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Redeveloping the National Innovative Capacity Framework: European Union Perspective

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Abstract: This paper aims to redevelop the national innovative capacity framework and specify the influence of its' elements on shaping the innovation performance of the EU nations. The objects of the empirical research are the EU member states for the period of 2000–2018. The collected data is employed in a multivariate Granger causality analysis that illustrates the causal links between the analyzed indicators and considers their dynamics. The results demonstrate that countries seeking to increase the levels of innovative outputs should mostly focus on scientific excellence and international economic activities. A redevelopment of the framework also helped discover that gender equality and corruption have causal links with all forms of the investigated innovation indicators—technological, non-technological, and commercial ones. The outcomes of this study highlight the most critical areas where EU member states could focus to improve their national innovation performance and may assist policymakers in the designing process of future innovation policies.

Keywords: innovation; innovation performance; national innovative capacity; European Union; innovation policy

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1. Introduction

In 2021, the European Union (EU) improved its relative innovation performance position towards global competitors. Nevertheless, South Korea, Canada, Australia, the United States, and Japan do not abandon their positions as the strongest innovators in the world (European Commission 2021). A substantial amount of research has been dedicated to the question of how macro-level innovation performance can be enhanced. We may thus wonder whether it is mainly affected by the R&I investment or (and how) it is also influenced by the broader environment and conditions determining the country's ability to carry out innovative activities, create innovative products, and establish requirements for the dissemination and implementation of the results of innovative activities in practice.

Starting from the initial economic state, continuing with the national social, cultural, and political aspects, such as mentality, bureaucracy, corruption, illogical investment decisions, lack of political concern, and even low qualification of the project management—all these factors may influence the degree of country's capabilities to reach highest innovation performance possible. A number of researchers (e.g., Azagra-Caro and Consoli 2016; Malik 2020; Proksch et al. 2017; Santana et al. 2015; Wu et al. 2017) admit that out of a wide variety of different models used to examine this 'broader environment', one remains as the most appropriate for use in macro-level analysis. The concept of the national innovative capacity (NIC) framework was initially introduced by (Furman et al. 2002). It is composed of the new ideas-driven endogenous growth theory by Romer (1990), the cluster-based theory of national industrial competitive advantage by Porter (1990), and the national innovation systems theory by Nelson (1993).

Concerning the NIC drivers (inputs), Furman et al. (2002) included three dimensions into the model: (1) Common innovation infrastructure that defines a country's overall science and innovation policy environment; (2) Cluster-specific environment for innovation that defines cluster-specific circumstances and investments, and (3) Quality of linkages between the common innovation infrastructure and industrial clusters. However, researchers investigating at the macro level suggest that more factors have a significant effect on national innovative performance (e.g., Dincer 2019; Khan and Cox 2017; Puia and Ofori-Dankwa 2013).

Furman et al. (2002, p. 89) described national innovative capacity as 'the ability of a country to produce and commercialize a flow of innovative technology over the long term'. Therefore, with a time lag of three years, international patents and international patents per million of the population were chosen as the variables of innovative output when analyzing 17 OECD countries. However, an ardent debate has been developed over time regarding the innovative outputs of the national innovative capacity. According to an extensive literature analysis performed by Dziallas and Blind (2019), 74% of the scientific papers within 1980–2015 applied technological indicators of innovation that mainly represent the manufacturing industry. These are usually patents either in the form of the absolute number or their rate per million people, and the patent citation rate (as in Azagra-Caro and Consoli 2016; Furman et al. 2002; Faber and Hesen 2004; Hu and Mathews 2008; Huang et al. 2010; Santana et al. 2015; Wu et al. 2017). Nevertheless, patents are quite effective at capturing innovation in manufacturing, but they cannot fully explain innovation in services (Janger et al. 2017). Also, not all innovative solutions are granted the right of a patent (Wu et al. 2017). Consequently, in order to properly evaluate national innovation performance, it is crucial to broaden the exceptionally prevalent focus on technological innovative output.

Having these challenges in mind, this paper aims to redevelop the original national innovative capacity framework by Furman et al. (2002) and specify the influence of its' elements on shaping the innovation performance of EU nations. The study is organized as follows: Section 2 describes the selection of indicators that reflect the national innovative capacity inputs and outputs, and presents the methods chosen for empirical analysis; Section 3 summarizes the results; Section 4 discusses the findings and Section 5 outlines the conclusions, and implication of the research results.

2. Methodology

Seeking to fulfil the first part of the aim of this article, i.e., to redevelop the original national innovative capacity framework, a comparative scientific literature analysis is performed. The gathered insights are later used as a basis for the selection of variables employed in the empirical research.

The sequence of methodological steps of the research is presented in Figure 1. Section 2.1 covers the debate on the indicators that are efficient in capturing the national innovative capacity inputs. Those inputs are classified into seven dimensions. We overview and, with slight modifications, keep the three original dimensions—common innovation infrastructure, cluster-specific environment for innovation, and the quality of linkages—as in a model by (Furman et al. 2002). Keeping in mind the research that was done since the introduction of the original framework in the year 2002, we add four new dimensions—international economic activities, diversity and equality, legal and political strength, and general socioeconomic conditions.

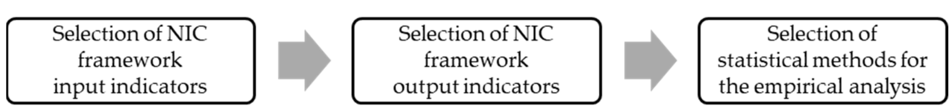

Figure 1. The sequence of methodological steps.

To continue with the output part of the framework, as described in the introduction, there is a variety of forms of innovation and it may stem from diverse sources, yet the formal technological and economic aspects of innovation have been considered in a far greater amount of scientific research (including Furman et al. 2002). Thus, Section 2.2 provides information about indicators reflecting different types of innovation.

Section 2.3 is devoted to the description of the chosen method used to achieve the second part of this article's aim, i.e., to specify the influence of national innovative capacity elements on shaping the innovation performance of the EU nations.

2.1. Selection of the Redeveloped National Innovative Capacity Framework Input Indicators

2.1.1. Common Innovation Infrastructure

According to Furman et al. (2002), common innovation infrastructure defines a country's overall science and innovation policy environment. Here, the authors include the variables of GDP per capita*, the patent stock as a proxy for the knowledge stock, the population**, the amount of scientific and technical skills devoted to the production of new technologies, R&D personnel, R&D investment, expenditures on higher education, IPR protection*, openness to international competition*, and stringency of antitrust policies** (* the current or slightly modified form of these variables are now included in other dimensions of the redeveloped model, see Sections 2.1.4, 2.1.6 and 2.1.7.; ** these variables were insignificant, hence they were omitted from the analysis).

As there is substantial agreement that nat ional innovation performance greatly depends on expenditures directly related to innovative processes (Baesu et al. 2015; Castellacci and Natera 2013; Proksch et al. 2017; Zang et al. 2019), the total R&D investment in a country, as well as its R&D investment in the public sector and the government's expenditures on education, were left as parts of the common innovation infrastructure (see Table 1). This dimension also consists of variables representing the scientific skills devoted to the development of new or significantly improved products and processes, i.e., R&D personnel. According to Bilbao-Osorio (2018), upgrading a country's science base is vital to prompt and accelerate scientific excellence and foster the development and adoption of innovations. Hence, another variable is scientific publications among the top 10% most cited publications worldwide. In addition, countries where people can build on previous knowledge tend to produce higher innovative output (Proksch et al. 2017). Even though the above-listed scholars along with Doran et al. (2018); Furman et al. (2002); Hu and Mathews (2005, 2008); Krammer (2009) and Wu et al. (2017) used the patent stock as a proxy for the knowledge stock, we focus on both technological and non-technological innovative outputs. Therefore, it was decided to form a composite construct. By using factor analysis, a construct was created from the granted patents stock, granted trademarks stock, and the stock of granted designs from 2000 to 2018.

Another variable of the 'common innovation infrastructure' dimension is the employees possessing tertiary education (*note:* Faber and Hesen (2004) and Carvalho et al. (2015) *used a slightly different variable of the average years of education of employees*). This indicator reflects the quality of human capital in a country. Finally, keeping in mind that the current time requires an ICT-friendly environment, the variable of ICT access is included in this dimension (*note:* Ege and Ege (2019); Filippetti et al. (2017) and Lee et al. (2016) *used a slightly different variable of 'internet users'*). The ICT index weights three ICT indicators: (1) Percentage of individuals using the Internet; (2) Fixed (wired)-broadband Internet subscriptions per 100 inhabitants; (3) Active mobile-broadband subscriptions per 100 inhabitants. The variables, their definitions, justification, and sources are represented in Table 1.

Table 1. Variables of the redeveloped dimension 'Common innovation infrastructure'.

Variable	Definition	Justification	Source
rd	R&D investment (% of GDP).	Azagra-Caro and Consoli (2016); Baesu et al. (2015); Castellacci and Natera (2013); Ege and Ege (2019); Faber and Hesen (2004); Filippetti and Guy (2020); Filippetti et al. (2017); Furman et al. (2002); Hu and Mathews (2005, 2008); Huang et al. (2010); Khan and Cox (2017); Krammer (2009); Malik (2020); Proksch et al. (2017); Zang et al. (2019).	Eurostat (2021)
public_rd	R&D investment in the public sector (intramural, % of GDP).	Baesu et al. (2015); Carvalho et al. (2015); Castellacci and Natera (2013); Faber and Hesen (2004); Hu and Mathews (2005, 2008); Krammer (2009); Rodríguez-Pose and Wilkie (2019); Santana et al. (2015).	Eurostat (2021)
edu_exp	Total public investment on education (% of GDP)	Baesu et al. (2015); Faber and Hesen (2004); Filippetti and Guy (2020); Furman et al. (2002); Hu and Mathews (2005, 2008); Huang et al. (2010); Krammer (2009); Proksch et al. (2017); Wu et al. (2017).	Eurostat (2021)
rd_fte	Total R&D personnel and researchers (% of total employment).	Baesu et al. (2015); Doran et al. (2018); Faber and Hesen (2004); Furman et al. (2002); Hu and Mathews (2005, 2008); Huang et al. (2010); Lee et al. (2016); Proksch et al. (2017).	Eurostat (2021)
knowledge_stock	Variable constructed from the granted patents stock, the granted trademarks stock, and the granted designs stock.	Doran et al. (2018); Furman et al. (2002); Hu and Mathews (2005, 2008); Krammer (2009); Proksch et al. (2017); Wu et al. (2017).	WIPO (2020)
pub_top10	Scientific publications among the top 10% most cited publications worldwide.	Filippetti et al. (2017); Furman et al. (2002); Hu and Mathews (2005); Hudec (2015); Proksch et al. (2017); Wu et al. (2017).	Web of Science (2020)
employees_edu	Employees with tertiary education (% of total employees).	Faber and Hesen (2004); Carvalho et al. (2015).	Eurostat (2021)
ict	The ICT index.	Ege and Ege (2019); Filippetti et al. (2017); Lee et al. (2016).	World Bank (2020)

2.1.2. Cluster-Specific Environment for Innovation

A cluster-specific environment for innovation defines cluster-specific circumstances and investments. In the original NIC framework, this dimension includes two variables: private R&D investment and specialization, i.e., patents by class granted by the United States Patent and Trademark Office. As Furman et al. (2002) solely focused on the determinants of commercialized technological innovation, only patents that belong to chemical, electrical and mechanical patents classes were considered. Apart from Furman et al. (2002), who positioned business R&D investment at the core of their NIC concept, many other scholars (e.g., Castellacci and Natera 2013; Doran et al. 2018; Faber and Hesen 2004; Hu and Mathews 2005, 2008; Krammer 2009; Proksch et al. 2017) proved that private R&D investment acts as the engine of innovation performance because the exploitation of the scientific and technological opportunities leads to launching created products and processes.

