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The Battle for Strategic Minerals and Technological Sovereignty: An RCA Study of China-EU Rare Earth Trade Dynamics[1]

Olivia Marie Blanchard[2]

Abstract

This paper examines the dynamics of the trade in rare earth materials (REM) between China and the European Union (EU) from 2020 to 2024, focusing on revealed comparative advantage (RCA), export values, and geopolitical policy shifts. China maintains a dominant position with RCA values consistently above 1.4 and export volumes surpassing those of the EU by large margins. However, Chinese export restrictions in 2024 caused a sharp decline in both RCA and exports, signaling significant supply chain vulnerabilities. The EU's intermittent export growth did not translate into increased competitiveness, highlighting persistent dependency. These findings underscore the urgent need for EU policy interventions to build domestic capacity, enhance recycling, and foster innovation to reduce supply risks amid past and current export regulations. Future research should examine firm-level innovation dynamics and the long-term effects of policy changes on the rare-earth sector's resilience and strategic autonomy.

Key words

Rare Earth Materials (REMs), Revealed Comparative Advantage, China, European Union, Trade Policy, Innovation and Supply Chain Resilience

JEL Classification: F13, O31, Q35

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Introduction

Rare earth materials (REMs) are essential to the contemporary global economy, notably in green technologies, electronics, aerospace, and defense systems (Golev et al., 2014; Humphries, 2013; European Commission, 2020). Although their name suggests scarcity, these elements are relatively abundant but are rarely found in economically exploitable concentrations outside limited geographic regions. China currently dominates global REM production and processing, controlling over 70% of mining output and more than 90% of processing capacity (Lewis, 2025; Josephs, 2025; Ghiaie & Gorelli, 2025). This near-monopoly affords China strategic leverage over global markets and geopolitics, posing particular challenges for regions such as the European Union (EU), which relies heavily on REMs imports, as this paper argues.

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[2] Mgr. Olivia Marie Blanchard, Bratislava University of Economics and Business, Faculty of Commerce, Department of International Business, Dolnozemská cesta 1, 852 35 Bratislava, olivia.blanchard@euba.sk Massachusetts Institute of Technology, Sloan School of Management, 100 Main Street, Cambridge, MA 02142, omblanch@mit.edu demonstratesREM imports, as this paper argues

The EU has limited domestic production capacity but is pursuing strategies to bolster local sourcing and processing of rare earths amidst escalating geopolitical risks and supply vulnerabilities. This study employs the Revealed Comparative Advantage (RCA) method to assess the export competitiveness of China and the EU concerning key rare earth elements. It discusses policy implications, impacts on global value chains (GVCs), and innovation trajectories in both regions.

China's dominance is underpinned by extensive mineral reserves, an integrated supply chain from extraction to magnet manufacturing, and supportive governmental policies. In 2025, China enforced stricter export controls, including licensing requirements for neodymium, praseodymium, cerium, and dysprosium, citing national security concerns (Davidson, 2025). These controls extend extraterritorially to products containing Chinese-sourced materials or technologies, aiming to preserve strategic resources, promote domestic value addition, and enhance geopolitical influence amid US and EU efforts to diversify supply sources. Despite a temporary suspension of some export restrictions following diplomatic negotiations, China continues to tightly regulate REM exports, contributing to global supply chain uncertainties (Jowitt et al., 2018).

The Chinese policy landscape is evolving rapidly. In April 2025, China imposed export restrictions on seven types of REMs, notably heavy and medium rare earths, which are vital for defense and advanced manufacturing. By October 2025, additional elements were added to the control list, accompanied by licensing mandates on the export of REMs and related products, including extraterritorial controls. A temporary suspension of these measures was enacted in late 2025 as part of a U.S.-China agreement, though the initial restrictions remain in effect (Davidson, 2025). These export controls provide China with significant strategic leverage, allowing delays or denial of licenses for products critical to national security and high-tech industries, thereby creating considerable uncertainty for E.U. and U.S. buyers and impacting global supply chains.

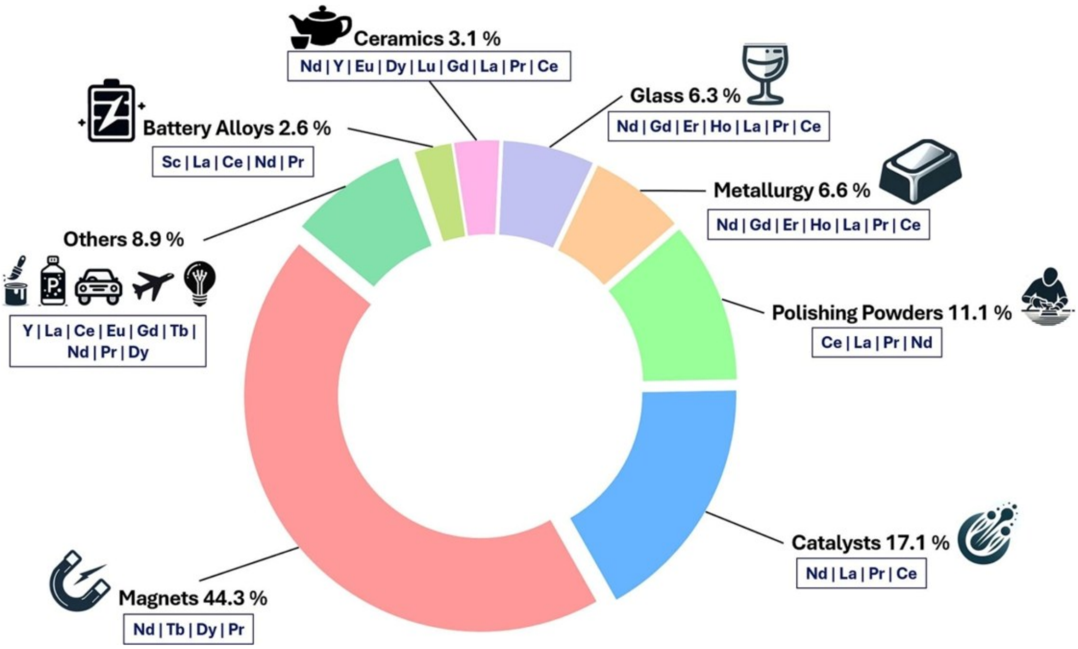
Despite global efforts, especially in the European Union and the U.S. to diversify and develop alternatives to Chinese rare earths, experts indicate that China's dominance will likely persist for at least another decade due to its entrenched investment in the entire supply chain. The EU's rare earth production remains nascent but growing, with key projects in France (Solvay facility), Norway (Fen deposit), Sweden, and Finland aiming to boost local output and processing (Hache, 11/06/2024; Josephs, 07/08/2025; Ghiaie & Gorelli, 29/10/2025). The EU imports more than 90% of its REM needs from China and other countries, including Russia and Malaysia, posing significant supply risks (Hintermayer & Hmaidi, 2025; Eurostat Joint Research Center, June 2025).

