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National innovation beyond linear models: An exploratory QCA of asymmetric pathways to successful and failure-bound innovation strategies of EU economies post-Covid-19

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ABSTRACT

This study examines the asymmetric pathways leading to different innovation performance outcomes in the 27 European Union (EU) member states in the years before and after Covid-19. The study offers a novel approach to innovation analysis that contrasts with traditional linear approaches. Crisp-set qualitative comparative analysis (csQCA) was used to analyze variations in innovation performance pre-Covid-19 (2019) and post-Covid-19 (2023) across the 27 EU member states. Data were sourced from the Global Innovation Index (GII), published annually by the World Intellectual Property Organization (WIPO). The analysis focused on five key dimensions: human capital and research, infrastructure, market sophistication, business sophistication, and gross domestic product (GDP). The results reveal configurations (strategies) of these conditions (dimensions) that lead to successful or failed innovation performance. Four strategies lead to success and three lead to failure, with perfect consistency (1.0) observed across all solutions. A key finding is that the decline of market sophistication is a necessary condition for failure. The study also reveals several complex causal relationships, in which similar conditions can produce opposite outcomes depending on their configurational context. The findings contribute to the innovation policy literature by highlighting the importance of developmental approaches to innovation and by challenging the assumption that singular improvements in firm sophistication necessarily lead to higher innovation performance. Moreover, the research provides interesting insights for policymakers and practitioners, particularly in the context of the new EU Competitiveness Compass and the emerging environmental, social, and governance (ESG) regulatory framework. The study offers evidence-based recommendations for designing resilient innovation strategies in post-crisis scenarios.

Introduction

Covid-19 has reshaped the global innovation landscape, particularly the European Union (EU) innovation ecosystem. Although existing research has extensively documented Covid-19′s immediate impact on innovation systems, there remains a critical gap in understanding the complex causal patterns that have led to divergent innovation performance across EU member states post-Covid-19. These events have had unfavorable consequences for the development, competitiveness, and innovation growth of countries in the short and long term (Blockmans & Russack, 2020).

Innovation is fundamental to economic growth, global competitiveness, and sustainable development in modern economies (Duarte & Oliveira Carvalho, 2024). In the EU, innovation analysis is essential to understand the economic and technological dynamics that determine the EU's leadership on the global stage. The Global Innovation Index (GII) is published annually by the World Intellectual Property Organization (WIPO). It presents a comprehensive assessment of the innovation ecosystems of 133 economies, including a detailed focus on EU member states.

Based on these data, this paper analyzes the current state of innovation in the 27 EU member states. The analysis focuses on variations between their 2020 ranking (based on data from the 2019 GII gathered pre-Covid-19) and their 2024 ranking (based on data from the 2023 GII) and explores the key indicators of the 2020 GII and the 2024 GII for the 27 EU member states. The analysis thus focuses on the EU member

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states' capacity to innovate sustainably and deal with global challenges such as the effects of climate change, geopolitical tensions, and emerging technological demands. Particular attention is paid to national innovation policies, resource efficiency, and collaborative strategies within the EU framework.

This research is relevant because it offers a comprehensive overview of the current state of innovation in the EU and provides evidence-based recommendations for policymakers, managers, and researchers (Zagoršeková et al., 2017). The aim is to contribute to the design of public policies and business strategies that boost innovation in the 27 EU member states, thereby helping consolidate the EU's innovation leadership in an increasingly competitive and technological world.

According to the WIPO GII for 2024, innovation investment declined sharply in 2023, reversing the rising trend seen from 2020 to 2022. Meanwhile, scientific publication volume fell by 5 % in 2023 following annual growth rates of >8 % in 2020 and 2021, with a slight reduction in 2022. Worldwide, research and development (R&D) expenditure by companies with the highest R&D investment grew by around 6 % in real terms in 2023, below the long-term growth rate of the previous six years (around 8 %). R&D expenditure also slowed significantly with respect to the highs of 10 % and 13 % observed between 2019 and 2021 and with respect to pre-Covid-19 growth rates (all in real terms). The number of international patent applications, which had been stagnant since 2021, decreased by 1.8 % in 2023, a figure not seen since 2009. From the perspective of the socioeconomic impact of innovation (Castellacci & Natera, 2011), the situation has become positive again. Many indicators have grown from the results reported in the 2023 edition of the GII, but some have not yet reached pre-Covid-19 levels.

This study addresses the knowledge gap around divergent innovation performance across EU member states by examining how different combinations of innovation-related factors influenced EU countries' positions in the GII between 2020 and 2024. This exploratory study answers the following research question: What innovation drivers enable an EU country to increase its innovation capacity in the face of major global shocks such as Covid-19? The analyzed factors were market sophistication, business sophistication, human capital and research, gross domestic product (GDP), and infrastructure. The analysis focuses on the behavior of these factors in each of the EU-27 countries.

In Europe, Switzerland, Sweden, and the United Kingdom led the GII rankings in 2024. Switzerland ranked first in the GII for the 14th consecutive year. Sweden remained second, with Ireland (19th) and Luxembourg (20th) rising by three positions and one position, respectively. Other EU countries have improved their ranking. For example, the Czech Republic (30th) moved into the top 30, Cyprus (27th) and Spain (28th) bettered their position, and Poland (40th) moved into the top 40.

In sum, Switzerland remains a world leader in innovative output, ranking first in knowledge and technology production and creative output. It also ranks in the top 5 in all other dimensions of the GII, except for infrastructure. Sweden is a leader in infrastructure, business sophistication, knowledge production, technology, human capital, and research (Bate et al., 2023). It ranks highest in research, intellectual property payments and revenues, knowledge-intensive jobs, global brand value, and low-carbon energy use. These findings highlight the progress as well as the challenges at four key stages of the innovation cycle: investment in science and innovation, technological progress, technology adoption, and the socioeconomic impact of innovation (Kastrinos & Weber, 2020).

Unlike traditional linear analyses, configurational approaches offer a more effective way to uncover the complex means by which human capital, infrastructure, market sophistication, business sophistication, and economic growth interact to determine innovation outcomes. The present research thus contributes to the literature in three main ways. First, it systematically analyzes how pre-existing innovation capabilities interacted with Covid-19-induced changes to shape post-crisis innovation performance. Second, it reveals asymmetric causal patterns of successful and failed innovation strategies, thus demonstrating that the paths to innovation success differ fundamentally from those leading to failure. Third, it challenges the conventional assumption that business sophistication improvements uniformly contribute to innovation success. It reveals a more nuanced reality where similar conditions can yield contrasting outcomes, depending on their configurational context. By analyzing the 27 EU member states using crisp-set qualitative comparative analysis (csQCA), this study moves beyond the identification of individual success factors, instead explaining how different combinations of conditions create distinct innovation pathways.

The csQCA methodology provides an understanding of the outcome of interest in terms of the dichotomous coding (calibration) of the outcome and explanatory conditions used in the proposed model for a set of empirical cases. This approach is particularly relevant for policymakers seeking to understand why seemingly similar innovation policies may produce different outcomes across national contexts. The findings support evidence-based policymaking by identifying specific configurations of conditions that enabled or hindered innovation performance improvements post-Covid-19. This understanding is essential for developing targeted interventions for national innovation systems given their complex, interdependent nature.