On the other hand, according to Lhuillery et al. (2017), R&D represents only about one-third of innovation costs, hence proving that non-R&D innovation investment is also a very important input for innovation. Some examples of non-R&D innovation investment include the acquisition of advanced machinery, computer hardware and software, and market research or training related to the introduction of new products or processes (European Commission 2020a).

According to Castellani et al. (2019, p. 280), who compared R&D and productivity in the U.S. and the EU, *'industrial composition might affect the overall aggregate outcome since technological opportunities and appropriability conditions are very different across industries'*. To represent the cluster-specific environment in a country, two variables were included: the share of the industry sector and the share of the services sector.

Finally, as a substitute for the co-location of economic actors and economic activity, the variable of urban population was chosen (Wu et al. 2017; Zang et al. 2019). According to the European Commission (2020a), these areas have a higher likelihood to be more innovative since people, government, enterprises, and educational institutions are located more closely; therefore, it simplifies the process of knowledge diffusion (see Table 2).

Table 2. Variables of the redeveloped dimension 'Cluster-specific environment for innovation'.

Variable	Definition	Justification	Source
private_rd	R&D investment in the business sector (intramural, % of GDP).	Doran et al. (2018); Halkos and Skouloudis (2018); Hudec (2015); Faber and Hesen (2004); Franco and Leoncini (2013); Furman et al. (2002); Hu and Mathews (2005, 2008); Huang et al. (2010); Krammer (2009); Proksch et al. (2017); Rodríguez-Pose and Wilkie (2019).	Eurostat (2021)
non_rd	Non-R&D innovation investment in the business sector (% of the total turnover).	European Commission (2020a).	Eurostat (2021)
sector_industry	Industry sector employment (% of the total employment).	Filippetti and Guy (2020); Filippetti et al. (2017); Rodríguez-Pose and Wilkie (2019).	Eurostat (2021)
sector_services	Services sector employment (% of the total employment).	Filippetti and Guy (2020); Filippetti et al. (2017); Rodríguez-Pose and Wilkie (2019).	Eurostat (2021)
pop_urban	Urban population (% of the total population).	Wu et al. (2017); Zang et al. (2019).	World Bank (2020)

2.1.3. Quality of Linkages

According to Furman et al. (2002), the quality of linkages between the common innovation infrastructure and industrial clusters is revealed by university R&D performance and the strength of venture capital markets. Although the variable of the availability of venture capital was not significant in the Furman et al. (2002) analysis, other scholars, such as Faber and Hesen (2004) and Proksch et al. (2017) proved that venture capital helps in sharing the R&D costs and risks, hence stimulating innovation (note: this article uses venture capital as a percentage of GDP).

Higher education institutions constitute a crucial part of networking in the Triple Helix (politics, business, and science). Universities produce skilled graduates for the labor market and act as an easily accessible source of research both for industry and other sectors, therefore university R&D investment is defined as another determinant of innovation performance according to the NIC approach.

The estimations by Jaklič et al. (2014) confirm that, apart from R&D investment, innovation cooperation is the most significant factor in the prospect for firms to innovate. For example, Pereira and Leitão (2016) found that firms establishing coopetition relationships with their competitors tend to generate more product innovations. Renda (2015, p. 22) holds a similar position by claiming that investment in R&D does not act as a sufficient strategy unless companies develop a synergetic relationship, *'fed by the university system, supported by public or private funding sources, <…> and facilitated by an innovation-oriented government'*. To represent the public-private collaboration, a variable of public-private co-authored research publications was used. Lastly, the cooperation between companies is proxied with a variable of a percentage of innovative SMEs collaborating with others out of all SMEs (see Table 3).

Table 3. Variables of the redeveloped dimension 'Quality of linkages'.

Variable	Definition	Justification	Source
higher_ed_rd	R&D investment in the higher education sector (intramural, % of GDP).	Azagra-Caro and Consoli (2016); Faber and Hesen (2004); Furman et al. (2002); Hu and Mathews (2005, 2008); Huang et al. (2010); Krammer (2009); Proksch et al. (2017); Rodríguez-Pose and Wilkie (2019).	Eurostat (2021)
venture_cap	Venture capital (% of GDP).	Carvalho et al. (2015); Faber and Hesen (2004); Furman et al. (2002); Hu and Mathews (2005); Proksch et al. (2017); Wu et al. (2017).	Eurostat (2021)
public_private_collab	Total of public–private co-authored research publications.	Halkos and Skouloudis (2018).	Web of Science (2020)
inno_smes_collab	Innovative SMEs collaborating with others (% of SMEs).	Carvalho et al. (2015); Faber and Hesen (2004); Pereira and Leitão (2016).	European Commission (2020b)

2.1.4. International Economic Activities

According to Wu et al. (2017), since the introduction of the NIC framework by Furman et al. (2002), inadequately little scientific contribution has been given to a broader analytic approach that international economic activities are also important for the national innovative capacity. The results of the research performed by scholars defined in Table 4 show that not only local effects, but also global network position and international cooperation have to be considered while analyzing the country-level innovative capacity.

Because of exchange, international economic activities yield increased opportunities for information sharing (Huang et al. 2010; Castellacci and Natera 2013). Trade openness motivates exporters to advance their resources and create innovative solutions while seeking to compete with other firms (Bloom et al. 2016). Therefore, the variable of exports of goods and services is included in the redeveloped NIC framework dimension 'International economic activities'. It is also worth mentioning that, besides exports, imports stimulate direct learning from the experience of a foreign country, thus facilitating knowledge and technology diffusion. Concerning foreign direct investment (FDI), the literature highlights mixed evidence related to its relationship to innovation. On the one hand, Wu et al. (2017) remarked that inward FDI adds only to the ability of developing countries to produce forefront technologies, but this effect does not extend to countries that already are innovation leaders. On the other side, FDI can promote local producers to enhance their R&D efforts, which would lead to more prominent knowledge flows followed by innovation (Filippetti et al. 2017; Malik 2020).

Table 4. Variables of the additional dimension 'International economic activities'.

Variable	Definition	Justification	Source
exports	Total exports of goods and services (% of GDP).	Baesu et al. (2015); Filippetti et al. (2017); Krammer (2009); Lee et al. (2016); Malik (2020); Proksch et al. (2017); Wu et al. (2017); Zang et al. (2019).	Eurostat (2021)
imports	Total imports of goods and services (% of GDP).	Filippetti et al. (2017); Krammer (2009); Schneider (2005); Zang et al. (2019).	World Bank (2020)
fdi	Inward FDI (% of GDP).	Filippetti et al. (2017); Halkos and Skouloudis (2018); Hudec (2015); Krammer (2009); Malik (2020); Schneider (2005); Wu et al. (2017).	World Bank (2020)

2.1.5. Diversity and Equality

Diversity enhances the knowledge stock because complementary ideas provide new combinations of benefits in creating new products and processes. Researchers investigating at the macro level suggest that a significant relationship exists between a nation's culture and its degree of innovativeness (Khan and Cox 2017; Puia and Ofori-Dankwa 2013). The importance of cultural diversity is discussed in the works of DiRienzo and Das (2015), Halkos and Skouloudis (2018), Puia and Ofori-Dankwa (2013), and Zang et al. (2019). Though scholars employed various indexes as proxies for cultural diversity (e.g., the Greenberg diversity index), we use a direct measure of the foreign country population as a percentage of the total population to reflect the cultural diversity of a nation (see Table 5).

The balance between male and female employees is emphasized to be important as well because gender-diverse teams increase the probability of innovating. As Bührer and Frietsch (2020) found out, an increased proportion of women in the science system brings a considerable contribution to the nation's innovative outputs—citations and excellence rates are high for female authors. The benefits of differentiating the internal and external knowledge pool at scientific teams were also proved by Díaz-García et al. (2013). They demonstrated that gender diversity results in high levels of radical innovation, especially in the technology-intensive industries. Therefore, the element of gender equality was included, which is proxied by the share of females in the senior and middle management (see Table 5).

Regarding income inequality, it is worth elaborating on the reality that significant erosions in the incomes of a particular part of the population create an environment full of uncertainties for not only those people who are facing the challenge of lower incomes but for society as a whole (Ege and Ege 2019). The results of the research by Jacobs (2016) illustrate this phenomenon. This scholar found out that children who were born in wealthy families are much more likely to obtain a patent later in their lives than those who were born in low-income families. It means that the redistribution from the rich to the poor can positively affect both the innovative process and innovative outputs. Therefore, the poverty level was chosen as a variable that reflects the level of income inequality in the country.

Table 5. Variables of the additional dimension 'Diversity and equality'.

Variable	Definition	Justification	Source
multi_culture	Cultural diversity: foreign country or stateless population (% of the total population).	DiRienzo and Das (2015); Halkos and Skouloudis (2018); Puia and Ofori-Dankwa (2013); Zang et al. (2019).	Eurostat (2021)
gender_equality	Female share of employment (% in the senior and middle management).	Bührer and Frietsch (2020); Díaz-García et al. (2013).	World Bank (2020)
income_inequality	People at risk of poverty or social exclusion (% of the population)	Ege and Ege (2019); Jacobs (2016).	Eurostat (2021)

2.1.6. Legal and Political Strength

According to Zang et al. (2019), a nation may try to imitate the innovation policies of others, but it still heavily depends on the abilities of its authorities whether these policies can meet the expected goals. Castellacci and Natera (2013), Law et al. (2018), and Malik (2020) claim that the countries which are denoted by high institutional quality are more innovative. The importance of the strength of the legal and political environment is also discussed by Ege and Ege (2019), Halkos and Skouloudis (2018), Wu et al. (2017), and Zang et al. (2019). This variable, when used as a proxy, is a combined variable that includes judicial independence, the rule of law, and political stability in a country, ranked from 1 to 7 (see Table 6).

Scholars argue that corruption may cause the inability of the public sector to target R&D projects efficiently. Corruption deteriorates the trust of innovators in the legal system, leads to a surge in risks (Dincer 2019), and weakens the underlying fundamentals of governing institutions that are necessary for higher levels of innovative activity within the country. Hence, the corruption perception index was employed to demonstrate the level of corruption in a country. Although initially, the score of 0 would represent a very high level of corruption, and the score of 100 would represent a corruption-free country, a reversed ranking (the Excel RANK.AVG function) was chosen, meaning that the higher the rank, the more corrupt the country is.

