No. Patents High Int. Collab.	Number of new patent families filed in quarter t by applicant i in IPC subsections with higher than median likelihood of patents with cross-border collaborations.
No. Patents Low Int. Collab.	Number of new patent families filed in quarter t by applicant i in IPC subsections with lower than median likelihood of patents with cross-border collaborations.
No. Patents High RCA	Number of new patent families filed in quarter t by applicant i in IPC subsections in which the country of applicant i has a revealed comparative advantage (RCA) higher than 1 (Balassa, 1965).
No. Patents Low RCA	Number of new patent families filed in quarter t by applicant i in IPC subsections in which the country of applicant i has a revealed comparative advantage (RCA) lower than 1 (Balassa, 1965).
Citing Pat. w/GB Inv.	Average number of patents with only UK based inventors citing patents filed by applicant i in quarter t .
Citing Pat. w/GB Part.	Average number of patents with only UK based partners citing patents filed by applicant i in quarter t .
Citing Pat. w/EU Inv.	Average number of patents with only EU based inventors citing patents filed by applicant i in quarter t .
Citing Pat. w/EU Part.	Average number of patents with only EU based partners citing patents filed by applicant i in quarter t .
Citing Pat. w/(GB-EU) Inv.	Average number of patents with both UK and EU based inventors citing patents filed by applicant i in quarter t .
Citing Pat. w/(GB-EU) Part.	Average number of patents with both UK and EU based partners citing patents filed by applicant i in quarter t .
Funding Int. Collab.	Dummy variable equal to 1 if funded project consists of co-applicants from different countries, and 0 otherwise.

Table A3: Impact of policy uncertainty on UK organisations patenting activities: Poisson count model.

	(1)	(2)	(3)	(4)	(5)	(6)
	No. Patents	Dom. Pat.	Int. Pat.	EU-GB Pat.	UK PTO	EU PTO
$BXT_t \times UK_i$	-0.121*** (0.0268)	-0.112*** (0.0302)	-0.146** (0.0625)	-0.126 (0.104)	-0.130* (0.0665)	-0.140*** (0.0270)
Observations	318,936	307,841	63,666	9,944	29,025	306,160
	(7)	(8)	(9)	(10)	(11)	(12)
	No. Inv.	No. GB Inv.	No. EU Inv.	No. Part.	No. GB Part.	No. EU Part.
$BXT_t \times UK_i$	0.0162 (0.0141)	0.113** (0.0530)	-0.122* (0.0643)	-0.0181*** (0.00654)	0.0211 (0.108)	0.0728 (0.0950)
Observations	310,524	57,160	288,343	312,690	32,596	288,100
	(13)	(14)	(15)	(16)	(17)	(18)
	No. Granted	Breakthrough	H Int. Collab.	L Int. Collab.	H RCA IPC	L RCA IPC
$BXT_t \times UK_i$	-0.134*** (0.0325)	-0.123*** (0.0270)	-0.157*** (0.0269)	-0.0372 (0.0621)	-0.134*** (0.0297)	-0.0978* (0.0518)
Observations	284,337	85,454	257,732	192,214	232,275	244,189

Notes: Estimates from a panel two-way fixed effects (TWFE) difference-in-differences (DID) poisson count model using PATSTAT data at the applicant-quarter level for the period Q1/2012-Q4/2019. Organisation patent stock, quarter, and applicant-year fixed-effects included in all estimations. Robust standard errors reported in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A4: Impact of policy uncertainty on patents citing UK organisations patents.