To prepare for these challenges, the EU has introduced strategies such as the

Critical Raw Materials Act to secure the bloc's REM supply, promote sustainable extraction, diversify sourcing, and adopt circular-economy approaches. The act sets specific benchmarks for domestic capacity by 2030, including mining 10%, processing 40%, and recycling 25% of the EU's strategic raw materials needs. The EU policy also emphasizes the development of downstream manufacturing capabilities to capture greater value from the rare-earth supply chain (European Union, 03/05/2024). Nonetheless, challenges persist due to limited scale, technological gaps in refining, and the capital intensity of mining ventures.

In this context, this study seeks to answer the following core research question: How have China's evolving rare earth export controls and the European Union's policy responses from 2020 to 2024 influenced the revealed comparative advantage, export competitiveness, and innovation capacity of both regions in rare earth materials, and what are the implications for global value chain resilience and strategic autonomy in advanced technologies?

Fig. 1 - REEs applications by market sector



Source: Gajendra et al., 2025, p.2

Figure 1 depicts the primary end-use sectors for rare earth materials (REMs) globally, detailing their demand shares and the specific elements employed. Permanent magnets dominate, accounting for 44.3% of global REM consumption, primarily involving neodymium (Nd), terbium (Tb), dysprosium (Dy), and praseodymium (Pr). Other significant uses include catalysts (17.1%), polishing powders (11.1%), and metallurgy (6.6%), with ceramics (3.1%), glass (6.3%), battery alloys (2.6%), and various "other" sectors making up the remainder. Each application relies on distinct rare earth combinations, underscoring industries' technological dependence on these critical materials, including electronics, renewable energy, automotive, and advanced manufacturing. REMs comprise 17 chemically similar metals in the periodic table, including the fifteen lanthanides plus scandium and yttrium, which have unique electronic, magnetic, and optical properties vital for high-performance magnets, batteries, electronics, green energy, and defense (Gajendra et al., 2025; Humphries, 2013; Golev et al., 2014; Ghiaie & Gorelli, 2025).

Trade flows are examined primarily under HS code 2846, covering compounds of rare-earth metals, yttrium, scandium, or their mixtures. Sub-categories include 2846.10 (cerium compounds) and 2846.90 (other rare-earth compounds such as lanthanum, neodymium, praseodymium, and dysprosium). This code captures both raw and processed REM inputs relevant to industrial and technological sectors, ensuring that the trade data discussed pertain chiefly to geopolitically sensitive materials for advanced manufacturing and supply chains, especially between China, the EU, and the global market.

1 Methodology

The Revealed Comparative Advantage (RCA) index, coined by Balassa (1965), measures a country's export specialization relative to the global average. An RCA_{ij} value greater than 1 indicates that country i exports product j more intensively than the world average, suggesting a revealed comparative advantage in that product or sector. Conversely, an RCA_{ij} value below 1 implies a revealed comparative disadvantage. Higher RCA values, therefore, reflect stronger specialization and competitiveness in specific industries, while lower values may signal sectors with limited export strength or strategic potential for diversification. The Balassa Index (1) is calculated as follows:

$$RCA_{ij} = \frac{(X_{ij}/X_{it})}{(X_{wj}/X_{wt})} \quad (1)$$

Where:

- X_{ij}: Exports of product j by country ix
- X_{it}: Total exports of all products by country i
- X_{wj}: World exports of product j ● X_{wt}: Total world exports of all products

1.1 Interpretation

- If $RCA_{ij} > 1$: Country i has a **revealed comparative advantage** in product j (it exports proportionally more of j than the world average).
- If $RCA_{ij} < 1$: Country i has a **revealed comparative disadvantage** in product j.

The Revealed Comparative Advantage (RCA) serves as a metric for evaluating a nation's relative export performance in a particular commodity or sector compared to the global average. An RCA value exceeding 1 indicates a comparative advantage for the country in question. In response to the need for robust measurement, a considerable body of literature has emerged, employing diverse methodological approaches. Vollrath (1991) appraised alternative measures of revealed advantage and introduced import-based variants to mitigate asymmetries; Hinloopen and Marrewijk (2001) examined the empirical distribution of the Balassa index and recommended practical classification thresholds (RCA<1: comparative disadvantage; 1–2: weak comparative advantage; 2–4: moderate comparative advantage; ≥4: strong comparative advantage) to improve consistent interpretation over time.

2 Results and Discussion

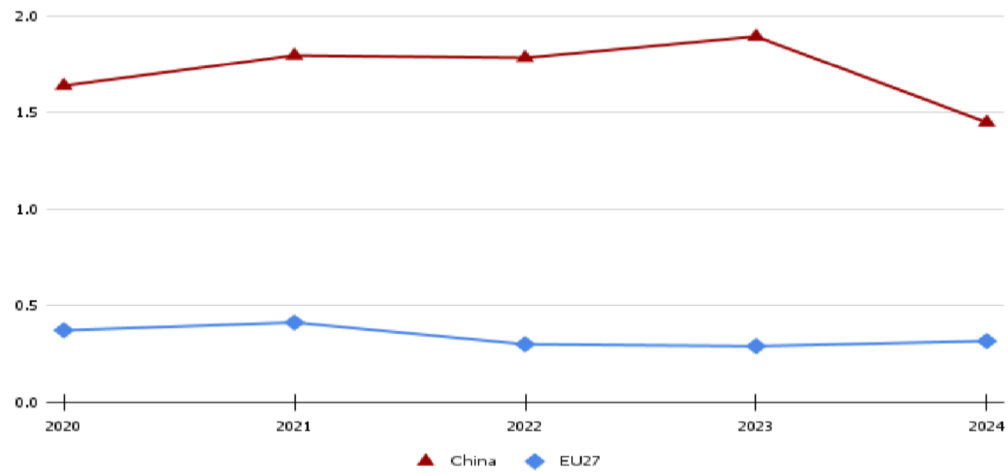
The period 2020–2024 was chosen for this RCA analysis due to its significant relevance to the global rare earth mineral trade and policy actions. During this time, China implemented and expanded licensing restrictions and export controls on rare earth elements, affecting international trade and supply chains (Lewis, 10/10/2025). Concurrently, the European Union launched the European Green Deal and advanced the Critical Raw Materials Act (CRMA), focusing on supply security and innovation for critical minerals, including rare earths (European Commission, 03/05/2024). The COVID-19 pandemic, commencing in 2020, further exposed vulnerabilities in global supply networks, prompting China and the EU to reconsider their resource security and technological independence strategies (Chapman, 2018). This timeframe enables alignment with recent policies and current trade data from sources such as TradeMap and UN Comtrade (TradeMap ITC, 11/2025).