Corruption, politicized decisions, irrational funding, and other 'shadow' activities can be ceased by proper legal and regulatory inclusiveness. According to Ege and Ege (2019), people must believe that nobody is exempt from the rules and that no part of the community has any illegal privileges. The significance of legal systems, including the protection of intellectual property rights, is shown in the works of DiRienzo and Das (2015), Furman et al. (2002), Hu and Mathews (2005, 2008), Hudec (2015), Krammer (2009), Malik (2020), Proksch et al. (2017), Wu et al. (2017), Zang et al. (2019). As DiRienzo and Das (2015) conclude, an innovator may freely share the original knowledge only when he/she is assured that a patent or another form of intellectual property protection will protect this new information. Therefore, trust in the government and the legal system is crucial if we seek to incentivize innovation.

Table 6. Variables of the additional dimension 'Legal and political strength'.

Variable	Definition	Justification	Source
legal_political	Strength of the legal and political environment.	Ege and Ege (2019); Halkos and Skouloudis (2018); Wu et al. (2017); Zang et al. (2019).	World Bank (2020)
corruption	Reversed corruption perception index.	Castellacci and Natera (2013); DiRienzo and Das (2015); Malik (2020).	Eurostat (2021)
ipr	Protection of intellectual property rights, patent protection, and copyright protection.	Faber and Hesen (2004); Furman et al. (2002); Hu and Mathews (2005, 2008); Krammer (2009); Proksch et al. (2017); Schneider (2005); Wu et al. (2017).	Property Rights Alliance (2020)

2.1.7. General Socioeconomic Conditions

In order to minimize the omitted variable bias, several socioeconomic variables were selected and included as parts of the additional dimension 'General socioeconomic conditions'. As presented in Table 7, it contains GDP per capita to create the image of a nation's relative prosperity and socioeconomic development and the labor force that represents the critical mass of potential innovators.

Table 7. Variables of the additional dimension 'General socioeconomic conditions'.

Variable	Definition	Justification	Source
gdp_capita	Gross domestic product (euro per capita).	Azagra-Caro and Consoli (2016); Carvalho et al. (2015); Castellacci and Natera (2013); Faber and Hesen (2004); Franco and Leoncini (2013); Furman et al. (2002); Halkos and Skouloudis (2018); Hu and Mathews (2005, 2008); Huang et al. (2010); Law et al. (2018); Lee et al. (2016); Malik (2020); Proksch et al. (2017).	Eurostat (2021)
labor_force	Labor force—employment and activity (millions of persons aged from 15 to 64).	Furman et al. (2002); Hu and Mathews (2005); Proksch et al. (2017).	Eurostat (2021)

To sum up, innovation takes place in complex systems of governments, companies, and knowledge institutions within a comprehensive regulatory and social framework. It is also based on complex processes involving a large number of persons with diverse backgrounds, knowledge, and experiences. This leads to countries generating different innovation outputs from their current level of inputs. By employing the insights of scholars who performed empirical research on the topic of the national innovative capacity, the input part of the original framework introduced by Furman et al. (2002) was redeveloped to consider the constantly changing essence of innovation and its surrounding environment. The indicators were added or slightly adjusted in the three initial dimensions, i.e., the 'Common innovation infrastructure', 'Cluster-specific environment for innovation', and the 'Quality of linkages'. Furthermore, the framework was supplemented with the following dimensions, i.e., 'International economic activities', 'Diversity and equality', 'Legal and political strength', and 'General socioeconomic conditions'.

2.2. Selection of the Redeveloped National Innovative Capacity Framework Output Indicators

The Introduction section of this paper indicated an issue that there is much more attention given to technological output. Hence, seeking to redevelop the original national innovative capacity framework by Furman et al. (2002) and adapt it to today's challenges, the potential NIC framework output indicators are overviewed and selected. The breakdown by type is based on the 2018 Oslo Manual (Eurostat and OECD 2018) and the EIS Methodology Report (European Commission 2020a).

The first group of outputs are chosen to reflect technological innovation. Patents can be described as the traditional and most commonly used indicator in this context. They have a well-established background, and it is relatively easy to make comparisons throughout sectors and different time periods (De Liso and Vergori 2017). As there is a time gap between the application process and the issue of an intellectual property right (IPR), applications instead of granted IPRs are used because they provide a more timely account of innovative activity (Schneider 2005). The same logic is applied not only to patent but also to design, and trademark variables (see Table 8). Furthermore, in order to account for the varying size of the member states, IPR applications per capita are calculated. Another indicator for measuring the technological innovative output is the share of SMEs introducing product or process innovations. The rationale of taking SMEs is due to them being the dominant type, accounting for 99% of the enterprise sector on average (Čučković and Vučković 2018).

The second group of the redeveloped national innovative capacity framework output indicators includes the non-technological ones: trademark applications, design applications, and the share of SMEs introducing marketing or organizational innovations. The motivation for including trademark applications as a national innovation performance indicator lies behind several reasons: first, the trademark is an imperative innovation indicator for the service sector (European Commission 2020a), and, secondly, it is a highly undervalued type of IP in the empirical research of innovation (Dziallas and Blind 2019; van den Besselaar et al. 2018). As emphasized in the study by Lhuillery et al. (2017), there is also a lower amount of interest in using design as an indicator of innovation though it typically involves significant levels of scientific input (Sunley et al. 2008). A report by the World Intellectual Property Organisation (WIPO 2020) shows that for the first time, applications for designs worldwide exceeded 1 million per year, and this represents an increase of 14.3% in comparison with 2017. Therefore, we emphasize the growing recognition of this IP and include it in our study. The last indicator in this group is SMEs introducing marketing or organizational innovations. According to the European Commission (2020a), a lot of firms, especially in the services sectors, innovate through these forms of innovation.

Table 8. Variables proxied for national innovative capacity framework outputs.

Variable	Definition	Justification	Source
Technological innovative outputs			
patent	Total patent applications to the European Patent Office (by priority year, per million inhabitants).	Baesu et al. (2015); Doran et al. (2018); Filippetti et al. (2017); Law et al. (2018); Malik (2020); Rodríguez-Pose and Wilkie (2019); Schneider (2005); Varga and Sebestyén (2017).	Eurostat (2021); European Patent Office (2020)

smes_pp	SMEs introducing product or process innovations (% of all enterprises).	Čučković and Vučković (2021).	Eurostat (2021)
Non-technological innovative outputs			
trademark	EU trademark applications (per million inhabitants).	Baesu et al. (2015).	Eurostat (2021)
design	Community design applications (per million inhabitants).	Baesu et al. (2015).	Eurostat (2021)
smes_mo	SMEs introducing marketing or organizational innovations (% of all enterprises).	European Commission (2020b); Stojčić et al. (2020).	Eurostat (2021)
Commercialization of innovation			
inno_sales	Sales of new-to-market and new-to-firm innovations (% of turnover).	Carvalho et al. (2015); Napiorkowski (2018).	Eurostat (2021)
exports_hitech	Exports of high technology products (% of total product exports).	European Commission (2020b).	Eurostat (2021)
exports_kis	Exports of knowledge-intensive services (% of total services exports).	European Commission (2020b).	Eurostat (2021)

The third group of outputs shows the commercial part of innovation. The motif to include these indicators in the redeveloped NIC model is related to a challenge named the 'European paradox' when EU countries successfully promote R&D inputs but are not able to transform these results into commercial benefits (Napiorkowski 2018; Radicic and Pugh 2017). Therefore, the sales of new-to-market and new-to-firm innovations, as well as exports of high technology products and knowledge-intensive services were included in the analysis to find out whether the national innovative capabilities of the member states influence the commercialization of innovation.

The conceptual scheme showing the redeveloped framework of national innovative capacity is presented in Figure 2.

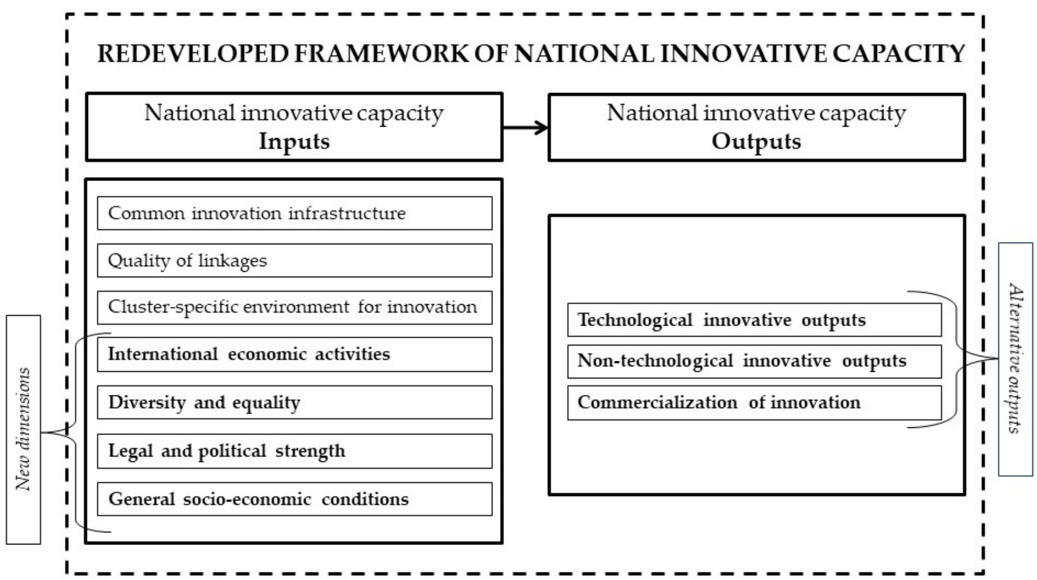

Figure 2. A conceptual scheme of the redeveloped national innovative capacity framework.

As Figure 2 demonstrates, additionally to the original dimensions, the redeveloped framework has four new ones—international economic activities, diversity and equality, legal and political strength, and general socioeconomic conditions. On the right side, one can get acknowledged with the alternative outputs that were employed instead of the international patents initially used by Furman et al. (2002).

2.3. Method for the Empirical Research

This subsection is devoted to the description of the chosen method that is used to achieve the second part of this article aim, i.e., to specify the influence of national innovative capacity elements on shaping the innovation performance of EU nations.

In the year 2000, the European Council promoted the Lisbon strategy with the ambition of the EU becoming the most competitive and dynamic knowledge-based economy in the world. Therefore, it was selected as a starting point for the empirical investigation and the panel dataset was compiled with the latest available data from 2000 to 2018. Seeking to include as much data as possible and reflect tendencies over time, the United Kingdom was kept in the analysis together with the 27 current member states. The 2019 version of Microsoft Excel and Statistical Data Processing Package SPSS version 21.0 were used for processing and analyzing the data. EViews 11 was employed for econometric analysis. Variables, together with their definitions, justification, and sources can be found in the previous sections, see Tables 1–8.