This study's novelty lies in its factual approach, which is oriented toward researching and discussing the cases under analysis. The findings contribute to the academic debate on how to evaluate long-term innovation in the presence of an external shock. This research can help policymakers identify successful and failed strategies for improving long-term innovation in the face of globally disruptive events. It offers recipes to make innovation systems more robust and to explain their comparative performance in a globally competitive context post-Covid-19.

This article is structured as follows. Section 2 introduces the conceptual framework, highlighting the most relevant lines of academic debate on innovation, human capital and research, infrastructure, market sophistication, business sophistication, and GDP post-Covid-19. This section presents the proposed model based on these dimensions of innovation. Section 3 then describes the methodology and data sources. It clarifies the years evaluated in the GII and the methods used to operationalize the conditions and outcome in the model. Section 4 presents and discusses the results. Then, Section 5 outlines the main research and policy implications in terms of the design and evaluation of public policies on innovation and long-term economic development. Section 5 also discusses the contributions of the study and future research directions. Finally, Section 6 concludes.

Theoretical framework

Human capital and research

Human capital and research refers to a country's ability to develop, attract, and retain highly qualified talent and invest in R&D. Human capital and research is a fundamental component of the innovation performance of economies because it provides the basis for knowledge generation and application to solve economic and social problems. In EU countries, high-quality human capital and investment in research are crucial to maintain competitiveness in a changing global landscape. As explained by Audretsch and Feldman (2004), the theory of endogenous growth describes the importance of investment in R&D and human capital.

Studies have shown that a highly educated and organized workforce catalyzes innovation. According to Lee et al. (2023), organizational culture can indirectly affect innovation performance through knowledge sharing under a partial mediating effect. Kastrinos and Weber (2020) reported that countries with strong policies supporting basic research tend to achieve greater benefits in applied innovation. Such countries are also supported by investment in sustainability, which strengthens their ability to compete internationally. The EU also faces the challenge of retaining talent in key sectors. For example, Bate et al. (2023) reported the importance of creating attractive and competitive work environments that allow countries to avoid brain drain, which can greatly limit innovation potential.

Cooperation between academic, government, and private-sector institutions is essential to maximize the impact of R&D investment. According to a report by Benissa and Patil (2024), well-founded strategies aim to foster a dynamic and interconnected research community. Countries that foster cross-sector alliances tend to make greater progress in technological innovation. Yang et al. (2018) showed that knowledge sharing mediates the relationship between collaborative culture and product and process innovation. Research infrastructure is at the core of the knowledge triangle formed by research, education, and innovation (Kowalski, 2018). EU member states that invest in advanced education, research infrastructure, and international collaboration achieve superior performance in innovation indicators, allowing them to compete effectively in the global economy.

Infrastructure

A country's infrastructure is fundamental for creating and developing a national innovation system (Lee & Kang, 2018; Lundvall, 2004). The infrastructure includes the technical structures for transferring and disseminating technological knowledge (Castellacci & Natera, 2011). Innovation infrastructure refers to the use of information and communication technologies (ICT), which are essential for developing innovation processes by spreading new ideas and reducing the cost of access to information (Fagerberg et al., 2012; OECD, 2012). ICT allows scientists to access global knowledge (OECD, 2012).

Meanwhile, environmentally sustainable infrastructures such as green public transport systems and renewable energy infrastructures are also essential for any national innovation system to function properly. They create a conducive environment and reduce economic and financial costs that can be allocated to other objectives (Hekkert et al., 2007). Similarly, Fagerberg et al. (2012) suggested that a well-developed general infrastructure promotes innovation and economic growth. Specifically, communication, transport, and energy infrastructures are essential in the development and growth of an economy because they improve the flow of ideas and innovative services (Zhou et al., 2022). These outcomes are crucial for the e-commerce sector, promoting exports and optimizing the industrial structure (Zhou et al., 2022).

In summary, infrastructure is essential for a country's innovation capacity. ICT, electrical, and transport infrastructures, as well as environmentally sustainable infrastructures, are fundamental for economic development and the promotion of innovation. A well-developed infrastructure facilitates the transfer and dissemination of technological knowledge, improves productivity, increases resource availability, and supports independent innovation capacity and national competitiveness (Fagerberg et al., 2012; Zhou et al., 2022).

Market sophistication

Market sophistication refers to having the market conditions that enable and encourage innovation, particularly regarding access to finance, availability of venture capital, and demand for innovative products. This factor is included in the GII and is essential to understand how financial systems and market structure influence innovation levels (Dutta et al., 2023). In the context of the 27 EU member states, market sophistication analysis helps identify differences in innovation ecosystems and the economic policies needed to enhance them.

The academic literature reports a positive correlation between financial market development and innovation capacity. According to Beck and Levine (2004), credit availability and capital market development are key factors for R&D (Bate et al., 2023), especially in emerging economies. Furthermore, Acemoglu et al. (2006) reported that sophisticated markets allow for a greater allocation of resources to high-risk projects, encouraging disruptive innovation. For example, an analysis of national innovation systems in EU member states suggested that digital intensity and market sophistication are key conditions for high levels of innovation (Duarte & Oliveira Carvalho, 2024).

In Europe, studies have found that disparities in access to venture capital and bank credit are associated with differences in innovation levels between Northern and Southern European countries (Hall & Lerner, 2010). These inequalities reflect structural differences between economies and the effectiveness of public policies aimed at market development. In the EU, economies with more sophisticated markets tend to be innovation leaders, whereas countries with less developed markets face greater challenges in reaching the same levels of innovation.

Business sophistication

Business sophistication encompasses companies' ability to adopt and implement innovations and the quality of interactions within the business ecosystem (Bate et al., 2023). It also refers to collaboration between companies, universities, and research centers, knowledge networks, and advanced business practices (Chesbrough, 2006). In the EU, business sophistication is fundamental to explain differences in levels of competitiveness and innovation between member states.

The EU institutions were pushed to the limit during the Covid-19 crisis. It put the EU's public health systems to the test. Recovering from Covid-19 has also tested the EU's economic systems (Chesbrough, 2020). Therefore, innovation has played an essential role in the recovery from the Covid-19 crisis.

Several studies have highlighted the importance of business sophistication in promoting innovation. Bloom and Van Reenen (2007) studied 732 companies in the United States, France, Germany, and the United Kingdom, showing that advanced management practices positively affect productivity, profitability, Tobin's Q, company survival rates, and company innovation capacity. Likewise, Cohen and Levinthal (1990) introduced the concept of *absorptive capacity*, arguing that more sophisticated companies are better equipped to adopt and implement external innovations.