The analysis examines trade flows at the HS six-digit level, ensuring specificity and comparability across years. This approach captures policy-driven shifts in China's rare earth exports and enables insight into the EU's strategic repositioning (Bradsher, 2010; Humphries, 2013; European Commission, 2020). While extending the analysis could highlight longer-term trends, this period best reflects the ongoing transformation of global value chains and innovation strategies driven by recent policy shifts.

2.1 China's Rare Earth Industry and Policy Landscape

China's rare earth materials (REM) sector is characterized by substantial geological reserves, a comprehensive industrial ecosystem, and a longstanding state commitment to resource nationalism and strategic development (Bradsher, 2010). Over the past two decades, China has consistently accounted for over 70% of global REM production and more than 90% of refining capacity, exerting significant influence over upstream extraction and downstream manufacturing (Humphries, 2013; Ghiaie & Gorelli, 2025; Attinasi et al., 2025). This dominance is supported by vertically integrated value chains, state subsidies, preferential credit, and coordinated trade policies (Mancheri et al., 2019).

Graph 1 - Rare Earth Materials Revealed Comparative Advantage Over Time (2020-2024)



Source: O. Blanchard, 2025

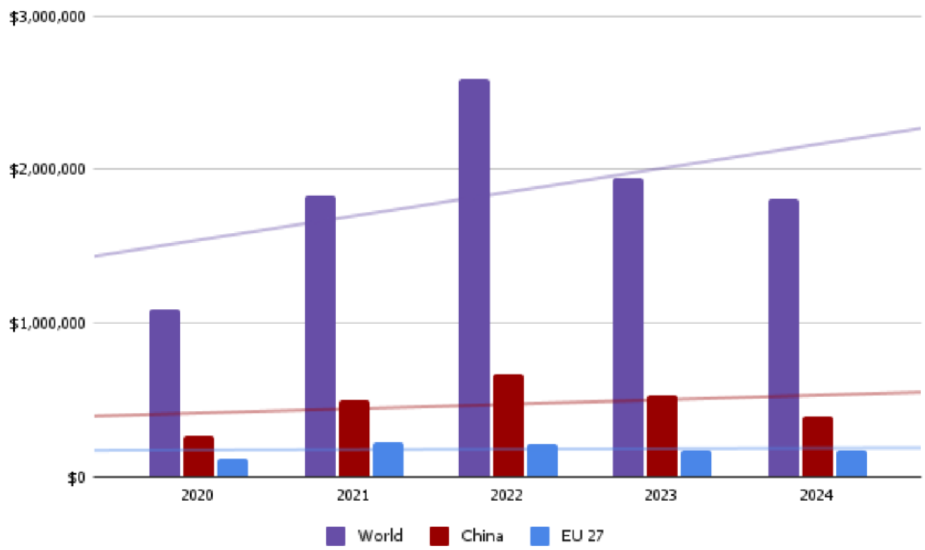
The analysis of RCA values from 2020 to 2024 indicates a persistent and significant disparity between China and the EU27 in rare-earth element export competitiveness (see Graph 1). China's RCA rose from 1.64 in 2020 to a peak of 1.90 in 2023, before declining to 1.45 in 2024 following stricter export controls (Banin et al., 06/2025). Conversely, the EU27's RCA remained narrowly between 0.37 and 0.41, reflecting a deep-rooted comparative disadvantage and continued dependence on external supplies, as measured by Hinloopen & Marrewijk's (2021) and Balassa's (1965) scales. These findings confirm that China's export specialization in REMs is structurally resilient to policy shocks, whereas the EU27's reliance endures despite policy initiatives since 2024.

China's 2025 export licensing restrictions, justified as resource conservation and geopolitical leverage (Lewis, 10/10/2025), imposed strict quotas and licensing on primary REM exports and extended extraterritorial restrictions to processed or manufactured products using Chinese-origin REMs and technologies, regardless of ultimate transformation location. This policy has introduced uncertainty into global value chains, particularly affecting high-tech sectors such as clean energy, communications, and defense, which are highly vulnerable to supply disruptions (Chapman, 2018; Ghiaie & Gorelli, 29/10/2025). By linking access to REMs to national security and industrial policy interests, Beijing continues to strategically leverage its dominance in this domain (Kiggins, 2015).

2.2 The European Union's Rare Earth Industry and Policy Landscape

Compared to China, the EU's rare earth industry remains nascent but carries strategic importance due to increasing supply chain vulnerabilities. Europe's limited mineral resources and fragmented development efforts have resulted in minimal primary extraction and processing capacities (Mancheri et al., 2019). Initiatives such as Solvay's La Rochelle chemical plant in France, along with prospective mining projects at the Fen deposit in Norway and Norra Karr in Sweden, represent targeted investments to bolster domestic supply (European Commission, 03/05/2024). The recent Critical Raw Materials Act (CRMA) signifies a shift towards sustainable extraction, supply diversification, and circular economy principles, aiming to reduce reliance on single suppliers and promote resource recycling (Eurostat, 2025).

Graph 2 - Rare Earth Materials Exported Value in Hundred Thousand US Dollars Over Time (2020-2024)