Before analyzing the panel data, the unit root test was performed to test the stationarity of the time series. The testing procedure is carried out via the unit root test by using the Dickey–Fuller criterion (here and afterwards based on Min (2019)). Testing for the unit root includes the following equation:

$$Y_t = \alpha + \varrho Y_{t-1} + \varepsilon_t \rightarrow \Delta Y_t = \alpha + \gamma Y_{t-1} + \varepsilon_t \quad (1)$$

where $\Delta Y_t = Y_t - Y_{t-1}$, $\gamma = \varrho - 1$, and ε_t is white noise. If $\varrho < 1$ or $\gamma < 0$, series Y_t is stationary. If $\varrho = 1$ or $\gamma = 0$, then the series is integrated of order one.

The Dickey–Fuller test formulates the following hypotheses based on the equation:

$$H_0: \gamma = 0 \text{ vs. } H_1: \gamma < 0 \quad (2)$$

The null hypothesis means that there is a unit root. It was specified to test for a unit root in the Level, 1st difference, and 2nd difference. When the test fails to reject the null hypothesis of a unit root in the level but rejects the null in the 1st difference, then it means that the series contains one unit root in the level and is of integrated order one, I(1).

Later, the Granger causality approach is used to check whether x causes y in order to examine how much of the present y may be explained by past values of y and then to assess if adding lagged values of x helps in improving the explanation. Since this article seeks to check whether certain elements of the country's innovative capacity cause its national innovation performance, the following equation is applied. It is tested whether the explanatory variable X_t affects the dependent variable Y_t in the sense that changes in variable X_t induce changes in variable Y_t (including a reasonable lag length, ι):

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \ldots + \alpha_\iota Y_{t-\iota} + \beta_1 X_{t-1} + \ldots + \beta_\iota X_{t-\iota} + \varepsilon \quad (3)$$

As the indicators that reflect the macro-level drivers and gains of national innovative capacity were selected and the method for the empirical research is described, the next section is devoted to the presentation and analysis of the results.

3. Results

Table 9 demonstrates that four independent variables (employees_edu, multi_culture, private_rd, and public_private_collab) are integrated of order 1, thus a series of successive differences is calculated to make them stationary (marked as d(variable)).

Table 9. Unit root test for the independent variables.

Common innovation infrastructure	
rd	I(0)
public_rd	I(0)
edu_exp	I(0)

rd_fte	I(0)
knowledge_stock	I(0)
pub_top10	I(0)
d(employees_edu)	I(1)
ict	I(0)
Cluster-specific environment for innovation	
d(private_rd)	I(1)
non_rd	I(0)
sector_industry	I(0)
sector_services	I(0)
pop_urban	I(0)
Quality of linkages	
higher_ed_rd	I(0)
venture_cap	I(0)
d(public_private_collab)	I(1)
inno_smes_collab	I(0)
International economic activities	
exports	I(0)
imports	I(0)
fdi	I(0)
Diversity and equality	
d(multi_culture)	I(1)
gender_equality	I(0)
income_inequality	I(0)
Legal and political strength	
legal_political	I(0)
corruption	I(0)
ipr	I(0)
General socioeconomic conditions	
gdp_capita	I(0)
labor_force	I(0)

I(1)—integrated of order one, explained in the methodology section, d() means first differences.

Table 10 demonstrates that out of the 11 dependent variables which are used as a proxy for the national innovation performance, only the variable of 'exports_kis' turned out to be not stationary, hence, in the latter analysis, the values of differences shall be used.

Table 10. Unit root test for the dependent variables.

Technological innovative outputs	
patent	I(0)
smes_pp	I(0)
Non-technological innovative outputs	
trademark	I(0)
design	I(0)
smes_mo	I(0)
Commercialization of innovation	
inno_sales	I(0)
exports_hitech	I(0)
d(exports_kis)	I(1)

I(1)—integrated of order one, explained in the Methodology section, d() means first differences.

The next step in the empirical research is Granger causality tests that help find the factors that may have influenced the outcomes. Therefore, we use Granger causality analysis to (1) check whether the independent variables x (EU member states' innovative capacity elements belonging to different dimensions) cause the dependent variable y (EU member states' innovation performance proxied as individual outputs, e.g., patent applications or exports of knowledge-intensive services), (2) see whether adding lagged values of independent variables x can improve the explanation. The tests were repeated for five-time lags to control the variability of the results. We assume that there is Granger causality evidence only in the case when at least two lag specifications in a row turn out to have significant results (see Tables A1–A8 in Appendix A).

Table 11 shows the existence of Granger causal relationships between the elements of the redeveloped NIC model's dimension 'Common innovation infrastructure' and the three groups of output indicators which are used as a proxy for the national innovation performance (full results can be found in Appendix A). The total R&D investment in a country exhibits a Granger causal relationship with both technological innovative outputs and one non-technological output, i.e., marketing and organizational innovations introduced by SMEs. R&D investment in the public sector may cause trademark applications and marketing and organizational innovations as well as exports of knowledge-intensive services. Expenditures for education, on the other hand, also have a causal relationship with design applications and exports of high-technology products. The total amount of R&D personnel and researchers seem to cause at least one variable from each of the types of innovative output. Surprisingly, the knowledge stock, the 'pool of the previous knowledge' which is a composite construct formed from the stock of granted patents, the stock of granted trademarks, and granted designs does not cause any of the dependent variables. The variable of scientific publications among the top 10% most-cited publications worldwide showed a Granger causal relationship with all three groups of NIC output indicators, proving the important role of scientific excellence. The usage of ICT demonstrated similar tendencies, though with fewer effects. Finally, the variable which represents the share of employees with a higher education appeared to cause only non-technological innovative outputs.

Table 11. Granger causal relationship: the redeveloped NIC framework dimension 'Common innovation infrastructure'.

Common Innovation Infrastructure	Technological Innovative Output	Non-Technological Innovative Output	Commercialization of Innovation
rd →	patent; smes_pp	smes_mo	-
public_rd →	-	trademark; smes_mo	d(exports_kis)
edu_exp →	-	trademark; design	exports_hitech; d(exports_kis)
rd_fte →	smes_pp	trademark; design; smes_mo	exports_hitech; d(exports_kis)
knowledge_stock →	-	-	-
pub_top10 →	patent; smes_pp	trademark; design; smes_mo	inno_sales; exports_hitech; d(exports_kis).
d(employees_edu) →	-	trademark; design; smes_mo	-
ict →	smes_pp	smes_mo	d(exports_kis)

The next redeveloped NIC framework dimension to be discussed is 'Cluster-specific environment for innovation'. The results indicated in Table 12 suggest that R&D investment in the business sector causes all technological and non-technological innovative outputs, yet it has no influence on the commercialization of innovation. Non-R&D investment, on the contrary, shows a Granger causal relationship with the variable of SMEs introducing marketing and organizational innovations and it also influences the sales of innovation and exports of high technology products. Interestingly, there are almost no differences in the Granger causal relationships of employment in the industry or services sector except that the latter one also influences the exports of knowledge-intensive services. Finally, it seems that densely populated countries are more successful in the application for patents, the introduction of all types of innovations, and commercial exploitation of knowledge-intensive services (see Table 12).

Table 12. Granger causal relationship: the redeveloped NIC framework dimension 'Cluster-specific environment for innovation'.

Cluster-Specific Environment for Innovation	Technological Innovative Output	Non-Technological Innovative Output	Commercialization of Innovation
d(private_rd) →	patent; smes_pp	trademark; design; smes_mo	-
non_rd →	-	smes_mo	inno_sales; exports_hitech
sector_industry →	smes_pp	trademark; smes_mo	exports_hitech
sector_services →	smes_pp	trademark; smes_mo	exports_hitech; d(exports_kis)
pop_urban →	patent; smes_pp	smes_mo	d(exports_kis)

As the next step of our research, Table 13 presents the Granger causal relationship between the redeveloped NIC framework dimension 'Quality of linkages' and the output indicators. R&D investment in the higher education sector causes both indicators from the technological innovative output group. It also causes marketing and organizational innovations. In addition to this, by helping to share the R&D costs and risks, venture capital prompts to submit design applications, and it also acts as an incentive for exports of high-technology products. The results also show that the collaboration between the public and private sectors causes both technological and non-technological innovative outputs, but it does not have a role in the commercialization of innovation, differently from the case of collaboration between the innovative SMEs which also induce exports of high technology products.

Table 13. Granger causal relationship: the redeveloped NIC framework dimension 'Quality of linkages'.

Quality of Linkages	Technological Innovative Output	Non-Technological Innovative Output	Commercialization of Innovation
higher_ed_rd →	patent; smes_pp	smes_mo	-
venture_cap →	-	design	exports_hitech
d(public_private_collab) →	patent; smes_pp	trademark; design	-
inno_smes_collab →	patent	smes_mo	exports_hitech

The results outlined in Table 14 suggest that supplementing the original NIC framework by Furman et al. (2002) with the dimension of 'International economic activities' was worthwhile since the majority of its elements indicated below showed a Granger causal relationship with the output indicators. All three independent variables, i.e., exports, imports, and foreign direct investment, play a role in affecting trademark and design applications as well as sales of new-to-market and new-to-firm innovations. Exports and inward FDI also induce patent applications and exports of knowledge-intensive services.

Table 14. Existence of Granger causal relationship: the additional NIC framework dimension 'International economic activities'.

International Economic Activities	Technological Innovative Output	Non-Technological Innovative Output	Commercialization of Innovation
exports →	patent; smes_pp	trademark; design	inno_sales; d(exports_kis)
imports →	smes_pp	trademark; design	inno_sales
fdi →	patent	trademark; design	inno_sales; d(exports_kis)

Continuing with the additional dimension 'Diversity and equality', the results presented in Table 15 demonstrate that the cultural diversity in a country has a Granger causal effect on high-tech production exports. The variable that shows the national level of gender (in)equality by reflecting the percentage of female share of employment in senior and middle management does have a Granger causal effect on all types of innovative outputs, including patent, trademark, design applications, and innovation sales. The national income inequality causes the introduction of new or significantly improved products and processes as well as innovation sales and exports of knowledge-intensive services.

Table 15. Existence of Granger causal relationship: the additional NIC framework dimension 'Diversity and equality'.

Diversity and Equality	Technological Innovative Output	Non-Technological Innovative Output	Commercialization of Innovation
d(multi_culture) →	-	-	exports_hitech
gender_equality →	patent	trademark; design	inno_sales
income_inequality →	smes_pp	-	inno_sales; d(exports_kis)

Table 16 demonstrates that judicial independence, rule of law, and political stability and strength (variable 'legal_political') are important when we analyze the introduction of product, process, marketing, and organizational innovations as well exports of knowledge-intensive services. Corruption likewise causes at least one output from each of the output groups, showing similar tendencies as the previous variable, except that it may also affect the number of design applications. Finally, it seems that businesses feel more motivated to bring in various types of innovations when they are assured that the introduced novelties will be legally protected (see causal relationships with variable 'ipr' in Table 16).

Table 16. Existence of Granger causal relationship: the additional NIC framework dimension 'Legal and political strength'.

Legal and Political Strength	Technological Innovative Output	Non-Technological Innovative Output	Commercialization of Innovation
legal_political →	smes_pp	smes_mo	d(exports_kis)
corruption →	smes_pp	design; smes_mo	d(exports_kis)
ipr →	smes_pp	smes_mo	-

The last dimension of the redeveloped NIC model is 'General socioeconomic conditions'. GDP per capita causes at least one element from each of the output indicators' groups. The labor force, on the other hand, may cause only exports of knowledge-intensive services (Table 17).