	(1)	(2)	(3)	(4)	(5)	(6)
	Citing Pat. w\GB Inv.	Citing Pat. w\GB Part.	Citing Pat. w\EU Inv.	Citing Pat. w\EU Part.	Citing Pat. w\GB-EU Inv.	Citing Pat. w\GB-EU Part.
$BXT_t \times UK_i$	-0.000733 (0.0149)	-0.00806 (0.0160)	-0.0419*** (0.00699)	-0.0225*** (0.00467)	-0.0473*** (0.0108)	-0.0309*** (0.00685)
Observations	318,936	318,936	318,936	318,936	318,936	318,936
R-squared	0.780	0.864	0.820	0.844	0.831	0.848

Notes: Estimates from a panel two-way fixed effects (TWFE) difference-in-differences (DID) model using PATSTAT data at the applicant-quarter level for the period Q1/2012-Q4/2019. Organisation patent stock, quarter, and applicant-year fixed-effects included in all estimations. Robust standard errors reported in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A5: Heterogeneous impact of policy uncertainty on UK organisations patents: Organisation Productivity

	(1)	(2)	(3)	(4)	(5)	(6)
	No. Patents	Dom. Pat.	Int. Patents	EU-GB Pat.	UK PTO	EU PTO
Low Productivity	-0.0481* (0.0278)	-0.0032 (0.0271)	-0.0357 (0.0227)	0.0035 (0.0198)	0.0508 (0.0345)	-0.0010 (0.0380)
High Productivity	-0.0289** (0.0145)	-0.0133 (0.0155)	-0.0375*** (0.0107)	-0.0116* (0.0060)	-0.0059 (0.0136)	-0.0409*** (0.0153)
N	318,936	318,936	318,936	318,936	318,936	318,936
	(7)	(8)	(9)	(10)	(11)	(12)
	Sh. GB Inv.	Sh. EU Inv.	Sh. GB Part.	Sh. EU Part.	Pat. Granted	Breakthrough
Low Productivity	0.0174 (0.0270)	-0.0341 (0.0233)	0.0155 (0.0189)	-0.0079 (0.0113)	-0.0229 (0.0463)	0.0449*** (0.0160)
High Productivity	0.0142** (0.0064)	-0.0109** (0.0046)	0.0003 (0.0028)	0.0006 (0.0017)	-0.0580*** (0.0167)	-0.0281** (0.0122)
N	310,524	310,524	312,690	312,690	318,936	318,936
	(13)	(14)	(15)	(16)	(17)	(18)
	No. Citations	Originality	Generality	Pat. Quality	Int. Collab.	RCA IPC
Low Productivity	-0.0060 (0.0903)	0.0101 (0.0198)	-0.0193 (0.0326)	-0.0203 (0.0839)	-0.0151 (0.0433)	-0.0606 (0.0419)
High Productivity	-0.0754*** (0.0237)	0.0077* (0.0047)	-0.0077 (0.0068)	-0.0627*** (0.0211)	-0.0335** (0.0150)	-0.0317** (0.0158)
N	318,936	293,264	190,660	313,535	318,936	318,936

Notes: Estimates from a panel two-way fixed effects (TWFE) difference-in-differences (DID) model using PATSTAT data at the applicant-quarter level for the period Q1/2012-Q4/2019. Organisation patent stock, quarter, and applicant-year fixed-effects included in all estimations. Robust standard errors reported in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A6: Heterogeneous impact of policy uncertainty on UK organisations patents: Organisation Type