Source: O. Blanchard, 2025

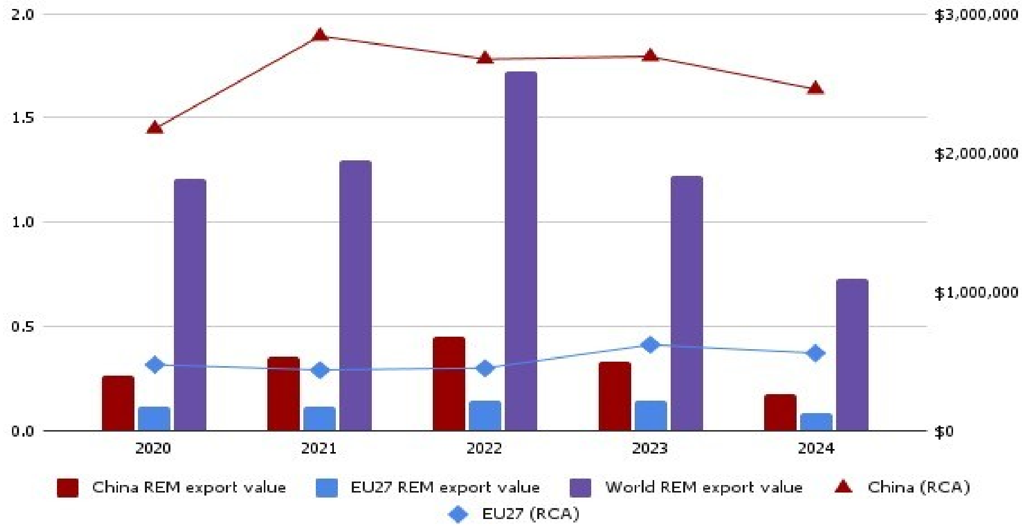
Absolute export values (graph 2) reinforce this structural imbalance: China's REMs export value surges from approximately $263 million (hundred thousand USD units in the graph) in 2020 to a high of $670 million in 2022, before declining to $393 million in 2024. The EU27, by contrast, rises from $122 million in 2020 to $219 million in 2021 but falls back to $165 million by 2024. The global total peaks at $2.59 billion in 2022. Notably, even during peak years, EU exports remain a fraction of China's, underlining the EU's limited share and supply vulnerability. The 2023–2024 decline for both China and the world corresponds directly to recently enacted Chinese export restrictions, illustrating the dominant impact of Chinese policy interventions on global volumes. Worldwide, the value of REMs is accelerating exponentially, as suggested by the purple trendline, while the value of European REMs has not increased significantly over this period: China's has.

The core obstacles to scaling REM production in the EU include the high capital intensity of new projects, the technological complexity of separation processes, and market uncertainties stemming from price volatility and policy risk (Ghiaie & Gorelli, 29/10/2025). EU projects also face competition not only from incumbent Chinese operators but also from alternative suppliers seeking to fill the widening gap left by tightening Chinese controls, raising questions about the region's ability to scale the rare-earth supply chain economically and sustainably.

2.3 Policy Implications and Impact on Global Value Chains

China's increasingly restrictive export policy has redoubled concerns about the security and resilience of global value chains, particularly those underpinning advanced manufacturing, renewable energy, and defense (Chapman, 2018). International buyers, especially in the EU, Japan, and the US, have faced heightened supply uncertainty due to the prospect of arbitrary delays or denials of strategic REM shipments, rising trade deficits with China, and tariff wars (Capistraneau & Nadeau, 24/07/2025).

Graph 3 - Rare Earth Materials: RCA and Export Values in Hundred Thousand USD for China, EU27, and World (2020–2024)



Source: O. Blanchard, 2025

The imposition of extraterritorial controls compounds this uncertainty by subjecting foreign firms using Chinese-origin REMs or technology to new layers of Chinese regulatory oversight, even if further processing occurs outside Chinese borders (Lewis, 2025).

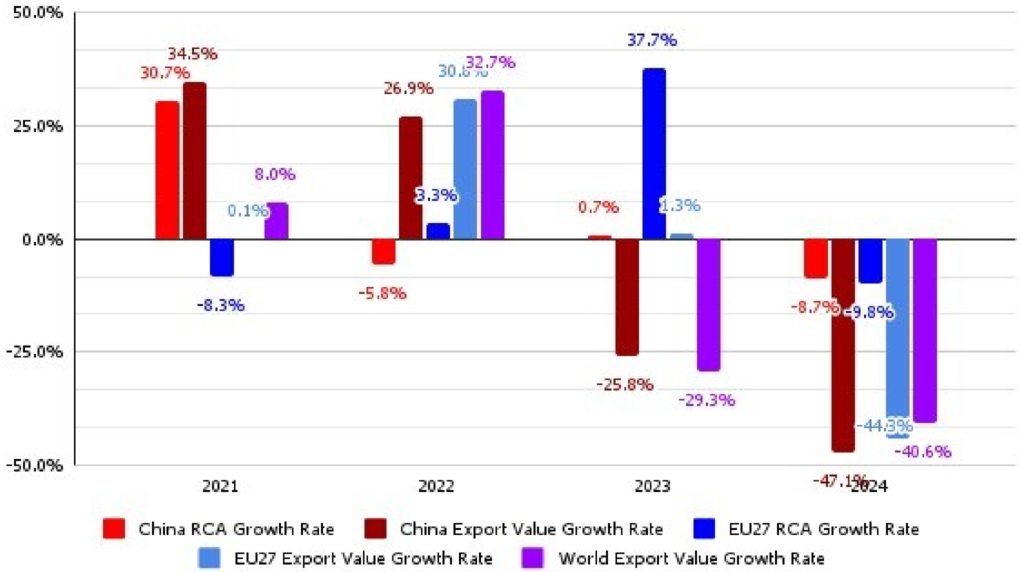
A synthesis of comparative advantage and scale (Graph 3) demonstrates a strong correlation between China's high RCA and its dominance in export value, particularly in

2021–2022, when RCA remained between 1.90 and 1.79, and export values peaked.

Conversely, the EU27's low RCA and export value highlight a dual challenge: limited specialization and scale. The dual-axis chart indicates that fluctuations in China's RCA and export value, especially a projected decline in 2024, impact global trends, revealing the vulnerability of value chains to Chinese policy shifts and the EU27's limited catch-up, despite China's significant RCA relative to its REMs exports and the EU.

Recent EU policies focus on domestic resource development, recycling, and innovation to substitute for Chinese rare earths or reduce dependency (Eurostat, 2025). These initiatives have sparked preliminary shifts in global supply chains, including new mining projects, enhanced intra-European R&D collaboration, and efforts to "friend-shore" supply from allied third countries (Jowitt et al., 2018). However, progress remains constrained by capacity and technological gaps, and most EU and allied manufacturers still rely on imported Chinese REM compounds and magnets or those processed with Chinese technology. This ongoing vulnerability underscores the need for coordinated policy action and robust multilateral frameworks for the governance of critical minerals (Mancheri et al., 2019).

Graph 4 - Annual Growth of RCA and Export Value of Rare Earth Materials for China and EU27 (2020–2024)



Source: O. Blanchard, 2025

Annual growth rates in RCA and export value (graph 4) reveal the sector's volatility and susceptibility to shocks. In 2021, China's RCA surged by 34.5% compared to 2020, with export value increasing by 30.7%. However, projections for 2024 indicate significant declines: RCA falling by 47.1% and export value decreasing by 44.3%. Notably, in December 2023, China imposed a ban on REE extraction and separation technologies, profoundly impacting global REE supply chains. China's technical expertise in solvent extraction processing, where Western firms face challenges, underscores its dominance in this domain (Baskaran & Schwarz, 2025). Although new separation and processing facilities are under construction, their full operationalization may take years. Meanwhile, the EU27 experienced intermittent export growth in 2022 and 2023 (up to 32.7% and 37.7%, respectively), yet RCA growth remained weak or negative, indicating limited improvements in strategic autonomy. Global export growth also mirrors China's volatility, declining by 40.6% in 2024, emphasizing the sector's sensitivity to China-driven policy shifts and the persistent challenge of structural competitiveness reforms.