Table 17. Existence of Granger causal relationship: the additional NIC framework dimension 'General socioeconomic conditions'.

General Socioeconomic Conditions	Technological Innovative Output	Non-Technological Innovative Output	Commercialization of Innovation
gdp_capita →	patent	trademark; design; smes_mo	d(exports_kis)
labor_force →	-	-	d(exports_kis)

In summation, all the chosen indicators that represent both national innovative capacity inputs and outputs were employed in the empirical analysis. Their Granger causal links were presented and shortly overviewed. The extended discussion along with the implications may be found in the next section.

4. Discussion

Seeking to reflect the constantly changing nature of innovation, the original concept of Furman et al. (2002) was redeveloped considerably. Framework outputs were changed to reflect not only the 'traditional' industry innovation indicators (i.e., patents) but also other types of innovation. The first group of outputs in the redeveloped framework is the technological innovative outputs—patent applications and product and process innovations introduced by SMEs. Keeping in mind the gap in the scientific and practical literature, the second group of indicators is the non-technological innovative outputs, i.e., trademark applications, design applications, and marketing and organizational innovations introduced by SMEs. Finally, since a substantial amount of debate is related to the ability of the EU to commercialize the innovative processes and products, the final group of outputs reflects the commercial part of innovation (sales of innovation, exports of high-technology products and knowledge-intensive services). The justification for using IPR applications instead of the granted IPRs is an attempt to avoid the limitation of a time gap between the application process and the issue of intellectual property rights.

To continue with the input indicators, first, the dimension 'Common innovation infrastructure' was supplemented by the variables of top-cited scientific publications, employees having a tertiary education and ICT access. The results show the importance of scientific excellence—publications seem to cause all the analyzed innovative output indicators. This situation at some point reflects the findings by Proksch et al. (2017), who found out that having a high base of journal publications may act as a way to positively influence the patent outcome. Meanwhile, employees with tertiary education have a causal relationship with non-technological innovative outputs, such as trademark and design applications and the introduction of marketing and organizational innovations.

ICT access seems to be essential for introducing all types of innovation, including process, product, marketing, and organizational ones, and exports of knowledge-intensive services. One of the most surprising results is that a composite knowledge stock variable that was formed from the stock of granted patents, the stock of granted trademarks, and the stock of granted designs turned out to be insignificant, though generally it reflects the 'pool of the previous knowledge' and is crucial for the science and innovation policy environment.

Since R&D represents only about one-third of the innovation costs, the next original dimension 'Cluster-specific environment for innovation' was extended by a variable of private sector non-R&D innovation investment. A variable of the urban population also complemented this dimension as a substitute for the co-location of economic actors and economic activity. It was discovered that non-R&D innovation investment by businesses has a causal relationship with marketing and organizational innovation and may induce commercialization of innovation, proxied as sales of new-to-market and new-to-firm innovations (as in Faber and Hesen 2004) and exports of high-tech products. The results also demonstrate that densely populated countries might be more successful in applying for patents, introducing all types of innovations, and commercial exploitation of knowledge-intensive services.

To improve the representation of dissemination of knowledge and the links between the different sectors, public-private sector collaboration and innovative SMEs' collaboration were included as the additional elements to the original framework dimension 'Quality of linkages'. Assuming that public institutions act as the generators of scientific knowledge, the research findings show that public-private collaboration exhibits a Granger causal relationship with patent, trademark and design applications, and product and process innovations. A study by Carvalho et al. (2015) demonstrated similar tendencies, showing that collaborative innovation networks within the so-called triple helix can serve as platforms for sharing ideas that are critical to innovation. The effect of cross-enterprise interactions and dissemination of good practice is proved by causal links between the variable that represents innovative SMEs collaboration and patent applications, marketing and organizational innovations, and exports of high technology products.

Considering that product and process innovations were not between the significant variables, these results differ from those by Pereira and Leitão (2016), who found that cooperating firms tend to generate more product innovations.

As innovation performance is also influenced by a country's position in the global trade network and international cooperation, the original model was supplemented with the new dimension 'International economic activity'. Exports, imports, and inward FDI seem to cause all three types of the analyzed innovative outputs—technological, non-technological, and commercial ones, proving the importance of knowledge flows across the countries. Filippetti et al. (2017), Krammer (2009), and Wu et al. (2017) presented similar findings, showing the positive association between trade intensity and patenting. Regarding the variable of inward FDI, the results are in line with the results of Krammer (2009) and Wu et al. (2017) but contradicts those of Filippetti et al. (2017).

The shared values within society play a unique role in motivating and encouraging its members to undertake innovative initiatives. Diversity leads to a more extensive amount of ideas, variance in creativity, and innovation. Therefore, the dimension 'Diversity and equality' was added to the framework by Furman et al. (2002). The results reveal that cultural diversity in a country may induce exports of high-technology products. A Granger causal relationship between the income inequality levels and sales of innovation and exports of knowledge-intensive services was also found. These findings go in line with DiRienzo and Das (2015), who found a link between ethnic and racial diversity, income inequality level, and a country's global innovation index. In addition, gender equality represented by the female share in senior and middle management seems to contribute to performance improvement and creativity stimulation by showing a causal relationship with all types of IP applications and innovation sales. These results conform the study by Bührer and Frietsch (2020), who showed the benefits that emerge from improved gender equality.

Trust in the political and legal system is vital if a country seeks to incentivize innovation. Public policy decisions, the rationale of budget allocation, and the impact of newly adopted laws depends on the strength of the legal and political environment. The research results show a Granger causal relationship between this environment and product, process, marketing, and organizational innovations along with the exports of knowledge-intensive services. Ege and Ege (2019) found out that legal/regulatory inclusiveness leads to higher levels of innovation performance as well. A variable of corruption represented by a reversed corruption index shows similar tendencies, except that it also has causal links with design applications. Lastly, IPR protection also induces all the analyzed innovative outputs. This result completely aligns with the findings of Faber and Hesen (2004), Furman et al. (2002), Hu and Mathews (2005, 2008), and Proksch et al. (2017), who proved that minimization of legal and profit-making risks increases the amount of innovations.

Finally, the potential effects of general socioeconomic conditions are analyzed. It was observed that GDP per capita that represents 'country's economic health' causes at least one element from each of the output indicators' groups, including patent, trademark, and design applications as well as marketing and organizational innovations and exports of knowledge-intensive services. On the contrary, the last analyzed independent variable, i.e., labor force that reflects a critical mass of potential innovators, has causal links only with the exports of knowledge-intensive services proving that quantity is not as important as quality in this context.

5. Conclusions

To conclude, this article enhances the existing knowledge on the national innovative capacity and highlights the most critical areas where the EU member states could focus to increase their innovation performance.

At the same time, it is important to present a few limitations accompanying the study. First, there is an issue related to the time–frame dataset. To be specific, the dependent variables 'smes_pp', 'smes_mo', and 'inno_sales' were obtained from the Community

Innovation Survey that is carried out every two years. Therefore, the considered time frame was 2004–2016 and the missing values were replaced by using an interpolation method that counts the mean of values of the particular variable in between the years. Second, this research represents general tendencies for the whole EU and calculations for specific countries are not performed. Having in mind the uniqueness of each member state, the final results might be distorted.

Despite these issues, a proposed redeveloped framework gives the floor for future research to enhance calculations at the individual member state level and compare the national innovative capabilities across the countries. It could also add value to the qualitative analysis and comparative case studies that would bring more insights into the underlying factors between each country's national innovative capacity values. Finally, the redeveloped framework may serve as a part of the instrument for innovation policy evaluation.

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Appendix A

Table A1. Granger causality test: NIC inputs → NIC outputs (patent).

Dependent Variable: Patent	Lags					Granger Causality
	1	2	3	4	5	
'Common innovation infrastructure'						
rd	16.33 ***	11.71 ***	5.91 ***	4.68 ***	3.21 **	Yes
public_rd	1.97	2.09	0.86	1.08	1.02	No
edu_exp	2.90 *	1.51	1.59	1.79	1.21	No
rd_fte	0.00	0.33	0.43	1.08	0.98	No
knowledge_stock	1.43	1.72	1.52	1.49	1.01	No
pub_top10	0.09	0.93	0.86	2.08 *	2.90 **	Yes
d(employees_edu)	4.13 **	1.36	0.27	0.62	0.36	No
ict	0.48	0.30	1.64	1.97	0.43	No
'Cluster-specific environment for innovation'						
d(private_rd)	3.65 *	2.28	3.43 **	2.74 **	2.32 **	Yes
non_rd	0.11	0.12	0.18	0.19	0.50	No
sector_industry	0.13	0.50	0.48	0.35	0.91	No
sector_services	0.02	0.33	0.39	0.30	0.50	No
pop_urban	0.24	0.58	1.50	5.88 *	9.44 *	Yes
'Quality of linkages'						
higher_ed_rd	16.50 ***	11.83 ***	6.13 ***	4.76 ***	3.24 **	Yes
venture_cap	0.43	1.00	1.12	0.51	0.62	No
d(public_private_collab)	11.76 ***	4.55 **	16.39 ***	6.45 ***	6.71 ***	Yes
inno_smes_collab	0.81	5.08 **	3.62 **	1.96	3.15 **	Yes
'International economic activities'						

exports	3.18 *	3.06 *	2.11	2.27	2.57 **	Yes
imports	3.42 *	2.19	1.26	1.76	2.49 **	No
fdi	3.61 *	2.77 *	2.38 *	1.54	1.35	Yes
'Diversity and equality'						
d(multi_culture)	0.73	0.82	0.85	0.55	0.73	No
gender_equality	0.38	4.41 **	4.91 ***	5.33 ***	4.38 ***	Yes
income_inequality	0.40	0.05	0.20	0.16	0.28	No
'Legal and political strength'						
legal_political	1.19	2.01	1.17	1.71	1.88	No
corruption	3.62 **	1.71	2.02	0.88	0.35	No
ipr	0.59	0.22	0.15	0.12	0.23	No
'General socioeconomic conditions'						
gdp_capita	1.21	1.27	0.90	2.55 **	1.00 ***	Yes
labor_force	0.14	0.50	0.45	0.39	0.19	No

* Significance level 10%. ** Significance level 5%. *** Significance level 1%; d means first differences.

Table A2. Granger causality test: NIC inputs → NIC outputs (smes_pp).