	(1)	(2)	(3)	(4)	(5)	(6)
	No. Patents	Dom. Pat.	Int. Patents	EU-GB Pat.	UK PTO	EU PTO
Firms	-0.0286* (0.0160)	-0.0132 (0.0169)	-0.0429*** (0.0113)	-0.0171*** (0.0060)	0.0009 (0.0148)	-0.0408** (0.0166)
Universities	-0.0449 (0.0289)	-0.0149 (0.0333)	-0.0212 (0.0267)	-0.0009 (0.0175)	-0.0319 (0.0321)	-0.0428 (0.0351)
Individuals	0.0024 (0.0574)	-0.0292 (0.0343)	0.0526 (0.0501)	0.1003** (0.0483)	0.0393 (0.0332)	0.0071 (0.0412)
Observations	310,274	310,274	310,274	310,274	310,274	310,274
	(7)	(8)	(9)	(10)	(11)	(12)
	Sh. GB Inv.	Sh. EU Inv.	Sh. GB Part.	Sh. EU Part.	Pat. Granted	Breakthrough
Firms	0.0140** (0.0071)	-0.0172*** (0.0051)	-0.0003 (0.0025)	-0.0017 (0.0014)	-0.0562*** (0.0180)	-0.0393*** (0.0133)
Universities	0.0153 (0.0141)	0.0032 (0.0098)	0.0048 (0.0114)	0.0069 (0.0072)	-0.0818** (0.0394)	0.0396 (0.0262)
Individuals	-0.0094 (0.0186)	0.0340 (0.0234)	-0.0126 (0.0258)	0.0276 (0.0197)	0.0313 (0.0546)	0.0057 (0.0301)
Observations	301,908	301,908	304,028	304,028	310,274	310,274
	(13)	(14)	(15)	(16)	(17)	(18)
	No. Citations	Originality	Generality	Pat. Quality	Int. Collab.	RCA IPC
Firms	-0.0993*** (0.0249)	0.0068 (0.0049)	-0.0162** (0.0073)	-0.0839*** (0.0225)	-0.0300* (0.0165)	-0.0387** (0.0170)
Universities	0.0636 (0.0626)	0.0179 (0.0128)	0.0393** (0.0168)	0.0501 (0.0521)	-0.0575* (0.0310)	-0.0126 (0.0358)
Individuals	-0.0160 (0.1253)	0.00003 (0.0239)	-0.0352 (0.0308)	0.0002 (0.1177)	0.0167 (0.0687)	-0.0672 (0.0675)
Observations	310,274	285,505	186,495	304,958	310,274	310,274

Notes: Estimates from a panel two-way fixed effects (TWFE) difference-in-differences (DID) model using PATSTAT data at the applicant-quarter level for the period Q1/2012-Q4/2019. Organisation patent stock, quarter, and applicant-year fixed-effects included in all estimations. Robust standard errors reported in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A7: IPC technological subsections by UK revealed comparative advantage and international collaboration intensity.

IPC Code	Subsector	UK RCA	IPC Code	Subsector	Int. Collab.
C3	METALLURGY	0.1935163	E0	BUILDING	0.0058128
D0	TEXTILES	0.2599383	A4	PERSONAL OR DOMESTIC ARTICLES	0.0068957
B2	SHAPING INSTRUMENTS	0.531276	F4	WEAPONS & BLASTING	0.0074802
B3	SHAPING INSTRUMENTS	0.5347388	B4	PRINTING	0.0080123
E0	BUILDING	0.5371273	G2	NUCLEAR	0.0088612
F2	LIGHTING & HEATING	0.5844558	D0	TEXTILES	0.0090362
A0	FOODSTUFFS & TOBACCO	0.6087089	D2	PAPER	0.0093289
C0	CHEMISTRY	0.6224141	B6	TRANSPORTING	0.0094522
B4	PRINTING	0.6248173	F1	ENGINEERING	0.0099396
A4	PERSONAL OR DOMESTIC ARTICLES	0.68577	F2	LIGHTING & HEATING	0.0102751
B0	SEPARATING & MIXING INSTRUMENTS	0.7053609	F0	ENGINES OR PUMPS	0.0107885
B6	TRANSPORTING	0.7266667	B2	SHAPING INSTRUMENTS	0.0108301
D2	PAPER	0.7568154	B3	SHAPING INSTRUMENTS	0.0153402
C2	METALLURGY	0.8681602	A0	AGRICULTURE	0.0173973
G1	ICT	0.9412378	B0	SEPARATING & MIXING INSTRUMENTS	0.0174872
F1	ENGINEERING	0.9605156	C2	METALLURGY	0.0219095
G2	NUCLEAR	1.037507	G0	MEASURING & OPTICS	0.0221588
F4	WEAPONS & BLASTING	1.068576	H0	ELECTRIC ELEMENTS & TECHNIQUES	0.0221737
A2	FOODSTUFFS & TOBACCO	1.080504	C0	CHEMISTRY	0.025048
A6	HEALTH & LIFE-SAVING	1.115007	A2	FOODSTUFFS & TOBACCO	0.025158
B8	NANOTECHNOLOGY	1.142	B8	NANOTECHNOLOGY	0.0269633
G0	MEASURING & OPTICS	1.171093	G1	ICT	0.0279003
H0	ELECTRIC ELEMENTS & TECHNIQUES	1.480595	C4	COMBINATORIAL TECHNOLOGY	0.0356662
F0	ENGINES OR PUMPS	1.568657	A6	HEALTH & LIFE-SAVING	0.0366446
C1	CHEMISTRY	1.717823	C3	METALLURGY	0.0378238
C4	COMBINATORIAL TECHNOLOGY	2.04079	C1	CHEMISTRY	0.0547124
E2	MINING	2.636878	E2	MINING	0.0736737