Similarly, Porter and Stern (2001) emphasized the importance of business ecosystems in creating competitive advantages, particularly in advanced economies such as within the EU. They argued that collaboration between companies and investment in human capital are crucial for business sophistication and therefore innovation. An advanced business ecosystem fosters technology adoption, improves production process efficiency, and facilitates product differentiation (Tödtling & Trippl, 2005). In the EU, business sophistication largely explains the disparities in innovation levels between member states.

Gross domestic product (GDP)

GDP is a standard measure of the total monetary value of final goods and services produced in a country during a specific period. The correlation between gross fixed capital formation and GDP is important when assessing the contribution of gross fixed capital formation to economic growth (Pavelescu, 2008). Following the outbreak of Covid-19, the euro area experienced an unprecedented recession that led to a sharp decline in GDP in the first and second quarters of 2020 (Soava et al., 2020). Although this decline was more pronounced than at the height of the global financial crisis, it was short-lived. A strong rebound was observed in the third quarter of 2020. The risk-taking response at both national and EU levels mitigated the impact of Covid-19 and boosted the recovery

Table 1
Conditions and outcome, calculation method, and case calibration criteria.

Label	Type	Description	Calculation method	Case calibration criteria
$SC_{20\text{–}24}$	Outcome	Score difference between 2020 and 2024 GII ranking	$SC_{2024} = SC_{24} - SC_{20}$	If $SC_{20\text{-}24} > 0$, calibration = 1 If $SC_{20\text{-}24} \leq 0$, calibration = 0
$HC_{20\text{–}23}$	Condition	Score variation in human capital and research (HC_{23}–HC_{20})	$HC_{20\text{–}23} = HC_{23} - HC_{20}$	If $HC_{20\text{-}23} > 0$, calibration = 1 If $HC_{20\text{-}23} \leq 0$, calibration = 0
$INF_{20\text{–}23}$	Condition	Score variation in infrastructure (INF_{23}-INF_{20})	$INF_{20\text{–}23} = INF_{23} - INF_{20}$	If $INF_{20\text{-}23} > 0$, calibration = 1 If $INF_{20\text{-}23} \leq 0$, calibration = 0
$MS_{20\text{–}23}$	Condition	Score variation in market sophistication (MS_{23}–MS_{20})	$MS_{20\text{–}23} = MS_{23} - MS_{20}$	If $MS_{20\text{-}23} > 0$, calibration = 1 If $MS_{20\text{-}23} \leq 0$, calibration = 0
$BS_{20\text{–}23}$	Condition	Score variation in business sophistication (BS_{23}-BS_{20})	$BS_{20\text{–}23} = BS_{23} - BS_{20}$	If $BS_{20\text{-}23} > 0$, calibration = 1 If $BS_{20\text{-}23} \leq 0$, calibration = 0
$GDP_{20\text{–}23}$	Condition	Score variation in GDP PPP$ (GDP_{23}-GDP_{20})	$GDP_{20\text{–}23} = GDP_{23} - GDP_{20}$	If $GDP_{20\text{-}23} > 0$, calibration = 1 If $GDP_{20\text{-}23} \leq 0$, calibration = 0

Notes. Compiled by the authors. HC = human capital and research; INF = infrastructure; MS = market sophistication; BS = business sophistication; GDP = gross domestic product.

(Santos-Rojo et al., 2025).

GDP is also widely used to assess a nation's economic performance. In the context of the EU-27, the relationship between GDP and the level of innovation is of particular interest, given that the ability to invest in R&D and emerging technologies primarily depends on the available economic resources (Maradana et al., 2017). Cazacu (2015) and Korez-Vide and Tominc (2016) highlighted the major impact of competitiveness on a country's GDP growth.

GDP is directly related to R&D spending. For example, Griffith and Van Reenen (2023) showed that countries with a high GDP per capita tend to devote more resources to innovation, reinforcing technological competitiveness. According to an analysis by Castellacci and Natera (2011), innovation depends on strong economic performance and drives long-term growth, creating a virtuous circle between these indicators.

In the EU, there are large disparities in GDP between member states. Economies with advanced sectors, high-precision technology, and cutting-edge manufacturing tend to allocate a higher percentage of their GDP to innovation. For example, Germany's strong manufacturing and automotive sectors drive technological innovation. Together with Sweden and the Netherlands, Germany has the highest GDP and R&D spending. Other member states, such as Bulgaria and Romania, face structural challenges that limit their capacity to invest in innovation (European Commission, 2023).

According to Eurostat (2023), countries that allocate >2 % of their GDP to R&D, such as Sweden and Finland, are among the most innovative in the world. GDP is thus central to assessing economic commitment to innovation. Nonetheless, Hall and Rosenberg (2010) reported that some countries achieve greater advances in innovation with moderate GDP levels thanks to effective policies and favorable institutional frameworks.

Conceptual model

Following the academic literature reviewed in this section, the EU-27 member states were chosen for analysis. The analysis focused on the variation of five constructs (human capital and research, infrastructure, market sophistication, business sophistication, and GDP) between 2019 (pre-Covid-19) and 2023 (post-Covid-19), according to the GII rankings for 2020 and 2024. The rankings for 2020 and 2024 were chosen because the GII ranking uses data from the immediately preceding year.

The outcome was the GII score. This outcome was calculated as the variation over time in the scores for each country according to the GII rankings of 2020 and 2024. The explanatory conditions in the analysis were the variations in human capital and research, infrastructure, market sophistication, business sophistication, and GDP, expressed in purchase power parity in dollars (PPP$), according to the GII rankings for 2020 and 2024.

Table 1 reports the data source and briefly explains how each condition was calculated. It also reports the coding method for the dichotomous calibration performed as part of the csQCA method. The methodology section explains other considerations regarding the data source, which was important to ensure the model's reproducibility. Table 1 also gives details on the model tested in this study, the conditions, the calculation method, and the calibration criteria.[1,2,3]

As a result of this discussion and the theoretical framework, the following model was proposed and tested using csQCA:

$$SC_{20-24} = f(HC_{20-23}, INF_{20-23}, MS_{20-23}, BS_{20-23}, GDP_{20-23})$$

Methodology

Data source and data collection

The GII rankings published by the WIPO for the years 2020, 2023, and 2024 were used in this study. A specific coding approach was used to create the dichotomous conditions and thus test the proposed model. All outcomes and conditions were identified for the two years of comparison of the innovation performance ranking (2020 GII vs. 2024 GII) and of human capital and research, infrastructure, market sophistication, business sophistication, and GDP (2020 GII vs. 2023 GII). If the score was higher post-Covid-19 than pre-Covid-19, the condition was coded as 1; if the score was lower, the condition was coded as 0. Thus, changes in the scores for the conditions and outcome in the model were identified. Table A1 in Appendix A shows the main variations in the conditions based on the evidence from the GII database provided by the WIPO for the years under study.