Dependent Variable: smes_pp	**Lags**					**Granger Causality**
	1	**2**	**3**	**4**	**5**	
'Common innovation infrastructure'						
rd	4.17 **	2.75 *	0.93	6.67 ***	7.22 ***	Yes
public_rd	0.13	0.10	0.21	0.40	3.30 **	No
edu_exp	0.72	1.10	0.85	1.44	1.17	No
rd_fte	6.61 **	3.68 **	1.77	1.42	1.36	Yes
knowledge_stock	0.80	0.56	0.71	0.61	0.86	No
pub_top10	14.20 ***	8.29 ***	3.86 **	3.13 **	2.24 *	Yes
d(employees_edu)	0.05	0.08	0.84	1.36	1.43	No
ict	5.26 **	5.41 **	0.14	0.04	0.73	Yes
'Cluster-specific environment for innovation'						
d(private_rd)	0.33	0.35	8.33 ***	9.62 ***	9.20 ***	Yes
non_rd	1.98	1.63	0.52	0.52	2.86 **	No
sector_industry	3.16 *	4.10 **	2.46 *	4.44 ***	3.69 ***	Yes
sector_services	5.54 **	5.21 **	3.35 **	4.01 ***	3.54 ***	Yes
pop_urban	2.56	4.23 **	3.26 **	2.57 **	2.33 **	Yes
'Quality of linkages'						
higher_ed_rd	3.89 *	2.63 *	0.88	6.06 ***	6.43 ***	Yes
venture_cap	0.01	1.02	0.16	0.22	0.41	No
d(public_private_collab)	5.32 **	3.12 *	3.61 **	2.99 **	2.16 *	Yes
inno_smes_collab	1.07	0.57	2.24	1.52	0.94	No
'International economic activities'						
exports	0.16	5.74 ***	4.97 ***	4.26 ***	3.66 ***	Yes
imports	0.21	1.10	2.15 *	3.06 **	-	Yes
fdi	0.06	0.04	0.21	0.21	0.31	No
'Diversity and equality'						
d(multi_culture)	0.73	0.35	0.73	0.48	0.60	No
gender_equality	0.15	1.23	1.32	1.17	1.38	No
income_inequality	3.95 *	1.74	1.79	1.09	1.35	No

'Legal and political strength'						
legal_political	3.86 *	3.60 **	2.51 *	2.22 *	1.53	Yes
corruption	4.82 **	2.69 *	1.60	1.74	1.69	Yes
ipr	4.32 **	5.67 ***	3.72 **	3.25 **	1.96 *	Yes
'General socioeconomic conditions'						
gdp_capita	1.69	3.99 **	1.63	1.76	1.58	No
labor_force	0.00	0.15	0.73	0.69	0.88	No

* Significance level 10%. ** Significance level 5%. *** Significance level 1%; d means first differences.

Table A3. Granger causality test: NIC inputs → NIC outputs (trademark).

Dependent Variable: Trademark	**Lags**					**Granger Causality**
	1	**2**	**3**	**4**	**5**	
'Common innovation infrastructure'						
rd	0.47	0.18	0.01	0.10	0.22	No
public_rd	7.04 **	3.74 **	2.21 *	1.64	1.28	Yes
edu_exp	0.56	0.13	1.99	3.84 ***	3.62 ***	Yes
rd_fte	0.05	0.54	0.86	2.07 *	3.02 **	Yes
knowledge_stock	0.01	0.06	0.08	0.10	0.50	No
pub_top10	0.80	5.15 **	4.47 ***	4.52 ***	3.53 ***	Yes
d(employees_edu)	5.88 **	18.58 ***	10.12 ***	7.06 ***	5.12 ***	Yes
ict	0.51	0.24	0.10	1.14	1.46	No
'Cluster-specific environment for innovation'						
d(private_rd)	10.59 ***	9.32 ***	1.68	0.49	0.79	Yes
non_rd	3.66 *	2.16	0.82	1.78	1.07	No
sector_industry	8.70 ***	4.49 **	4.99 ***	4.04 ***	0.89	Yes
sector_services	16.92 ***	8.35 ***	9.09 ***	6.36 ***	0.88	Yes
pop_urban	2.19	1.98	1.25	1.02	0.77	No
'Quality of linkages'						
higher_ed_rd	2.09	0.66	0.55	0.52	0.48	No
venture_cap	5.51 **	2.34	1.18	0.45	0.79	No
d(public_private_collab)	7.39 **	6.93 ***	10.42 ***	8.31 ***	7.98 ***	Yes
inno_smes_collab	0.34	0.18	0.19	0.57	1.09	No
'International economic activities'						
exports	13.86 ***	9.13 ***	5.43 ***	3.77 **	4.20 ***	Yes
imports	13.51 ***	7.74 ***	4.27 **	2.78 **	2.69 **	Yes
fdi	11.75 ***	6.87 ***	2.95 **	3.35 **	3.78 ***	Yes
'Diversity and equality'						
d(multi_culture)	1.26	0.71	1.11	1.09	2.53 **	No
gender_equality	2.54	9.12 ***	5.30 ***	3.53 **	3.06 **	Yes
income_inequality	0.91	0.50	0.91	0.80	1.10	No
'Legal and political strength'						
legal_political	0.64	0.43	0.61	0.59	0.78	No
corruption	0.06	0.32	1.07	0.61	0.94	No
ipr	1.20	0.73	0.47	0.08	0.24	No
'General socioeconomic conditions'						
gdp_capita	0.59	1.31	1.51	2.97 **	2.34 **	Yes
labor_force	4.56 **	2.24	1.11	0.83	0.47	No

* Significance level 10%. ** Significance level 5%. *** Significance level 1%; d means first differences.

Table A4. Granger causality test: NIC inputs → NIC outputs (design).

Dependent Variable: Design	Lags					Granger Causality
	1	2	3	4	5	
'Common innovation infrastructure'						
rd	1.89	0.51	0.50	0.44	0.42	No
public_rd	1.58	0.85	0.23	0.40	0.93	No
edu_exp	0.78	2.67	4.17 **	2.55 **	1.33	Yes
rd_fte	9.68 ***	5.76 ***	3.76 **	4.25 ***	1.53	Yes
knowledge_stock	0.01	0.06	0.08	0.10 *	0.50	No
pub_top10	3.55 *	3.50 **	2.26 *	2.16	1.87	Yes
d(employees_edu)	6.14 **	8.40 ***	6.22 ***	5.14 ***	7.49 ***	Yes
ict	0.38	3.48 **	1.98	2.86 **	0.61	No
'Cluster-specific environment for innovation'						
d(private_rd)	7.31 **	4.39 **	4.02 **	0.10	0.62	Yes
non_rd	0.10	0.11	0.17	0.32	1.00	No
sector_industry	1.81	0.10	0.22	0.60	2.45 **	No
sector_services	3.90 *	0.08	0.38	1.07	2.31 **	No
pop_urban	4.93 **	2.22	1.15	1.15	0.61	No
'Quality of linkages'						
higher_ed_rd	2.09	0.66	0.55	0.52	0.48	No
venture_cap	5.35 **	9.36 ***	3.47 **	2.59 **	3.06 **	Yes
d(public_private_collab)	4.51 **	13.43 ***	17.32 ***	12.36 ***	3.63 ***	Yes
inno_smes_collab	0.31	0.51	0.44	0.25	0.14	No
'International economic activities'						
exports	11.85 ***	7.64 ***	5.05 ***	4.89 ***	11.45 ***	Yes
imports	7.27 **	4.52 **	2.76 **	2.86 **	10.20 ***	Yes
fdi	8.62 ***	4.30 **	3.10 **	2.95 **	2.19 *	Yes
'Diversity and equality'						
d(multi_culture)	0.95	1.40	0.61	0.66	0.22	No
gender_equality	2.78	7.69 ***	4.78 ***	4.43 ***	1.21	Yes
income_inequality	3.46 *	1.34	1.50	1.19	0.65	No
'Legal and political strength'						
legal_political	2.05	3.07 *	0.95	0.37	0.07	No
corruption	7.49 **	2.88 *	1.78	1.44	0.47	Yes
ipr	0.71	2.49 *	0.86	0.24	1.79	No
'General socioeconomic conditions'						
gdp_capita	25.38 ***	14.92 ***	8.82 ***	8.32 ***	0.92	Yes
labor_force	0.04	0.22	0.11	0.17	0.42	No

* Significance level 10%. ** Significance level 5%. *** Significance level 1%; d means first differences.

Table A5. Granger causality test: NIC inputs → NIC outputs (smes_mo).

Dependent Variable: smes_mo	Lags					Granger Causality
	1	2	3	4	5	
'Common innovation infrastructure'						
rd	3.86 *	2.30	1.28	4.10 ***	3.44 **	Yes
public_rd	0.69	0.55	2.28 *	2.57 **	1.44	Yes
edu_exp	1.05	1.47	1.05	1.13	1.31	No
rd_fte	7.73 **	4.70 **	4.06 **	3.76 **	1.68	Yes
knowledge_stock	1.09	0.69	1.41	1.46	1.74	No
pub_top10	4.15 **	2.56 *	2.83 **	4.27 ***	2.38 **	Yes
d(employees_edu)	2.22	4.54 **	3.34 **	1.22	1.07	Yes
ict	6.29 **	6.00 ***	4.78 ***	3.95 **	1.10	Yes
'Cluster-specific environment for innovation'						
d(private_rd)	0.17	0.25	2.24 *	2.30 *	1.82	Yes
non_rd	0.37	1.20	2.47 *	2.27 *	4.14 ***	Yes
sector_industry	4.58 **	3.42 **	3.00 **	3.03 **	2.45 **	Yes
sector_services	7.77 **	4.79 **	6.85 ***	5.93 ***	4.37 ***	Yes
pop_urban	3.37 *	2.67 *	2.67 *	2.66 ***	1.96 *	Yes
'Quality of linkages'						
higher_ed_rd	3.87 *	2.33	1.28	3.67 **	2.92 **	Yes
venture_cap	0.56	3.06 *	1.37	1.97	1.89	No
d(public_private_collab)	2.01	1.50	1.39	0.89	0.50	No
inno_smes_collab	1.17	0.60	4.13 **	2.86 **	2.87 **	Yes
'International economic activities'						
exports	0.19	1.25	1.01	0.83	0.79	No
imports	0.48	0.92	1.01	0.94	0.75	No
fdi	0.02	0.05	0.13	0.43	2.36 **	No
'Diversity and equality'						
d(multi_culture)	1.02	0.92	0.99	1.26	1.79	No
gender_equality	0.22	1.56	1.12	1.01	0.53	No
income_inequality	3.30 *	1.91	1.99	1.02	0.88	No
'Legal and political strength'						
legal_political	8.61 ***	3.86 **	2.21 *	3.11 **	2.59 **	Yes
corruption	3.16 *	1.67	5.08 ***	4.05 ***	4.28 ***	Yes
ipr	12.27 ***	3.59 **	3.00 **	3.21 **	3.03 **	Yes
'General socioeconomic conditions'						
gdp_capita	4.85 **	10.43 ***	7.18 ***	6.21 ***	3.38 **	Yes
labor_force	1.02	0.55	0.88	0.90	1.48	No

* Significance level 10%. ** Significance level 5%. *** Significance level 1%; d means first differences.

Table A6. Granger causality test: NIC inputs → NIC outputs (inno_sales).