Notes: Revealed Comparative Advantage (RCA) measured for each IPC subsection and country using PATSTAT data in the pre-treatment period (Q1/2012-Q4/2015) using the Balassa (1965) index. IPC subsection propensity to international collaborations measured using PATSTAT data in the pre-treatment period (Q1/2012-Q4/2015) for all countries in our sample as the share of patents with applicants from different countries over the total number of patents filed.

Table A8: Impact of policy uncertainty on UK organisations patenting activities: Brexit Uncertainty Index.

	(1)	(2)	(3)	(4)	(5)	(6)
	No. Patents	Dom. Pat.	Int. Patents	EU-GB Pat.	UK PTO	EU PTO
$BUI_t \times UK_i$	-0.0176*** (0.00611)	0.00149 (0.00282)	0.00278 (0.00459)	-0.0176*** (0.00650)	0.00553 (0.00536)	-0.0246*** (0.00651)
Observations	318,936	318,936	318,936	318,936	318,936	318,936
R-squared	0.829	0.830	0.781	0.775	0.842	0.831
	(7)	(8)	(9)	(10)	(11)	(12)
	Sh. GB Inv.	Sh. EU Inv.	Sh. GB Part.	Sh. EU Part.	Pat. Granted	Breakthrough
$BUI_t \times UK_i$	-0.000465 (0.00294)	-0.00749*** (0.00210)	-0.00238 (0.00164)	-0.000420 (0.00092)	-0.0299*** (0.00686)	-0.0126** (0.00550)
Observations	310,524	310,524	312,690	312,690	318,936	318,936
R-squared	0.939	0.881	0.993	0.982	0.812	0.668
	(13)	(14)	(15)	(16)	(17)	(18)
	No. Citations	Originality	Generality	Pat. Quality	Int. Collab.	RCA IPC
$BUI_t \times UK_i$	-0.0172 (0.0109)	-0.000589 (0.00189)	0.000362 (0.00276)	-0.0181** (0.00904)	-0.0158** (0.00658)	-0.0167** (0.00673)
Observations	318,936	293,264	190,660	313,535	318,936	318,936
R-squared	0.768	0.599	0.555	0.664	0.843	0.838

Notes: Estimates from a panel two-way fixed effects (TWFE) difference-in-differences (DID) model using PATSTAT data at the applicant-quarter level for the period Q1/2012-Q4/2019. Organisation patent stock, quarter, and applicant-year fixed-effects included in all estimations. Robust standard errors reported in parenthesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Working Papers of Eesti Pank 2026

No 1

Erwan Gautier, Cristina Conflitti, Daniel Enderle, Ludmila Fadejeva, Alex Grimaud, Eduardo Gutiérrez, Valentin Jouvanceau, Jan-Oliver Menz, Alari Paulus, Pavlos Petroulas, Pau Roldan-Blanco, Elisabeth Wieland. Consumer Price Stickiness in the Euro Area During an Inflation Surge

No 2

Ana Kujundzic. Educational Assortative Mating and Household Income Inequality: Evidence from Brazil, Indonesia, Mexico, and South Africa

No 3

Nicolas Reigl. Monetary Policy, Mortgage Structure, and Household Sentiment: Evidence from the Euro Area