The GII has been used in multiple studies of different aspects of the structure of the index itself (Yu & Huarng, 2023; Yu et al., 2021). Scholars have also studied its relationship with other factors and macroeconomic metrics such as foreign investment, GDP (Çemberci et al., 2022), and national culture (Prim et al., 2017). The GII has also enabled empirical analyses of innovation, such as those by Huarng and Yu (2022) and those related to the behavior and evolution of innovation in the

[1] The data source (WIPO GII) is published in the first half of each year and uses data from the year before. Thus, the conditions in Table 1 refer to rankings for the years indicated in the subindexes and use data from the year n – 1. Hence, pre-Covid-19 data were used for the outcome and the conditions (2019 data from the 2020 GII). Post-Covid-19 data were also used. For the outcome, 2023 data were taken from the 2024 GII, and for the causal conditions, 2022 data were taken from the 2023 GII.

[2] At the time of writing, the latest published data corresponded to the 2024 GII.

[3] In line with the scope of this research, the data sources captured the pre-Covid-19 versus post-Covid-19 reality and established a causal relationship between the short- and long-term differences in the post-COVID-19 world.

BRICS countries (Bulut, 2020).

Qualitative comparative analysis (QCA)

QCA offers a robust methodological approach for analyzing complex causal relationships in the social sciences, particularly when examining institutional and policy outcomes across different countries. This methodology bridges the gap between qualitative case-oriented research and quantitative variable-oriented approaches, systematically analyzing complex causation through set-theoretic relationships (Ragin, 2009, 2014). In innovation studies, QCA provides valuable insights into how different combinations of conditions can lead to similar outcomes, acknowledging the principle of equifinality in social phenomena. The method's strength lies in its ability to identify necessary and sufficient conditions for specific outcomes while maintaining case sensitivity. This characteristic is particularly relevant when studying innovation systems, where multiple pathways can lead to similar outcomes, and contextual factors play essential roles. QCA's systematic comparison of cases allows researchers to identify patterns that might not be apparent in traditional statistical analyses or single case studies (Schneider & Wagemann, 2012).

The methodological approaches for QCA described by Fiss (2011) define how conditions contribute to outcomes through core and peripheral conditions. Core conditions represent essential, causally critical elements for which there is substantial evidence of a causal relationship with the outcome. These conditions maintain their causal relationship with the outcome across multiple solutions and show high consistency values. Peripheral conditions act as supporting elements, reinforcing core conditions but sharing a weaker causal relationship with the outcome. These conditions may vary across different solutions leading to the same outcome. Their presence contributes to the outcome, but they are less decisive than core conditions. This framework also allows for indifferent situations, where a condition's presence or absence is irrelevant to a configuration's outcome. These situations are particularly valuable for understanding causal complexity, highlighting how certain conditions may be dispensable in specific contexts but remain important in others. In QCA notation, core conditions are typically represented by large circles, peripheral conditions are denoted by small circles, and indifferent conditions are left blank, indicating their causal irrelevance in a given configuration. This distinction helps researchers identify the hierarchical importance of conditions in producing outcomes and leads to more nuanced theoretical and practical implications.

The choice of csQCA for this analysis of EU member states' innovation performance is suitable for several reasons. First, the binary nature of csQCA enables clear differentiation between the presence and absence of conditions. It is therefore especially suitable for studying distinct institutional arrangements and policy outcomes. Second, csQCA can effectively capture the complexity of national innovation systems across the EU while maintaining analytical clarity. The application of csQCA to the study of European innovation benefits from the method's ability to handle intermediate-sized samples, which is particularly relevant when studying the EU-27 member states. This approach enabled identification of complex causal patterns, while maintaining close connections to cases, allowing cross-case comparison and within-case analysis. The method's systematic nature helped reveal how different combinations of innovation-related factors (e.g., human capital, infrastructure, and market sophistication) combine to produce varying levels of innovation performance.

Furthermore, csQCA's set-theoretical basis is well-suited to analyzing institutional configurations and their outcomes in innovation systems because it can capture the interdependencies between different elements of national innovation systems. This feature makes csQCA particularly valuable for studying how various institutional arrangements and policy measures interact to produce innovation outcomes in other European contexts. The method's ability to identify multiple paths to the same outcome (equifinality) is also relevant in studies of European innovation, where countries with different institutional arrangements and histories can achieve similar innovation performance levels through different paths. This idea is aligned with the understanding that there is no single best practice model for innovation policy but rather multiple practical configurations that depend on national contexts.

In sum, this research is based on csQCA, which was used to examine variations in innovation performance across the 27 EU member states between pre-Covid-19 (2019) and post-Covid-19 (2023) periods, using the GII rankings for 2020 and 2024. The methodological approach identified causal configurations that led to positive (presence) or negative (absence) changes in countries' innovation performance. The analytical technique used to test the proposed model enabled analysis of phenomena based on small samples. Because of possible variable interdependence (e.g., homoscedasticity and collinearity), csQCA uses Boolean logic, thus overcoming some of the limitations of inferential statistical techniques (Fiss, 2011).

QCA addresses these limitations by adopting a distinct logic. Instead of estimating marginal effects under the assumptions of linearity, homoscedasticity, and independence underlying linear regression, it treats cases as having membership (1) or non-membership (0) in sets. It then searches for configurations of sufficient or necessary conditions for an outcome using Boolean algebra. Thus, collinearity ceases to be a problem and instead becomes part of causal combinations. CsQCA does not require constant variances or large-N samples. Moreover, it allows for equifinality (multiple paths to the same outcome) and asymmetric causality (the causes of presence are not the opposite of the causes of absence). The results are evaluated in terms of consistency and coverage, with comparative patterns prioritized over parametric inference.

Calculation of each condition involved computing the difference between the 2020 and 2023 scores in each case. This difference represented the change from pre- to post-Covid-19. Each difference was then calibrated into a crisp set (0 or 1) based on whether it represented a positive or negative variation. The outcome (SC20–24) reflected the overall change in innovation performance between the 2020 and 2024 GII. Table 1 shows the case calibration criteria based on the calculation method to provide the calibrated conditions and outcome from the database. The calibration process followed the crisp-set approach, where each condition was coded as either present (1) or absent (0), represented in the truth table by black and white circles, respectively. This binary coding enabled clear identification of condition combinations leading to success or failure in improving innovation performance. The analysis covered the 27 EU member states, providing a comprehensive assessment of changes in their innovation performance pre- and post-Covid-19. The analysis thus captured the diverse innovation capacities and economic structures within the EU.

Data were collected from the official GII reports. This approach ensured standardized measurements across all conditions/outcomes and countries. This standardization led to reliable cross-national comparisons and robust analysis of innovation performance changes over the studied period.

In this QCA research context, the first analysis type was necessity analysis. This necessity analysis examined whether specific conditions or combinations must be present for the outcome of interest to occur (despite not being included in the provided truth table). Then, sufficiency analysis was carried out. This sufficiency analysis, which relied on the truth table, shows which combinations of conditions are sufficient to produce the outcome. These combinations correspond to successful strategies (SS1 to SS4) for favorable outcomes and failed strategies (FS1 to FS3) for adverse outcomes. The results of the sufficiency analysis are based on the truth table with the corresponding consistency and coverage values. The results reveal perfect consistency (1.0) for successful and failed strategy configurations.