China's export controls have heightened awareness among EU industries of supply chain vulnerabilities, prompting efforts to shift to domestic sourcing, recycle, and diversify to reduce reliance on Chinese exports, reshape GVCs, and enhance resilience. Such shifts may involve geographic reconfiguration across raw-material extraction, refining, and manufacturing stages (Banin et al., 2025). Nonetheless, the EU faces significant hurdles in scaling processing capacity comparable to China's, risking dependence on intermediate import stages or licensing of Chinese technology. Trade tensions and export restrictions highlight the necessity for coordinated international governance of critical minerals.

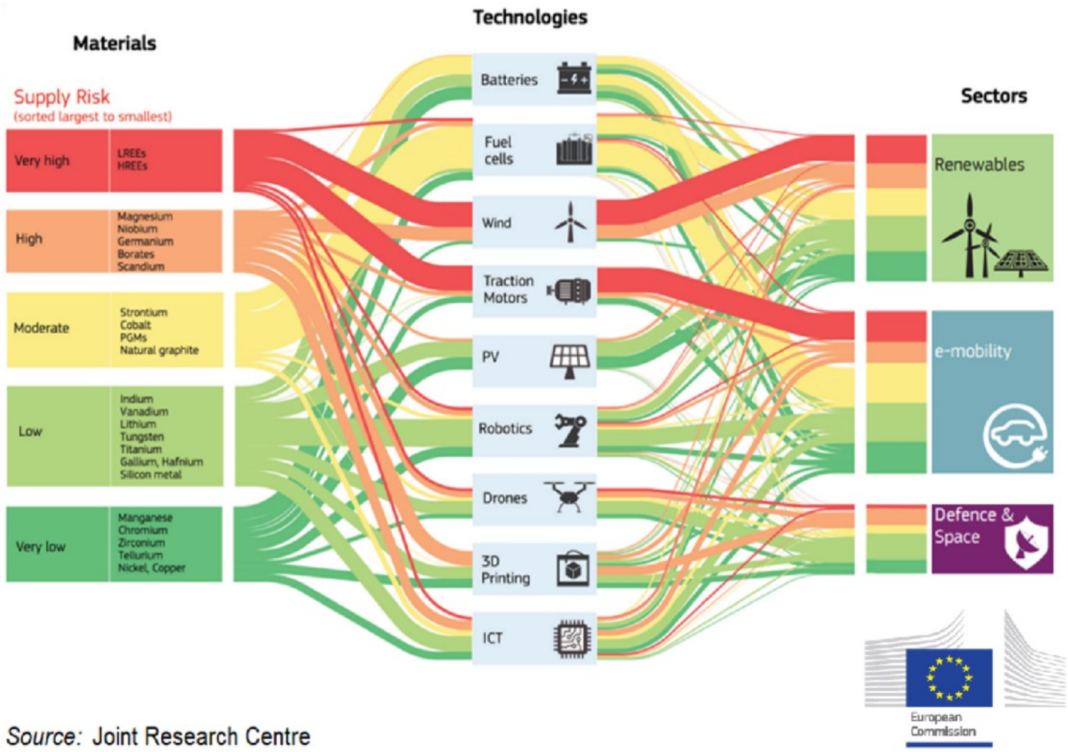
2.4 Innovation Challenges and Outlook for the EU

The data depicts a rare-earth sector predominantly controlled by China, both in specialization and scale. Despite incremental policy initiatives, the EU27 remains dependent on imports, with growth rates and export flows heavily influenced by Chinese regulatory decisions that impact global markets. Although the EU exhibits periodic export value increases, these are short-lived and not reflected in sustained improvements in relative comparative advantage (RCA). Consequently, achieving true supply chain resilience and competitive autonomy necessitates systemic transformation beyond current measures.

Integrating the supply of rare-earth materials with innovation-driven research and development (R&D) and startup ecosystems is crucial for maintaining and enhancing industrial competitiveness, particularly in the fields of advanced manufacturing and energy. This integration fosters a robust innovation environment, promotes sustainable practices, and ensures the steady availability of essential materials for technological advancement. China's dominance in RCA (rising from 1.64 in 2020 to 1.90 in 2023) has facilitated strategic investments in high-value segments like magnet production and battery chemistry, fostering feedback loops between supply security and technological innovation (Bradsher, 2010; Mancheri et al., 2019). Conversely, the EU27's low RCA (0.28–0.42) and modest export volumes limit the capacity of European startups and research consortia to scale complex REM-dependent technologies, heightening exposure to supply disruptions and price shocks.

Bridging this innovation gap requires coordinated investment in domestic extraction, processing, recycling, and mining startups, as well as collaboration among research institutes, industry, and policymakers (Eurostat, 2025; Jowitt et al., 2018). Despite policy efforts such as the Critical Raw Materials Act and green industrial funding, recent growth analysis shows volatility with no structural breakthroughs, as evidenced by transient export growth (up to 30.9% in 2022) followed by contractions (1.3% in 2023).

Fig. 2 - Critical raw materials and their supply risk



Source: Eurostat for the European Commission Joint Research Center, June 2025

Figure 2, from the European Commission's Joint Research Centre, underscores the systemic importance of critical raw materials with very high supply risk: the exceptionally light and heavy rare-earth elements (LREEs, HREEs) for advanced and strategic technologies. These high-risk materials are foundational to batteries, fuel cells, wind turbines, traction motors, and robotics, and play essential roles in the renewables, e-mobility, defence, and space sectors. Critically, the figure also highlights the indispensable role of rare earths in information and communication technology (ICT) and 3D printing, which are core domains for artificial intelligence (AI) hardware and semiconductor supply chains. The thick red risk flows connecting rare earths to ICT illustrate how supply disruptions in these minerals could rapidly propagate through the value chain, threatening the manufacturing of high-performance chips, quantum processors, and AI-enabling components. Consequently, securing the supply of rare earths is crucial not only for energy and defense but also for Europe's AI, digital sovereignty, and advanced technology leadership goals. The European AI Strategy seeks to position the EU as a global leader in AI, emphasizing that AI should be human-centric and trustworthy (European Union, 25.05.2018).

Europe's innovation horizon is inextricably linked to reliable access to REMs, given the centrality of these materials to artificial intelligence (AI) hardware and semiconductor supply chains (European Union, 25.05.2018). The concentration of REM processing in China exposes European chip and AI startups to uncertainty, as export controls and trade disruptions can delay or curtail access to neodymium, praseodymium, and dysprosium: elements essential for sensors, processors, advanced motors, and quantum computing (Mancheri et al., 2019). This vulnerability is amplified by the fact that the EU27's RCA shows minimal improvement, indicating that increased R&D spending or scaling local output has yet to translate into meaningful trade competitiveness in REMs.