Dependent Variable: inno_sales	Lags					Granger Causality
	1	2	3	4	5	
'Common innovation infrastructure'						
rd	0.09	0.59	0.28	0.29	0.56	No
public_rd	3.30 *	2.12	1.13	0.96	0.44	No
edu_exp	0.06	0.55	0.17	0.93	1.68	No
rd_fte	0.06	0.12	1.01	1.89	1.84	No
knowledge_stock	0.49	0.58	1.24	1.22	0.99	No
pub_top10	0.00	1.50	3.21 **	2.38 *	2.05 *	Yes

d(employees_edu)	5.47	1.63	0.95	1.14	0.60	No
ict	1.21	0.72	1.17	1.59	1.18	No
'Cluster-specific environment for innovation'						
d(private_rd)	1.01	0.81	0.55	0.42	0.66	No
non_rd	6.47 **	3.19 **	0.63	0.47	0.78	Yes
sector_industry	0.39	1.05	1.60	1.49	1.62	No
sector_services	0.14	0.21	1.93	1.96	1.98 *	No
pop_urban	0.16	0.16	0.14	0.15	0.09	No
'Quality of linkages'						
higher_ed_rd	0.09	0.43	0.17	0.18	0.53	No
venture_cap	1.90	1.04	0.45	0.25	0.97	No
d(public_private_collab)	0.46	0.29	0.38	0.06	0.19	No
inno_smes_collab	2.93 *	2.01	1.90	2.14 *	1.65	No
'International economic activities'						
exports	3.11 *	2.73 *	1.89	4.20 ***	3.61 ***	Yes
imports	2.53	1.35	0.86	2.21 *	2.63 **	Yes
fdi	0.31	0.81	3.08 **	2.28 *	1.63	Yes
'Diversity and equality'						
d(multi_culture)	0.32	0.21	0.03	0.20	0.38	No
gender_equality	0.37	2.23	3.22 **	2.05 *	1.57	Yes
income_inequality	2.92 *	3.98 **	3.04 **	2.42 *	1.96 *	Yes
'Legal and political strength'						
legal_political	0.10	0.39	1.38	0.78	2.01 *	No
corruption	0.02	1.28	1.56	1.02	1.03	No
ipr	0.81	0.97	0.81	1.26	4.15 ***	No
'General socioeconomic conditions'						
gdp_capita	0.25	0.98	0.59	0.59	0.47	No
labor_force	0.45	1.27	1.20	1.21	0.97	No

* Significance level 10%. ** Significance level 5%. *** Significance level 1%; d means first differences.

Table A7. Granger causality test: NIC inputs → NIC outputs (exports_hitech).

Dependent Variable: exports_hitech	Lags					Granger Causality
	1	2	3	4	5	
'Common innovation infrastructure'						
rd	0.74	2.07	1.81	1.17	0.73	No
public_rd	0.75	1.09	0.02	0.21	0.28	No
edu_exp	0.92	3.48 **	2.41 *	1.92	1.21	Yes
rd_fte	1.55	2.85 *	2.84 **	2.34 *	1.42	Yes
knowledge_stock	0.93	0.26	0.72	1.37	1.00	No
pub_top10	0.02	1.06	6.32 ***	5.00 ***	4.16 ***	Yes
d(employees_edu)	0.31	0.69	0.75	0.47	0.59	No
ict	3.38 *	2.13	0.14	0.45	0.39	No
'Cluster-specific environment for innovation'						
d(private_rd)	0.37	0.45	0.29	0.54	0.33	No
non_rd	2.17	0.21	0.40	1.63	2.49 **	Yes
sector_industry	3.09 *	3.02 *	4.19 **	4.39 ***	3.67 ***	Yes
sector_services	0.66	1.48	2.65 *	2.89 **	2.23 *	Yes
pop_urban	0.03	0.37	0.20	0.26	0.27	No

'Quality of linkages'						
higher_ed_rd	0.72	1.96	2.39 *	1.42	0.97	No
venture_cap	0.12	0.62	3.21 **	3.10 **	2.81 **	Yes
d(public_private_collab)	0.13	0.13	0.47	0.44	0.46	No
inno_smes_collab	1.25	2.85 *	2.25 *	1.29	1.81	Yes
'International economic activities'						
exports	0.31	0.23	0.84	0.59	0.65	No
imports	0.32	0.89	0.45	0.50	0.35	No
fdi	2.04	1.34	1.49	1.60	1.59	No
'Diversity and equality'						
d(multi_culture)	10.49 ***	5.31 **	3.08 **	3.95 ***	3.61 ***	Yes
gender_equality	0.28	0.31	0.64	0.92	0.85	No
income_inequality	0.36	0.20	0.72	1.09	0.90	No
'Legal and political strength'						
legal_political	0.03	1.15	0.24	0.46	0.52	No
corruption	0.10	0.04	0.41	1.10	1.13	No
ipr	0.05	0.26	0.11	1.63	1.87	No
'General socioeconomic conditions'						
gdp_capita	0.62	0.87	2.21 *	1.63	1.51	No
labor_force	0.99	0.25	0.29	0.36	0.30	No

* Significance level 10%. ** Significance level 5%. *** Significance level 1%; d means first differences.

Table A8. Granger causality test: NIC inputs → NIC outputs (exports_kis).

Dependent Variable: d(exports_kis)	**Lags**					**Granger Causality**
	1	**2**	**3**	**4**	**5**	
'Common innovation infrastructure'						
rd	1.22	2.32	1.83	1.72	2.75 **	No
public_rd	17.92 ***	6.83 ***	3.07 **	2.89 **	5.70 ***	Yes
edu_exp	0.41	3.11 *	3.24 **	2.94 **	2.36 **	Yes
rd_fte	1.88	3.27 **	2.20 *	1.45	1.68	Yes
knowledge_stock	0.75	0.99	1.04	1.42	1.85	No
pub_top10	12.69 ***	5.37 **	6.45 ***	5.69 ***	4.60 ***	Yes
d(employees_edu)	1.04	2.07	2.33 *	0.74	0.61	No
ict	7.61 **	3.39 **	1.74	1.04	0.71	Yes
'Cluster-specific environment for innovation'						
d(private_rd)	2.24	1.01	1.21	1.04	1.16	No
non_rd	2.11	0.74	1.18	1.28	1.14	No
sector_industry	0.60	1.39	1.22	1.85	1.89	No
sector_services	4.74 **	3.27 **	3.01 **	2.67 **	1.96 *	Yes
pop_urban	5.50 **	3.13 **	3.62 **	3.31 **	2.32 **	Yes
'Quality of linkages'						
higher_ed_rd	0.38	1.61	0.96	1.08	1.61	No
venture_cap	2.72	1.35	2.37 *	1.68	1.83	No
d(public_private_collab)	0.62	2.00	1.51	1.43	0.24	No
inno_smes_collab	6.85 **	2.13	2.67 *	1.91	0.53	No
'International economic activities'						
exports	2.80	1.53	3.39 **	2.58 **	0.58	Yes
imports	2.52	1.86	3.52 **	1.98	0.39	No
fdi	0.37	2.00	3.41 **	9.49 ***	7.33 ***	Yes

'Diversity and equality'						
d(multi_culture)	3.18 *	1.13	0.76	1.00	0.68	No
gender_equality	1.33	1.85	1.80	1.16	0.50	No
income_inequality	5.31 **	3.15 **	3.85 **	2.02 *	1.19	Yes
'Legal and political strength'						
legal_political	10.56 ***	5.32 **	3.22 **	1.73	1.45	Yes
corruption	10.42 ***	4.24 **	5.91 ***	4.80 ***	4.00 ***	Yes
ipr	17.63 ***	2.15	1.31	2.57 **	0.34	No
'General socioeconomic conditions'						
gdp_capita	16.76 ***	7.03 ***	6.17 ***	4.63 ***	4.69 ***	Yes
labor_force	0.01	7.58 ***	4.29 **	2.96 **	2.57 **	Yes

* Significance level 10%. ** Significance level 5%. *** Significance level 1%; d means first differences.

References

Azagra-Caro, Joaquín M., and Davide Consoli. 2016. Knowledge flows, the influence of national R&D structure and the moderating role of public–private cooperation. *The Journal of Technology Transfer* 41: 152–72.

Baesu, Viorica, Claudiu Tiberiu Albulescu, Zoltan-Bela Farkas, and Anca Drăghici. 2015. Determinants of the high-tech sector innovation performance in the European Union: A review. *Procedia Technology* 19*:* 371–78. https://doi.org/10.1016/j.protcy.2015.02.053.

Bilbao-Osorio, Beñat. 2018. Science, Research and Innovation Performance of the EU 2018 Strengthening the Foundations for Europe's Future European Commission Directorate-General for Research and Innovation Directorate A—Policy Development and Coordination. Available online: https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/support-national-research-and-innovation-policy-making/srip-report_en (accessed on 8 February 2021).

Bloom, Nicholas, Mirko Draca, and John Van Reenen. 2016. Trade induced technical change? The impact of Chinese imports on innovation, IT and productivity. *The Review of Economic Studies* 83: 87–117. https://doi.org/10.1093/restud/rdv039.

Bührer, Susanne, and Rainer Frietsch.2020. How do public investments in gender equality initiatives and publication patterns interrelate? The case of Germany. *Evaluation and Program Planning* 79: 101769. https://doi.org/10.1016/j.evalprogplan.2019.101769.

Carvalho, Nuno, Luisa Carvalho, and Sandra Nunes.. 2015. A methodology to measure innovation in European Union through the national innovation system. *International Journal of Innovation and Regional Development* 6: 159–80.

Castellacci, Fulvio, and Jose Miguel Natera. 2013. The dynamics of national innovation systems: A panel cointegration analysis of the coevolution between innovative capability and absorptive capacity. *Research Policy* 42: 579–94. https://doi.org/10.1016/j.respol.2012.10.006Get rights and content.

Castellani, Davide, Mariacristina Piva, Torben Schubert, and Marco Vivarelli. 2019. R&D and productivity in the US and the EU: Sectoral specificities and differences in the crisis. *Technological Forecasting and Social Change* 138: 279–91. https://doi.org/10.1016/j.techfore.2018.10.001.

Čučković, Nevenka, and Valentina Vučković. 2018. EU R&D funding as a way of incentivizing innovation of SMEs: A review of impacts. *Croatian Economic Survey* 20: 97–127. https://doi.org/10.15179/ces.20.2.4.

Čučković, Nevenka, and Valentina Vučković. 2021. The effects of EU R&I funding on SME innovation and business performance in new EU member states: Firm-level evidence. *Economic Annals* 66*:* 7–41. https://doi.org/10.2298/EKA2128007C.

De Liso, Nicola, and Anna Serena Vergori. 2017. The Different Approaches to the Study of Innovation in Services in Europe and the USA. *Metroeconomica* 68: 121–46.

Díaz-García, Cristina, Angela González-Moreno, and Francisco Jose Saez-Martinez. 2013. Gender diversity within R&D teams: Its impact on radicalness of innovation. *Innovation* 15: 149–60. https://doi.org/10.5172/impp.2013.15.2.149.

Dincer, Oguzhan. 2019. Does corruption slow down innovation? Evidence from a cointegrated panel of US states. *European Journal of Political Economy* 56: 1–10. https://doi.org/10.1016/j.ejpoleco.2018.06.001.

DiRienzo, Cassandra, and Jayoti Das. 2015. Innovation and role of corruption and diversity: A cross-country study. International *Journal of Cross-Cultural Management* 15*:* 51–72. https://doi.org/10.1177/1470595814554790.