Results and discussion

Necessity analysis

Necessity analysis identifies conditions that must be present (or absent) for an outcome to occur. A condition is necessary if it appears consistently in all cases, with consistency for the outcome being greater than or equal to 0.9 (Ragin, 2009). Some authors have reported false positives in necessity analysis, suggesting consistency levels higher than 0.95 (Dul et al., 2010). The results show necessity (consistency = 1) for the causal condition of absence of market sophistication ($\sim MS_{20-23}$) in the case of failed strategies. Another key metric in csQCA is coverage, which measures a condition's empirical relevance, indicating how much of the outcome is explained by its presence or absence. Table 2 shows the results of the necessity analysis.

The necessity analysis reveals distinct patterns between successful (SS) and failed (FS) innovation strategies in the EU-27 member states. Business sophistication (BS_{20-23}) had near-necessary consistency for both outcomes (SS: 0.889, FS: 0.944), suggesting that business sophistication improvements are paradoxically correlated with both success and failure. This result implies that business sophistication alone is insufficient for success but critical in both scenarios. The absence of market sophistication ($\sim MS_{20-23}$) was a perfect necessary condition for failure (FS consistency = 1.0, coverage = 0.783), indicating that stagnant or declining market sophistication universally predicts poor innovation outcomes. Conversely, MS_{20-23} had perfect coverage (1.0) for success but low consistency (0.444), suggesting that it was present but not decisive in all successful cases.

Infrastructure (INF_{20-23}) had a higher consistency for failure than success (FS consistency = 0.778 vs. SS consistency = 0.667). This result implies that infrastructure improvements are more critical for avoiding decline than for driving success. GDP variations were not necessary (consistency $\leq$ 0.556 for SS, $\leq$ 0.500 for FS). These results imply that economic growth alone does not determine innovation performance.

No condition met the strict necessity threshold (consistency = 1) for success. This result highlights the conjunctural nature of innovation performance. The results imply that failure is more strongly linked to specific weaknesses in market sophistication (e.g., $\sim MS_{20-23}$), whereas success requires combinations of conditions.

Sufficiency analysis

Table 3 shows the results of the sufficiency analysis, which reveals distinct patterns in how EU countries' innovation performance changed pre-Covid-19 (2019) to post-Covid-19 (2023). The model had high consistency values (1.0) for the solutions for successful and failed strategies, indicating robust causal relationships. According to QCA best practices, solution coverage was adequate (> 0.25) for both successful strategies (SS) and failed strategies (FS). Table 3 also reports the raw and unique coverage of the solutions.

Table 2
Necessity analysis.

Condition tested	Successful strategies (SS)		Failed strategies (FS)	
	Consistency	Coverage	Consistency	Coverage
HC_{20-23}	0.556	0.333	0.556	0.667
$\sim HC_{20-23}$	0.444	0.333	0.444	0.667
INF_{20-23}	0.667	0.300	0.778	0.700
$\sim INF_{20-23}$	0.333	0.429	0.222	0.571
MS_{20-23}	0.444	1.000	0	0
$\sim MS_{20-23}$	0.556	0.217	1.000	0.783
BS_{20-23}	0.889	0.320	0.944	0.680
$\sim BS_{20-23}$	0.111	0.500	0.056	0.500
GDP_{20-23}	0.444	0.308	0.500	0.692
$\sim GDP_{20-23}$	0.556	0.357	0.500	0.643

Notes. Compiled by the authors. HC = human capital and research; INF = infrastructure; MS = market sophistication; BS = business sophistication; GDP = gross domestic product. The symbol "∼" indicates the absence of a condition.

Solution coverage

The successful strategies had a solution coverage of 0.667, explaining two-thirds of the successful outcomes in innovation performance. The successful strategies had unique raw and unique coverage values of 0.333 (SS1) and 0.111 (SS2, SS3, and SS4), reflecting varying empirical relevance. The failed strategies had a solution coverage of 0.444, with individual raw coverage values ranging from 0.056 (FS3) to 0.278 (FS1) and unique coverage values ranging from 0.056 (FS3) to 0.167 (FS1).

Successful strategies

In SS1, Finland, France, and Germany adopted a strategy of improving their market sophistication and business sophistication while maintaining their human capital and research levels. This recipe had the highest coverage (0.333) of all successful strategies.

In SS2, the Netherlands followed a unique path of improving human capital and research and infrastructure. This solution shows that targeted enhancement in these areas can drive innovation success.

In SS3, Portugal achieved success by simultaneously improving human capital and research, GDP, and business sophistication, suggesting that coordinated improvements across multiple areas can enhance innovation performance.

In SS4, Estonia adopted a strategy of combining enhancements in human capital and research, infrastructure, market sophistication, business sophistication, and GDP, representing a holistic approach to improving innovation performance.

Strategies leading to failure

In FS1, Greece, Hungary, Italy, Poland, and Spain shared improvements in business sophistication development with stagnation or decline in other areas. FS1 had the highest coverage (0.278) of any failed strategy, reflecting a common problematic pattern in Southern and Eastern European countries.

In FS2, Belgium, Ireland, Poland, and Spain improved business sophistication but experienced a decline in human capital and research and market sophistication. The overlap with FS1 for Poland and Spain indicates deeply rooted structural challenges in these countries' economies.

In FS3, Malta experienced improvements in human capital and research and infrastructure but declines in other areas, particularly business sophistication. These results suggest that isolated improvements are insufficient for overall improvements in innovation performance.

A discussion of strategies

The observed successful strategies support the findings of Tödtling and Trippl (2005), who reported that an advanced business ecosystem fosters the adoption of technologies and improves efficiency in production processes. Bloom and Van Reenen (2007) also emphasized the importance of advanced management practices in positively influencing productivity and profitability.

Similarly, the results support the findings of Duarte and Oliveira Carvalho (2024), who suggested that market sophistication is a key condition for achieving high levels of innovation. The current results also corroborate the findings of Lundvall (2004) and Lee and Kang (2018), who reported that a country's infrastructure is fundamental in creating and developing a national innovation system, as well as in the transfer and dissemination of technological knowledge (Castellacci & Natera, 2011).

The results are also consistent with those of Lee et al. (2023), who reported that organizational culture indirectly affects innovation performance through knowledge sharing and that countries that invest in higher education and technical training are more likely to develop innovative products and services, thereby increasing global

Table 3
Sufficiency analysis.