However, these challenges also create a fertile environment for transformational innovation. The EU's push for diversified sourcing, sustainable mining, and closed-loop recycling aligns with a broader strategic vision to leapfrog into higher-value segments of the REM value chain (Eurostat, 2025; Jowitt et al., 2018). Investments in advanced separation technologies, urban mining, and proprietary refining will be essential to reduce dependency and unlock new forms of comparative advantage. Emerging clusters such as the battery and green magnet initiatives in France and Scandinavia, and the patenting of recycling technologies, are increasing, signaling opportunities for startups and SMEs to drive technology-led solutions for resource efficiency, process innovation, and alternative chemistries (Piore et al., 2025). Ultimately, sustained, systemic change will depend not merely on policy pronouncements or episodic export growth, but on forging durable links between resource security and a vibrant, internationally competitive innovation ecosystem.

Conclusion

This study conducts a quantitative and qualitative analysis of the trade dynamics related to rare earth materials (REM) between the People's Republic of China and the European Union (EU) from 2020 to 2024, with a focus on revealed comparative advantage (RCA), export values, regulatory changes, and innovation challenges. The principal findings substantiate China's entrenched and resilient hegemony in both sectoral specialization and export scale, as evidenced by RCA figures that have persistently exceeded 1.4 and export values that have reached nearly $670 million. In contrast, the EU27 remains a peripheral actor, characterized by RCA values markedly below 0.5 and an enduring dependence on imports, estimated at approximately 85–90%, chiefly sourced from China. China's imposition of stricter export controls in 2024 precipitated pronounced volatility, with both RCA and export volumes contracting by over 40%, leading to far-reaching global repercussions. Besides, some episodes of temporary export growth within the EU failed to signal substantive gains in competitive specialization, instead accentuating persistent structural impediments to the region's advancement in the rare-earth value chain.

In light of these findings, it is incumbent upon policymakers and industrial stakeholders to prioritize the formulation of integrated strategies to reduce European dependence on rare-earth imports while fostering resilience through innovation. Strategic recommendations encompass expanding domestic mining and processing capabilities through streamlined regulatory approvals and targeted capital investments, advancing recycling technologies to exploit the potential of urban mining, and cultivating robust research–industry collaborations to develop proprietary refining and magnet manufacturing technologies. While the European Critical Raw Materials Act and concomitant sustainability frameworks offer a foundational policy architecture, surmounting extant technical and financial barriers remains a critical challenge. Furthermore, enhancing supply chain transparency and consolidating strategic partnerships with allied nations are vital measures to mitigate emergent geopolitical risks.

Future research endeavours should be broadened to encompass firm-level innovation dynamics and detailed case studies of nascent European REMs initiatives, thus clarifying the fundamental reasons behind competitive convergence. Interdisciplinary analyses that synthesize environmental sustainability, economic imperatives, and geopolitical dynamics will be instrumental in informing comprehensive policy frameworks. Additionally, longitudinal examinations of export policy adjustments in the post-2024 era will be essential for discerning the ramifications on trade structures and technological sovereignty.

In sum, the rare-earth conundrum underscores the multifaceted complexity of critical mineral governance amid escalating resource nationalism and intensifying technological competition. The realization of European strategic autonomy will require aligning resource security objectives with innovation and sustainability imperatives, necessitating integrated policy interventions underpinned by robust empirical evidence and international collaboration.

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Do R&D Investments Translate into Trademark Activity? Evidence from a European Panel Study[1]

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Abstract

This study investigates the determinants of trademark activity across the European Union member states and the United Kingdom over the period 2014–2023 using a panel data approach with fixed effects. Drawing on data from the World Intellectual Property Organization and World Bank - World Development Indicators, the analysis focuses on the relationship between national economic indicators and trademark registrations. The results indicate that higher GDP per capita, stronger economic growth, and greater investment in research and development are significantly associated with increased trademark applications. The evidence supports the notion that stronger economic and innovation environments are linked to higher levels of trademarking. The study contributes to the literature by providing empirical evidence on how economic and innovation-related factors affect trademark behaviour in the European context.

Key words

Trademarks, European Union, R&D investment, GDP, Panel data analysis

JEL Classification: O30, O32, O34

Introduction

Over the past decades, interest in the economic aspects of intellectual property has steadily increased. Most of the existing research, however, has concentrated on patents and in contrast, trademarks have received comparatively little attention. Trademarks represent an important form of intellectual property protection, serving as key indicators of branding, market differentiation, and business activity.

According to the World Intellectual Property Organization (WIPO, 2025), a trademark is a tool that helps consumers recognize and differentiate the products or services of one company from those of another. Trademark registration provides the holder with the exclusive right to use the registered mark. Trademark registration usually lasts ten years and can be extended again by paying renewal fees (WIPO, 2025).

While the economic literature has traditionally emphasized patents as proxies for technological innovation, trademarks are increasingly recognized as complementary indicators that reflect non-technological innovation, entrepreneurship, and firm-level strategies (Allegrezza & Guard-Rauchs, 1999; Block et al., 2021; Castaldi & Dosso, 2018; Crass, 2020; Daizadeh, 2021; Jensen & Webster, 2009; Flikkema et al., 2014; Graham, 2013; Greenhalgh

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& Rogers, 2006; Llerena & Millot, 2019; Mendonca et al., 2004; Millot, 2012; Nasirov, 2018; Schmoch, 2003; Vetsikas, 2017). Despite their relevance, the macroeconomic drivers of trademark activity remain underexplored, particularly in a cross-country European context.

Until recently, there was very little research using trademark data. The study by Allegrezza and Guard-Rauchs (1999) was the first to look at what influences trademark filings. Greenhalgh & Rogers (2012) have pointed out that the limited attention given to trademarks, despite being the most commonly used form of registered intellectual property, especially among service firms, is a surprising gap in innovation studies. According to Millot (2012), trademarks can help us better understand innovation, especially in areas where traditional measures do not fully reflect certain types of innovative activity.

Allegrezza and Guard-Rauchs (1999) argued, that trademarks, especially when considered alongside patents, can offer new insights into the innovative behaviour of firms. Although traditional innovation indicators, such as patents and R&D expenditures, primarily reflect "hard" innovation, they fail to capture "soft" or non-technological innovation. Trademarks, however, have been shown to serve as indicators of such innovation, particularly in sectors like knowledge-intensive business services (Block et al., 2021).