Doran, Justin, Noirin McCarthy, and Marie O'Connor. 2018. Analysing national innovation capacity and its importance for competitiveness and growth. *International Journal of Competitiveness* 1: 257–78.

Dziallas, Marisa, and Knut Blind. 2019. Innovation indicators throughout the innovation process: An extensive literature analysis. *Technovation* 80: 3–29. https://doi.org/10.1016/j.technovation.2018.05.005.

Ege, Aylin, and A. Yavuz Ege. 2019. How to Create a Friendly Environment for Innovation? A Case for Europe. *Social Indicators Research* 144: 451–73. https://doi.org/10.1007/s11205-018-2039-4.

European Commission. 2020a. European Innovation Scoreboard Methodology Report. Available online: https://ec.europa.eu/docsroom/documents/41861 (accessed on 21 October 2020).

European Commission. 2020b. European Innovation Scoreboard 2002–2020. Available online: http://ec.europa.eu/DocsRoom/documents/17821 (accessed on 21 October 2020).

European Commission. 2021. EIS 2021 Executive Summary. Available online: https://ec.europa.eu/docsroom/documents/46411a (accessed on 24 August 2021).

European Patent Office. 2020. Patent Statistics. Available online: https://www.epo.org/about-us/annual-reports-statistics/statistics.html (accessed on 11 April 2020).

Eurostat. 2021. Official Eurostat Database. Available online: https://ec.europa.eu/eurostat/data/database (accessed on 15 February 2021).

Eurostat and OECD. 2018. Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation. Available online: https://www.oecd.org/science/oslo-manual-2018-9789264304604-en.htm (accessed on 15 May 2020).

Faber, Jan, and Anneloes Barbara Hesen. 2004. Innovation capabilities of European nations: Cross-national analyses of patents and sales of product innovations. *Research Policy* 33: 193–207. https://doi.org/10.1016/S0048-7333(03)00122-7.

Filippetti, Andrea, and Frederick Guy. 2020. Labor market regulation, the diversity of knowledge and skill, and national innovation performance. *Research Policy* 49: 103867. https://doi.org/10.1016/j.respol.2019.103867.

Filippetti, Andrea, Marion Frenz, and Grazia Ietto-Gillies. 2017. The impact of internationalization on innovation at countries' level: The role of absorptive capacity. *Cambridge Journal of Economics* 41: 413–39. https://doi.org/10.1093/cje/bew032.

Franco, Chiara, and Riccardo Leoncini. 2013. Measuring China's Innovative Capacity: A Stochastic Frontier Exercise, *Economics of Innovation and New Technology* 2013: 22. https://doi.org/10.1080/10438599.2012.744174.

Furman, Jeffrey L., Michael E. Porter, and Scott Stern. 2002. The determinants of national innovative capacity. *Research Policy* 31: 899–933. https://doi.org/10.1016/s0048-7333(01)00152-4.

Halkos, George, and Antonis Skouloudis. 2018. Corporate social responsibility and innovative capacity: Intersection in a macro-level perspective. *Journal of Cleaner Production* 182: 291–300. https://doi.org/10.1016/j.jclepro.2018.02.022.

Hu, Mei-Chih, and John A. Mathews. 2005. National innovative capacity in East Asia. *Research Policy* 34: 1322–49. https://doi.org/10.1016/j.respol.2005.04.009.

Hu, Mei-Chih, and John A. Mathews. 2008. China's national innovative capacity. *Research Policy* 37: 1465–79. https://doi.org/10.1016/j.respol.2008.07.003.

Huang, Hung-Chun, Hsin-Yu Shih, and Ya-Chi Wu. 2010. Constructing national innovative capacity in globalization: The network autocorrelation perspective. Paper presented at PICMET 2010 Technology Management for Global Economic Growth, Phuket, Thailand, July 18–20, pp. 1–12.

Hudec, Oto. 2015. Visegrad countries and regions: Innovation performance and efficiency. *Quality Innovation Prosperity* 19: 55–72. https://doi.org/10.12776/qip.v19i2.593.

Jacobs, Elisabeth. 2016. *What Do Trends in Economic Inequality Imply for Innovation and Entrepreneurship? A Framework for Future Research and Policy*. Technical report. Washington, DC: Washington Center for Equitable Growth. Available online: https://equitablegrowth.org/research-paper/trends-economic-inequality-imply-innovation-entrepreneurship/?longform=true (accessed on 26 May 2020).

Jaklič, Andreja, Jože P. Damijan, Matija Rojec, and Aljaž Kunčič. 2014. Relevance of innovation cooperation for firms' innovation activity: The case of Slovenia. *Economic Research-Ekonomska Istraživanja* 27: 645–61. https://doi.org/10.1080/1331677X.2014.975513.

Jürgen, Janger, Torben Schubert, Petra Andries, Christian Rammer, and Machteld Hoskens. 2017. The EU 2020 innovation indicator: A step forward in measuring innovation outputs and outcomes? *Research Policy* 46*:* 30–42. https://doi.org/10.1016/j.respol.2016.10.001.

Khan, Raihan, and Pamela Cox. 2017. Country culture and national innovation. *Archives of Business Research* 5: 2. https://doi.org/10.14738/abr.52.2768.

Krammer, Sorin M.S. 2009. Drivers of national innovation in transition: Evidence from a panel of Eastern European countries. *Research Policy* 38*:* 845–60. https://doi.org/10.1016/j.respol.2009.01.022.

Law, Siong Hook, Weng Chang Lee, and Nirvikar Singh. 2018. Revisiting the finance-innovation nexus: Evidence from a non-linear approach. *Journal of Innovation and Knowledge* 3*:* 143–53. https://doi.org/10.1016/j.jik.2017.02.001.

Lee, Sangwon, Yoonjae Nam, Seonmi Lee, Hyunjung Son. 2016. Determinants of ICT innovations: A cross-country empirical study. *Technological Forecasting and Social Change* 110: 71–77. https://doi.org/10.1016/j.techfore.2015.11.010.

Lhuillery, Stephane, Julio Raffo, and Intan Hamdan-Livramento. 2017. Measurement of innovation. In *The Elgar Companion to Innovation and Knowledge Creation*. Available online: https://www.elgaronline.com/view/edcoll/9781782548515/9781782548515.00013.xml (accessed on 4 April 2021).

Malik, Sakshi. 2020. Macroeconomic Determinants of Innovation: Evidence from Asian Countries. *Global Business Review* 1: 1–15. https://doi.org/10.1177/0972150919885494.

Min, Chung-Ki. 2019. *Applied Econometrics: A Practical Guide.* Routledge: Taylor and Francis group.

Napiorkowski, Tomasz M. 2018. The impact of Framework Programs on innovativeness in the European Union. In *Strengthening the Knowledge Base for Innovation in the European Union*. Edited by Marzenna Anna Weresa. Warszawa: Polish Scientific Publishers PWN, pp. 59–99.

Nelson, Richard R, ed. 1993. *National Innovation Systems: A Comparative Analysis*. New York: Oxford University Press on Demand.

Pereira, Dina, and João Leitão. 2016. Absorptive capacity, coopetition and generation of product innovation: Contrasting Italian and Portuguese manufacturing firms. *International Journal of Technology Management* 71: 10–37.

Porter, Michael E. 1990. The competitive advantage of nations. *Harvard Business Review* 68: 73–93.

Proksch, Dorian, Marcus Max Haberstroh, and Andreas Pinkwart.2017. Increasing the national innovative capacity: Identifying the pathways to success using a comparative method. *Technological Forecasting and Social Change* 116*:* 256–70. https://doi.org/10.1016/j.techfore.2016.10.009.

Property Rights Alliance. 2020. International Property Right Index. Available online: https://www.internationalpropertyrightsindex.org/ (accessed on 11 June 2020).

Puia, George, and Joseph Ofori-Dankwa. 2013. The effects of national culture and ethno-linguistic diversity on innovativeness. *Baltic Journal of Management* 8: 349–71. https://doi.org/10.1108/*BJOM-Jan-*2012-0002.

Radicic, Dragana, and Geoffrey Pugh. 2017. R&D programmes, policy mix, and the 'European paradox': Evidence from European SMEs. *Science and Public Policy* 44: 497–512, doi:0.1093/scipol/scw077.

Renda, Andrea. 2015. Europe and innovation: Is 2020 on the Horizon. *Intereconomics* 2015*:* 20–24.

Rodríguez-Pose, Andrés, and Callum Wilkie. 2019. Innovating in less developed regions: What drives patenting in the lagging regions of Europe and North America. *Growth and Change* 50: 4–37. https://doi.org/10.1111/grow.12280.

Romer, Paul M. 1990. Endogenous technological change. *Journal of Political Economy* 98: S71–S102.

Santana, Naja Brandão, Enzo Barberio Mariano, Flávia de Castro Camioto and Daisy Aparecida do Nascimento Rebelatto. 2015. National innovative capacity as determinant in sustainable development: A comparison between the BRICS and G7 countries. *International Journal of Innovation and Sustainable Development* 9: 384–405.

Schneider, Patricia Higino. 2005. International trade, economic growth and intellectual property rights: A panel data study of developed and developing countries. *Journal of Development Economics* 78: 529–47. https://doi.org/10.1016/j.jdeveco.2004.09.001.

Stojčić, Nebojša, Stjepan Srhoj, and Alex Coad. 2020. Innovation procurement as capability-building: Evaluating innovation policies in eight Central and Eastern European countries. *European Economic Review* 121*:* 103330. https://doi.org/10.1016/j.euroecorev.2019.103330.

Peter Sunley, Steven Pinch, Suzanne Reimer, James Macmillen. 2008. Innovation in a creative production system: The case of design. *Journal of Economic Geography* 8: 675–98.

van den Besselaar, Peter A. A., Ramon Flecha, and Alfred Radauer. 2018. Monitoring the impact of EU Framework Programmes. Available online: https://op.europa.eu/en/publication-detail/-/publication/cbb7ce39-d66d-11e8-9424-01aa75ed71a1 (accessed on 2 February 2021).

Varga, Attila, and Tamás Sebestyén. 2017. Does EU Framework Program participation affect regional innovation? The differentiating role of economic development. *International Regional Science Review* 40: 405–39. https://doi.org/10.1177/0160017616642821.

Web of Science. 2020. Database. Available online: https://clarivate.com/webofsciencegroup/ (accessed on 4 December 2020).

World Bank. 2020. World Development Indicators. Available online: https://databank.worldbank.org/source/world-development-indicators (accessed on 7 November 2020).

World Intellectual Property Organisation (WIPO). 2020. Available online: https://www.wipo.int/publications/en/details.jsp?id=4464 (accessed on 18 October 2020).

Wu, Jie, Zhenzhong Ma, and Shuaihe Zhuo. 2017. Enhancing national innovative capacity: The impact of high-tech international trade and inward foreign direct investment. *International Business Review* 26: 502–14. https://doi.org/10.1016/j.ibusrev.2016.11.001.

Zang, Leizhen, Feng Xiong, Xin Lao, and Yanyan Gao. 2019. Does governance efficiency matter for national innovative capacity? One tale from different countries. *Technology Analysis and Strategic Management* 31: 239–52. https://doi.org/10.1080/09537325.2018.1493450.