Condition	SS1	SS2	SS3	SS4	FS1	FS2	FS3
$HC_{20\text{-}23}$	○	●	⬤	●	◯	◯	●
$INF_{20\text{-}23}$		●	◯	●		◯	●
$MS_{20\text{-}23}$	●	○	○	●	◯	◯	○
$BS_{20\text{-}23}$	●	◯	●	●	●	●	◯
$GDP_{20\text{-}23}$	○	◯	●	●	◯		⬤
Raw coverage	0.333	0.111	0.111	0.111	0.278	0.222	0.056
Unique coverage	0.333	0.111	0.111	0.111	0.167	0.111	0.056
Consistency	1	1	1	1	1	1	1
Assumptions	(- - - - - -)				(- - - - - -)		
Solution coverage	0.667				0.444		
Solution consistency	1				1		

Notes. Compiled by the authors. Following Fiss (2011), black circles indicate the presence of a condition. White circles indicate the absence of a condition. Large circles indicate core conditions. Small circles indicate peripheral conditions. No circle indicates an indifferent condition. HC = human capital and research; INF = infrastructure; MS = market sophistication; BS = business sophistication; GDP = gross domestic product.

competitiveness. The results are also in line with those of Yang et al. (2018), who reported that knowledge sharing supports collaborative culture and several types of innovation. Likewise, the results support the findings of Kowalski (2018), who indicated that research infrastructures are key factors in the knowledge triangle of research, education, and innovation.

Finally, the results corroborate the importance of a country's economic situation, specifically GDP growth, in driving innovation. It has been shown that when GDP grows, the capacity to invest in R&D and emerging technologies also increases (Maradana et al., 2017). There is also a tendency to devote more resources to innovation (Griffith & Van Reenen, 2023).

Core conditions and internal reliability

Following the approach described by Fiss (2011), the sufficiency analysis reveals distinct configurations of core and peripheral conditions across successful and failed strategies. In SS1, all conditions are peripheral conditions. In SS2, human capital, infrastructure and market sophistication are peripheral conditions, whereas business sophistication and GDP are core conditions. In SS3, human capital and infrastructure are core conditions, whereas market and business sophistication and GDP are peripheral conditions. In SS4, all conditions are peripheral conditions.

Regarding strategies leading to failure in innovation performance, in FS1, human capital, business sophistication and GDP are core conditions, whereas business sophistication is a peripheral condition. In FS2, business sophistication is also a peripheral condition, and human capital, infrastructure and market sophistication are core conditions. In FS3, human capital, infrastructure, and market sophistication are peripheral conditions, whereas business sophistication an GDP are core conditions.

The peripheral conditions across both strategies highlight varying supporting roles in causal relationships leading to different innovation performance outcomes.

Contributions, implications, and directions for future research

Contributions of the findings

The findings make notable contributions to the study of innovation in the EU. For instance, unlike in the studies by Gong et al. (2024), Marques et al. (2025), De Massis et al. (2020), and the European Innovation Scoreboard (European Commission, 2025b), the current study uses a configurational approach based on csQCA. This methodological approach enables the identification of asymmetric causal patterns leading to both success and failure (Ragin, 2009; Schneider & Wagemann, 2012). In sum, the study identifies causal configurations that explain both success and failure in innovation by combining specific conditions that lead to divergent outcomes. This approach contrasts with those adopted in previous research such as the cited studies, which were based on the analysis of specific aspects that explain innovative performance.

For instance, unlike Gong et al. (2024), who also used QCA but focused on more global configurations and geographic scope, the current study identifies a stagnation or decrease in market sophistication (~MS) as a necessary condition for failure in innovation performance within the EU post-Covid-19. This finding should directly influence public policy design in the sense that it suggests that, without a sophisticated market environment, measures in other areas may not be effective.

In contrast, Marques et al. (2025) used a non-configurational approach. Their research does not explain how different variables such as the role of small and medium-sized enterprises (SMEs) and cooperation networks interact to affect innovation performance. The results of the present study show, for example, that countries such as Poland and Spain can correspond to successful or failed configurations depending on the combination of certain conditions with others. This finding reflects the logic of equifinality (Fiss, 2011).

De Massis et al. (2020) used interviews to analyze concepts associated with resilient management such as flexibility and collaboration in the processes of innovative companies. However, they did not adopt a supranational view based on systematic empirical evidence. Finally, this study identifies causal patterns, detects necessary and sufficient conditions, and integrates different dimensions to provide a better explanation of national innovation systems than the European Innovation Scoreboard (European Commission, 2025b), which is based solely on a descriptive approach.

One of the distinctive contributions of this study is its alignment with regulatory frameworks such as the Competitiveness Compass and the EU Corporate Sustainability Reporting Directive (CSRD) and Corporate Sustainability Due Diligence Directive (CSDDD). Another contribution is that it bases its analysis on the theory of national innovation systems (Lundvall, 2004) and the logic of complex causality. The study is thus able to show how countries with similar investment levels can achieve different levels of innovation performance. It also shows how improvements in a factor such as business sophistication do not automatically lead to successful innovation performance because this condition can contribute to both successful and unsuccessful strategies.

In summary, this study provides robust empirical evidence of the determinants of innovation post-Covid-19 in the EU. It does so thanks to its use of an advanced methodology that has not been used in other related studies. This approach shows the factors that matter and the ways in which they should be encouraged to interact in order to support the design of more effective public policies.

Implications for researchers

The analysis reveals that successful innovation strategies during the Covid-19 transition period typically involve coordinated improvements across multiple dimensions, particularly in business sophistication. Conversely, failed strategies often reflect isolated improvements, with a lack of comprehensive development across other dimensions of innovation. The high consistency (1.0) across all solutions indicates that the configurations in the solutions are clear causal patterns. Meanwhile, the varying coverage values suggest that there are multiple paths to success and failure in innovation performance. Crucially, the findings highlight the importance of balanced development across the dimensions of innovation. Business sophistication is a critical condition but is insufficient for success if not accompanied by improvements in other areas. Other dimensions, such as market sophistication, infrastructure, human capital and research, and GDP growth, are also important.

From the perspective of research implications, this study shows that an important area for further inquiry resides in the analysis of all factors that affect business sophistication. Such factors include public-private collaboration between companies and universities and companies' adoption of emerging technologies in entrepreneurship and innovation processes. It would also be of interest to analyze the extent to which talent retention strategies and the development of new R&D financing models can increase a country's overall innovation rate.

Finally, future research should focus on how the launch of the Competitiveness Compass by the European Commission can affect the EU economies and their GII ranking. Recent European Commission directives in the form of the CSRD and CSDDD have introduced major ESG disclosure and compliance obligations. These directives are not only regulatory burdens but also powerful forces reshaping the conditions for innovation. By increasing the demands on transparency, accountability, and sustainability-driven business models, the CSRD and CSDDD enhance market sophistication and business sophistication, two dimensions that the current csQCA-based study identifies as important conditions in the causal configurations leading to innovation success. As such, they serve as catalysts for aligning national innovation systems with broader EU policy objectives, including those laid out in the Competitiveness Compass and the European Green Deal.

The EU proposal is based on several pillars. One of these pillars is the launch of an applied artificial intelligence (AI) initiative for mass use in strategic sectors. However, only one in seven European companies use it. To this end, AI factories will be made available to them, where they can use their computers to train models. Another of these pillars is innovation, which is hampered by an excessive administrative burden. According to data from companies, Spain is the seventh most difficult country in which to operate. Brussels has proposed reducing bureaucratic obligations for large companies by 25 % and for SMEs by 35 % by 2029. The savings for firms will amount to 37 billion euros per year. To this end, the European Commission has proposed a unified legal framework.