Mendonca et al. (2004) suggest, that trademarks may reflect part of the innovation output generated by companies focused on profit. Trademark data can offer valuable insights into innovative activities that are not fully captured by traditional indicators like patents, as they may reflect types of innovation that are not typically patented (Graham, 2013). According to Schmoch (2003), trademark applications can be used as a basis for statistical analysis and serve as useful indicators of innovation, particularly in the knowledge-intensive services subsector.

Jensen and Webster (2009) examined the relationship between research and development (R&D) intensity and various intellectual property outputs, including trademark applications, Authors used firm-level data from approximately 1,400 medium and large Australian firms observed between 2001 and 2007. They found a positive correlation between research and development (R&D) spending and number of trademark applications. According to Allegrezza & Guard-Rauchs (1999), there is a positive relationship between the number of trademark filings, the size of the firm and the intensity of its research and development (R&D) efforts. Similarly, Daizadeh (2021) suggested that spending on research and development (R&D) plays a key role in the generation of patents and trademarks, based on the analysis of monthly U.S. data from 1977 to 2016. In line with this, Millot (2012) argued, both theoretically and empirically, that firms engaged in innovation have stronger incentives to apply for trademarks.

As stated by Vetsikas et al. (2017), economic growth has a strong and lasting effect on all types of intellectual property rights (IPRs), suggesting that a strong economy supports and encourages intellectual property rights activity over time. Mangani (2007) examine how macroeconomic characteristics of countries, specifically size, population, and national wealth, influence the variety and quality of goods and services traded globally under trademark protection. Based on this, they expect a positive correlation between total entries and a country's gross domestic product (GDP), population size, and gross domestic product (GDP) per capita.

Empirical studies show that the use of registered trademarks is positively associated with firm success and contributes to better performance outcomes (Crass, 2020). Trademarking firms tend to be more competitive, productive, and resilient in the market than non-trademarking ones (Block et al., 2021; Crass, 2020; Greenhalgh & Rogers, 2006; Greenhalgh

& Rogers, 2012; Llerena & Millot, 2019; Nasirov, 2018). Given this strategic relevance, trademark applications deserve greater attention in empirical research as a meaningful indicator within innovation-focused studies.

1 Methodology

This paper investigates the relationship between economic performance, innovation investment, and the volume of trademark applications across the European Union member states and the United Kingdom over the period 2014–2023. Using panel data regression with fixed effects, we examine how gross domestic product (GDP) per capita, research and development (R&D) expenditure, and gross domestic product (GDP) growth influence trademark activity at the national level. The aim is to provide empirical evidence on how broader economic and innovation-related conditions may shape trends in trademark filings across Europe.

Using data sourced from the World Bank - World Development Indicators (WDI) and World Intellectual Property Organization (WIPO) databases, this study applies a fixed-effects panel regression model to capture within-country variation over time. Slovenia was excluded from the analysis due to insufficient data on trademark applications for several years, which would have resulted in an unbalanced panel and potentially biased model estimates. The analysis was performed in Gretl, with robust standard errors clustered by country to ensure reliable inference.

In the analysis, the number of trademark applications (log-transformed) serves as the dependent variable. The key independent variables include gross domestic product per capita (in logarithmic form), research and development (R&D) expenditure as a percentage of GDP, and annual GDP growth, capturing both the economic performance and innovation investment at the national level.

The analysis applies a fixed-effects panel regression model to explore the relationship between trademark activity and selected macroeconomic and innovation-related indicators. The dependent variable, number of trademark applications, was log-transformed and gross domestic product (GDP) per capita was also expressed in logarithmic form.

An overview of all variables, their definitions, and data sources is provided in Table 1.

Table 1 Description of variables

Variables	Description	Source
l_TradeMarks	Natural logarithm of of total trademark applications	World Intellectual Property Organization (WIPO)
l_GDPpc	Natural logarithm of GDP per capita (current US$)	World Development Indicators (WDI)
GDPgrowth	GDP growth (annual %)	World Development Indicators (WDI)
R&D	Research and development expenditure (% of GDP)	World Development Indicators (WDI)

Source: authors' own calculations in GRETL based on data from WDI (2025) and WIPO (2025).

The model coefficients and parameters were estimated using GRETL software. The general structure of the panel data model is presented in the following section (Lukáčik et al., 2010):

$$y_{it}=a_i+\beta_1 x_{it1} + \beta_2 x_{it2} + ... + \beta_k x_{itk} + u_{it} \qquad (1)$$

The panel regression framework used in this study is structured as follows:

$$ln(TradeMarks_{it})=\beta_0+\beta_1 ln(GDPpc_{it})+\beta_2 GDPgrowth_{it}+\beta_3 R\&D_{it}+a_i+\varepsilon_{it} \qquad (2)$$

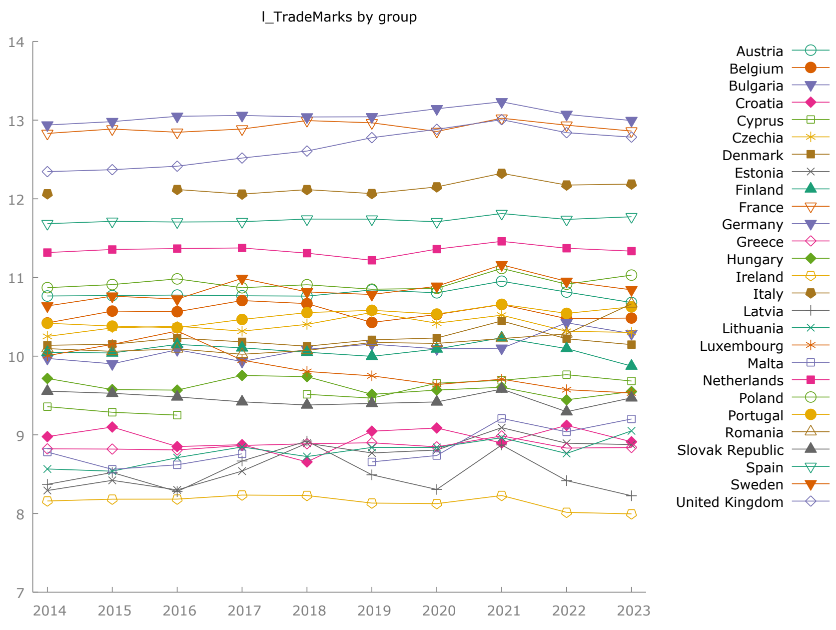
where

- $ln(TradeMarks_{it})$ is natural logarithm of the number of trademark applications in country i at time t,
- $lnGDPpc_{it}$ is natural logarithm of gross domestic product per capita (in current USD) in country i at time t,
- $GDPgrowth_{i\,t}$ is annual GDP growth rate of country i in year t,
- $R\&D_{it}$ is research and development expenditure as a percentage of GDP in country i at time t,
- a_i are fixed effects,
- ε_{it} is error term.