Regarding patents, Europe has the same percentage of patents as China, but only a third are used commercially. The problem is that money does not flow to companies that shelve their projects. First, R&D funding is low. It is 2.2 % of GDP in Europe, 3.6 % in the United States, and 2.6 % in China. Second, but no less critically, European capital markets are inefficient. For instance, only 5 % of venture capital is raised in the EU, compared to 52 % in the United States and 40 % in China (European Commission, 2025a).

The EU Competitiveness Compass is committed to balancing green ambitions with regulatory simplification. Although maintaining the course of the European Green Deal is essential, the emphasis on multiple omnibus packages raises key questions, such as whether simplifications will accelerate sustainability efforts or dilute essential ESG standards. Focusing on demand-side incentives for low-carbon products is a promising step, but without adequate safeguards, greenwashing is a risk. Moreover, it remains to be seen how these policies will affect industries outside the EU, especially in developing countries.

Implications for policymakers

The results of the study have a series of implications for those responsible for national public policies aimed at improving innovation and climbing the GII ranking. The following sections discuss some of the areas that this study highlights as important for legislation and policy promotion.

Market sophistication

Governments should pay maximum attention to this aspect. Relevant proposals include more ambitious tax credits for innovation, more effectively channeled venture capital, and the creation of research centers for emerging technologies. Several further suggestions can also be proposed. Specifically, governments should: (a) improve market sophistication through financial system innovation; (b) establish regional innovation banks and guarantee schemes for early-stage innovation financing in lagging EU member states; (c) mandate a minimum share of green bonds and innovation-linked instruments in national development banks' portfolios in all EU member states; and (d) link venture capital support to ESG-aligned innovation missions.

Business sophistication

In this area, governments should use their policies to promote startups and the development of digital platforms to foster relations between companies and public research institutions. Governments should launch open innovation hubs in partnership with universities, SMEs, and multinationals to promote co-development. They should develop tax incentives tied to collaborative R&D rather than in-house spending alone.

Infrastructure

Infrastructure is an excellent opportunity to promote innovation in a country where the government is the leading actor. This study shows that this aspect is important and that government participation is fundamental. Areas where intervention should be intensive include investments in high-tech infrastructure such as broadband networks and efficient transport systems that fully connect the region and reduce travel times in a sustainable way. Also, policymakers should: (a) prioritize digital infrastructure (e.g., 5 G and broadband access) in rural and semi-urban innovation zones; and (b) enable cross-border innovation corridors using TEN-T and EU Cohesion Fund synergies.

Human capital and research

The last area that the study indicates as relevant for improving the GII ranking is human capital and research investment. Once again, public decision-makers have a great responsibility in this area and can make a real difference. Increasing grants and subsidies for technological and scientific projects is crucial because it provides greater incentives for R&D and fosters programs to enhance international collaboration. Finally, policymakers should: (a) implement dual education systems combining technical training with digital and green skills (Fagerberg et al., 2012); (b) expand talent return programs and incentives for diaspora scientists and innovators (Lee et al., 2023); and (c) use the Competitiveness Compass to promote many of these initiatives. The launch of the Competitiveness Compass should greatly affect sustainable innovation processes related to ESG strategies and the European CSRD and CSDDD directives.

Additional policy implications

Beyond the previously identified implications, policymakers should consider integrating innovative ecosystems that leverage cross-border collaborations within the EU. This approach requires the development of harmonized regulatory frameworks that facilitate technology transfer and knowledge sharing among member states. Establishing pan-European innovation corridors and connecting regional innovation hubs could enhance the collective innovation capacity of the EU. Policymakers should also focus on developing targeted support mechanisms for transitioning traditional industries toward digital and sustainable business models. This approach includes creating specialized funding instruments that combine innovation grants with technical assistance programs. Implementing innovation voucher schemes for SMEs that adopt emerging technologies could accelerate digital transformation. Furthermore, innovation-focused public procurement policies could create leading markets for innovative solutions, particularly in strategic sectors such as AI, biotechnology, and clean energy. This approach would help align innovation policies with the EU's strategic autonomy objectives.

Implications for practitioners

For the heads of companies, research centers, and non-governmental technology institutions, the findings of this study can also help guide decisions around increasing innovation and thus achieving a positive effect on the overall innovation index. For example, it is important to: (a) encourage collaboration with universities and public research centers; (b) study access to specific funding for innovation projects by venture capital and public institutions; (c) improve market analysis to identify particular niches and opportunities for the commercial development of products; (d) promote open innovation in the organization and be vigilant in the participation of emerging technology projects; (e) improve investment in broadband networks and sustainable infrastructure; (f) offer more specific training for employees; and (g) promote talent retention programs.

Innovation practitioners in EU organizations must adopt more sophisticated approaches to innovation management that account for the complex interplay between the different success factors identified in the present analysis, while considering the Triple, Quadruple, and Quintuple Helix Models (Carayannis & Campbell, 2010; Carayannis et al., 2012; Del Giudice et al., 2017; Carayannis & Campbell, 2021; Armas & Villegas, 2025). This approach requires developing comprehensive innovation scorecards that track progress across multiple dimensions simultaneously.

Organizations should implement structured innovation portfolio management systems that balance incremental improvements with transformative initiatives. This approach includes establishing dedicated innovation units with direct reporting lines to senior management and ensuring that innovation strategies receive appropriate resources and attention. Organizations should create career paths designed explicitly for innovation specialists, combining technical advancement opportunities with management responsibilities. Practitioners must also focus on building robust innovation ecosystems through strategic partnerships. This approach includes: (a) establishing formal collaboration frameworks with research institutions; (b) developing innovation-focused supplier development programs; (c) creating internal venture capital arms to invest in promising startups; and (d) implementing open innovation platforms to engage with external stakeholders.

Additionally, organizations should develop, analyze, and interpret sophisticated metrics to measure innovation performance beyond traditional R&D indicators. These metrics should incorporate market impact, sustainability outcomes, and social value creation, in line with the circular transition (Eiselein & Langenus, 2025).

Research propositions for future studies

Drawing on the seven distinct configurations (SS1, SS2, SS3, SS4, FS1, FS2, and FS3) identified in the analysis, several testable research propositions can be explored in future research.

P1: The presence of market sophistication is necessary but not sufficient for positive innovation performance in EU countries during post-crisis recovery.

P2: Improvements in business sophistication only contribute to innovation performance when accompanied by simultaneous improvements in at least one of the following areas: human capital and research, infrastructure, and market sophistication.

P3: Isolated gains in GDP, without supporting improvements in institutional or knowledge-based factors, are not associated with success in innovation performance.

P4: Countries with holistic innovation advancement across all five pillars (human capital and research, infrastructure, market sophistication, business sophistication, and GDP) are most likely to achieve sustained improvement of innovation performance post-crisis.

P5: Configurations leading to failed innovation performance often include the paradox of greater business sophistication but declining market sophistication, suggesting a misalignment between organizational capacity and systemic support.