2 Results and Discussion

The following section reviews trademark activity trends in European countries over the past decade. Figure 1 provides an illustrative overview of trademark applications across the 27 countries from 2014 to 2023.

Figure 1 The European Union countries and the UK trademark applications, 2014 - 2023



Source: authors' own processing based on data from World Bank - World Development Indicators (2025).

The data reveal that the number of applications remained relatively stable over the period, with only moderate year-to-year fluctuations. Countries such as Germany, France, Italy and Spain consistently reported the highest levels of trademark activity, whereas smaller economies, including Ireland, Malta, Latvia and Lithuania, maintained comparatively lower but steady volumes. These patterns show a persistent gap between countries in trademark activity, indicating that differences in market size and economic performance continue to affect intellectual property filings across Europe.

The following section reports the outcomes of the panel regression analysis, which aims to explore the relationship between trademark application activity and selected macroeconomic indicators. Specifically, a fixed-effects model was estimated using 214 observations from 27 countries, covering the period from 2014 to 2023, with the number of yearly observations per country ranging from 7 to 9. The model examines the influence of Gross Domestic Product per capita (lnGDPpc), GDP growth, and R&D expenditure on the number of trademark applications. Standard errors are clustered at the country level to account for potential within-unit correlation. The regression results are summarized in Table 1.

Table 1 Panel Regression Results – Fixed Effects Model

Model 1: Fixed-effects, using 214 observations
Included 27 cross-sectional units
Time-series length: minimum 7, maximum 9
Dependent variable: l_TradeMarks
Standard errors clustered by unit

	coefficient	*std. error*	*t-ratio*	*p-value*	
const	6,43049	1,20114	5,354	1,32E-05	***
l_GDPpc	0,327558	0,119928	2,731	0,0112	**
GDPgrowth	0,005372	0,002216	2,424	0,0226	**
R&D	0,279124	0,128749	2,168	0,0395	**

Significance levels: *** p < 0.01, ** p < 0.05, * p < 0.1

Mean dependent var	10,27951	S.D. dependent var	1,343849
Sum squared resid	2,721924	S.E. of regression	0,121627
LSDV R-squared	0,992924	Within R-squared	0,253827
Log-likelihood	163,3633	Akaike criterion	−266,7267
Schwarz criterion	−165,7474	Hannan-Quinn	−225,9220
rho	0,332847	Durbin-Watson	1,10034

Joint test on named regressors -
Test statistic: F(3, 26) = 6,04396
with p-value = P(F(3, 26) > 6,04396) = 0,00289834

Robust test for differing group intercepts -
Null hypothesis: The groups have a common intercept
Test statistic: Welch F(26, 66,8) = 144,523
with p-value = P(F(26, 66,8) > 144,523) = 4,94595e-49

Hausman test -
Null hypothesis: GLS estimates are consistent

Asymptotic test statistic: Chi-square(3) = 34,6533
with p-value = 1,44204e-07

The fixed-effects panel regression results indicate that all three macroeconomic indicators, GDP per capita, GDP growth, and R&D expenditure, are positively and significantly associated with trademark application activity. Specifically, a 1% increase in GDP per capita is linked to an estimated 0.33% rise in the number of trademark applications. Similarly, a one percentage point increase in GDP growth corresponds to approximately a 0.54% increase in trademark applications.

Our results show that GDP per capita and GDP growth both have a significant positive effect on trademark application activity, which aligns with the findings of Vetsikas et al. (2017) that economic growth has a strong and lasting effect on intellectual property rights in general. Likewise, our evidence supports Mangani (2007), who expected a positive relationship between a country's GDP, national wealth, and the intensity of trademark activity

Investment in research and development also shows a significant positive effect: a one percentage point increase in research and development (R&D) expenditure is associated with approximately 27.9% rise in trademark applications. These results reflect a strong positive relationship between innovation investment and trademark activity. This aligns with earlier studies (Allegrezza & Guard-Rauchs, 1999; Daizadeh, 2021; Jensen & Millot, 2012; Webster, 2009).

The LSDV R-squared value of 0.993 indicates that the model explains approximately 99.3% of the total variation in the dependent variable. Meanwhile, the within R-squared value of 0.254 suggests that about 25.4% of the variation is explained by changes within individual cross-sectional units over time. This implies that while a substantial portion of the model's explanatory power derives from differences across units, the model also captures meaningful within-unit temporal variation.

The joint test of the regressors shows an F-statistic of 6.04 ($p = 0.0029$), meaning the variables together have a significant effect on the dependent variable. The test for different group intercepts gives a Welch F-statistic of 144.52 ($p < 0.001$), showing that intercepts vary across groups and justifying their inclusion in the model.

This model uses clustered standard errors to correct for autocorrelation and heteroscedasticity.

Based on the Hausman test (Chi-square = 34.65, p-value < 0.001), the null hypothesis that the random effects model provides consistent estimates was strongly rejected. Therefore, we conclude that the fixed effects model is more appropriate for this analysis.

Conclusion

In the past, trademark data were not widely used in empirical research. However, as access to administrative trademark databases improves, they offer new and valuable opportunities for exploring key questions in economics, business, and innovation policy. Empirical studies indicate that firms using registered trademarks tend to perform better, being more competitive, productive, and resilient than those without trademarks.

The results from the fixed-effects panel regression demonstrates that macroeconomic conditions play an important role in driving trademark activity. Using a fixed-effects panel model for EU member states and the United Kingdom over 2014–2023, we find that gross domestic product (GDP) per capita, gross domestic product (GDP) growth, and research and development (R&D) expenditure all have a significant positive effect on trademark application activity. These findings are consistent with previous research such as Mangani (2007) and Vetsikas et al. (2017), who emphasize the role of national wealth and economic growth in shaping intellectual property dynamics.

Investment in research and development (R&D) also appears to have a significant positive effect on trademark activity. The results suggest that countries allocating a higher share of resources to research and development (R&D) tend to generate more trademarks, reflecting both greater innovation output and a stronger commitment to protecting intellectual property. This outcome aligns with previous studies, such as Allegrezza & Guard-Rauchs (1999), Daizadeh (2021), Jensen & Millot (2012), Webster (2009).

Overall, the results suggest that stronger economies with higher investment in innovation tend to generate more trademarks, reflecting both greater product variety and an active approach to protecting intangible assets. This underlines the importance of policies that foster economic growth and support research and development (R&D) investment as a way to stimulate innovation and enhance competitiveness through trademark activity.

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