These propositions can serve as the basis for future mixed-methods-based empirical studies using csQCA, fsQCA, or mvQCA, along with regression analysis or structural equation modeling. In addition, new causal approaches based on difference-in-differences and longitudinal case studies can be used to assess the dynamic interplay among the constructs of interest.

Conclusions

The post-Covid-19 innovation landscape in the EU involves complex patterns of success and failure that transcend simple cause-and-effect relationships. The present analysis was conducted within the context of major global disruptions and emerging EU regulatory frameworks. It reveals the importance of applying configurational approaches to understand innovation performance.

The study's key findings are that successful innovation strategies require synchronized improvements across multiple dimensions, particularly in market sophistication and business sophistication. Identifying distinct pathways to success and failure provides valuable policy development and organizational strategy insights.

Nonetheless, several limitations warrant consideration in future research. First, the binary nature of csQCA delivers clear insights but may oversimplify some nuanced relationships. Future studies could employ fuzzy-set qualitative comparative analysis (fsQCA) to capture more granular variations. Additionally, the temporal scope of the current analysis focused on the immediate period post-Covid-19. This temporal scope could be extended to examine longer-term innovation pathways.

The study provides future research opportunities by considering the EU's new regulatory landscape. The European CSRD and CSDDD directives, coupled with the Competitiveness Compass framework, open new avenues for investigating how sustainability requirements and competitiveness objectives influence innovation pathways. Specifically, future research could examine how organizations balance innovation imperatives with ESG compliance requirements and how the EU's AI initiative affects innovation strategies across different sectors. Reflecting the proposals of the Competitiveness Compass, the relationship between smaller administrative burdens and innovation acceleration presents another promising research direction.

The post-Covid-19 recovery period has shown that innovation in the EU is not the outcome of isolated improvements in single areas but rather the result of complex, interdependent configurations of conditions. This finding has several critical implications for organizational strategies and national policy frameworks.

First, organizations must recognize that although business sophistication is necessary, it is insufficient to ensure successful innovation performance. As the QCA results show, improvements in business sophistication, when not complemented by progress in areas such as market conditions or infrastructure, can still be associated with failed innovation performance. For firms, this finding highlights the need to embed innovation in broader ecosystems, emphasizing the importance of inter-organizational collaboration, participation in research networks, and investment in absorptive capacity (Chesbrough, 2020; Cohen & Levinthal, 1990; Del Giudice et al., 2017).

Second, the study underlines the core relevance of market sophistication, given the consistent association between an absence of market sophistication and failure. Policymakers should focus on reforming financial ecosystems by scaling up access to venture capital, incentivizing R&D through tax incentives, and fostering demand for innovative solutions through public procurement and green objectives (Hall & Lerner, 2010; Acemoglu et al., 2006; Dutta et al., 2023).

Third, variations in success strategies suggest that context-sensitive policies are essential. For instance, the success of Estonia (SS4) is rooted in holistic, systemic improvement across all dimensions. Meanwhile, Portugal (SS3) succeeded through targeted gains in GDP, human capital, and business sophistication. These findings imply that one-size-fits-all approaches are ill-suited to the EU's diverse economies. Instead, country-specific roadmaps that leverage regional strengths and address structural bottlenecks should guide innovation strategies (Carayannis & Campbell, 2021; Tödtling & Trippl, 2005).

This study provides new insights into the complex, asymmetric pathways that drive national innovation performance in the EU post-Covid-19. Using csQCA of the 27 EU member states, the study shows that multiple configurations lead to successful and failed innovation performance. The findings show that innovation pathways are shaped not by isolated improvements but rather by the interplay of conditions, including market sophistication, human capital and research, infrastructure, business sophistication, and GDP growth.

One of the most consistent findings is that the absence of market sophistication is necessary for innovation failure. This finding highlights the central role of financial and demand-side structures in supporting innovation. Similarly, business sophistication appears in both success and failure pathways, suggesting that organizational capabilities alone do not guarantee performance gains unless accompanied by systemic alignment with other institutional factors. These insights contribute to the literature by challenging linear innovation models and reinforcing the importance of contextual, configuration-based approaches.

From a policy perspective, the results support the design of differentiated, context-aware innovation strategies across the EU. For high-performing economies, the focus should be on reinforcing cross-sector synergies and scaling frontier technologies. Meanwhile, priorities for emerging innovation systems include strengthening venture capital markets, upgrading infrastructure, and retaining talent.

The propositions for future research outlined earlier lay the groundwork for future studies using fsQCA, panel data econometrics, other case-based comparative approaches, structural equation modeling, or longitudinal case studies to assess the dynamic interplay among these constructs. Future research should also explore how evolving EU policies such as the Competitiveness Compass, the CSRD and CSDDD, and the AI initiative shape innovation performance, particularly regarding sustainability transitions and administrative reforms.

Overall, the findings show that innovation success depends not only on capacity building but also on achieving systemic coherence across multiple dimensions in the current post-Covid-19 era. National innovation strategies in the EU must embrace configurational thinking to ensure that EU member states remain competitive, sustainable, and resilient.

CRediT authorship contribution statement

Fernando Castelló-Sirvent: Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Cristina Santos-Rojo:** Writing – review & editing, Writing – original draft, Investigation, Funding acquisition, Conceptualization. **Juan Manuel García-García:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization.

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Appendix A

Table A1

Table A1
Key indicators in 2024 for the analyzed sample.

European countries with successful strategies (data for 2024)				European countries with failed strategies (data for 2024)			
Country	Population (millions)	GDP (PPP$ bn)	GDP per capita (PPP$)	Country	Population (millions)	GDP (PPP$ bn)	GDP per capita (PPP$)
Austria	9.1	626.5	69,069	Belgium	11.7	769.7	65,813
Estonia	1.4	61.0	45,236	Bulgaria	6.8	216.5	33,780
Finland	5.6	335.8	59,869	Croatia	3.9	164.7	42,873
France	66.4	3868.6	58,765	Cyprus	1.3	49.7	53,931
Germany	84.5	5538.0	66,038	Czechia	10.8	539.3	49,025
Lithuania	2.9	137.3	49,245	Denmark	5.9	441.8	74,958
Netherlands	18.1	1297.0	73,317	Greece	10.2	417.0	39,864
Portugal	10.4	465.1	45,227	Hungary	9.7	421.7	43,601
Sweden	10.6	716.0	66,209	Ireland	5.2	722.9	137,638
				Italy	59.5	3193.2	54,259
				Latvia	1.9	76.5	40,892
				Luxembourg	0.7	94.2	143,304

(*continued on next page*)

Table A1 (*continued*)

European countries with successful strategies (data for 2024)				European countries with failed strategies (data for 2024)			
Country	Population (millions)	GDP (PPP$ bn)	GDP per capita (PPP$)	Country	Population (millions)	GDP (PPP$ bn)	GDP per capita (PPP$)
				Malta	0.5	33.3	63,481
				Poland	38.8	1712.6	45,538
				Romania	19.1	780.8	41,029
				Slovakia	5.5	229.6	42,228
				Slovenia	2.1	108.7	51,407
				Spain	47.9	2413.1	50,472

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