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Contact to corresponding author: Meda Andrijauskiene, meda.andrijauskiene@ktu.lt

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Meda Andrijauskiene
Kaunas University of Technology, Lithuania
orcid.org/0000-0001-7999-6557

Daiva Dumciuviene
Kaunas University of Technology, Lithuania
orcid.org/0000-0002-3500-3389

Alina Stundziene
Kaunas University of Technology, Lithuania
orcid.org/0000-0001-6812-8471

EU framework programmes: positive and negative effects on member states' innovation performance

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Abstract

Research background: Seeking to ensure competitiveness in the global market, the EU is constantly improving its innovation policy. Compared to other EU initiatives, the Framework Programs for Research and Innovation (FPs) act as the main instrument with the longest history and the largest budget to boost member states' innovation performance. Despite the initial presumptions that these financial inflows should bring positive and constructive effects, the results significantly diverge across the countries with highly uneven and incoherent progress. Therefore, complex and reliable tools must be adopted to evaluate the long-term influence of EU investment and the reasons which distort the innovation performance in separate member states.
Purpose of the article: The purpose of this article is to evaluate the influence of EU investment on its member states' innovation performance by using a redeveloped national innovative capacity framework and including technological, non-technological and commercial innovative output.
Methods: Panel unit root tests were used to assess the time series stationarity. Autoregressive distributed lag models helped in calculating the long-term influence of EU investment on member

states' innovation performance. Finally, by employing dummies, it was analysed how this influence varied over time and across different countries.
Findings & value added: The findings provide evidence that EU investment exerts positive long-term influence on the technological innovative output proxied as total, business and higher education institutions' patent applications, as well as product and process innovations. The effects were also positive on trademarks and marketing, and organisational innovations. However, small but negative influence was found in the case of patent applications by the government sector and the exports of hi-tech products and knowledge-intensive services. These insights may serve in the designing process of the specific instruments and the future innovation policies, which would bring the maximum benefit for the society and economy.

Introduction

In the 1980s, it became clear that a common and regular European Union (EU) research and innovation (R&I) policy is needed as investments of European countries were overlapping, product standards largely differed, and the competitiveness worldwide was relatively low (Kim & Yoo, 2019). Based on the need for systematic cooperation within European countries, a joint research and development initiative named the first Framework Program was launched in 1984. It had a budget of approximately 3 billion euros and was followed by a series of multi-annual FPs which were growing progressively in size, scope and broadening of the focus on new fields of research. The latest research and innovation FP Horizon 2020 (2014–2020) was assigned a budget of 80 billion euros and Horizon Europe, running from 2021–2027, get 95.5 billion euros for reaching the settled aims (European Commission, 2021).

Nevertheless, despite the above-mentioned emphasis on the innovation-based growth and R&I targeting, in 2020, the EU's innovation gap separating it from the strongest innovators in the world — Japan, Canada and Australia — has increased (European Commission, 2020a). Moreover, the innovation performance visibly differs across the member states with highly uneven and incoherent progress (European Commission, 2020a). Having these challenges in mind, complex and reliable tools must be adopted to evaluate the magnitude of the influence of EU investment.

Undoubtedly, the effects of R&I programmes do not develop in a vacuum and each member state has its own specificities that include, but are not limited to, diverse regulatory, legislative, and political context, the degree of availability of human capital (Bruno & Kadunc, 2019), mentality, bureaucracy, corruption, or even illogical investment decisions (Andrijauskiene & Dumciuviene, 2018). Therefore, the environment and conditions which determine the national level ability to carry out innovative activities and to create innovations, i.e., national innovative capacity, is as important as EU R&I policy which sets the priorities for investment.

The aim of this article is to evaluate the influence of EU investment on its member states' innovation performance by using a redeveloped national innovative capacity framework and including three forms of innovative output: technological, non-technological and commercial one.

A unit root test was performed to test the stationarity of the time series. Later, Granger causality analysis was used to define Granger causal links between the analysed indicators while taking into account their dynamics. In the next stage, regression analysis was applied by using OLS, Fixed effects, Random effects, as well as autoregressive distributive lag and stepwise regression models. The application of these models helped in evaluating the significance of independent variables and the calculation of a long-run multiplier to assess the long-term influence of EU investment on the member states' innovation performance. Also, these models assisted in a more precise examination of the influence of EU investment and the investigation of systematic differences across the set of countries and different FPs over time.

This article consists of an introduction, literature review, research methodology, results, discussion and conclusions. The literature review analyses the role and additionality effects of EU research and innovation investment as well as the current methods used in the evaluation of the framework programmes. The next section is devoted to the development of a methodology for the assessment of the influence of EU investment on the member states' innovation performance. The results section involves the implementation of the empirical model and empirical evaluation of the influence of EU investment. The last sections of this article are devoted to the summary of findings and possible directions of future research.

Literature review

Evaluations of government policy measures play a specific role in judging the merit, worth, and value of an investment and builds an evidence base so that to improve the quality of future programmes. The following subsections will overview the additionality effects and evaluation methods of all EU FPs since the year 2002, when the Barcelona target was introduced with the ambition for the EU to turn into the most dynamic and competitive knowledge-based economy worldwide.

The additionality effects of EU Framework Programmes

EU FP6 (2002–2006) contributed towards industrial competitiveness, network externalities, and knowledge infrastructure (European Commission, 2010; Simmonds *et al.*, 2010). It improved the researchers' mobility, internationalised the research teams and aided the integration of the new Member states into the European Union. According to Fisher *et al*. (2009), the effects of FP6 especially include the added value at the firm level because this funding acted as access to complementary resources and skills; an instrument to monitor the market; an opportunity to exploit high level and pre-competitive research, and a tool to keep up with technological developments. However, Bondonio *et al.* (2016) had no evidence found that FP6 or FP7 have additional effects on employment, sales or added value (in comparison with the firms receiving only national funding). Moreover, as stated in the official evaluation by European Commission (2010), despite being substantial beneficiaries, the universities and institutes' incentives were hardly affected by this Framework programme.

The official ex-post evaluations of FP7 (Fresco *et al*., 2015; European Commission, 2016) showed that FP7 prompted the collaboration and networking between the different sectors; was particularly useful in strengthening scientific excellence; helped in coping with such societal challenges as food safety, climate change, migration, or radicalisation; resolved cross-border challenges which could not be addressed by member states alone. In 2018, Piirainen *et al.* (2018) prepared a study that examined the benefits of participating in the EU FPs (FP6 and FP7 in particular). These benefits included enhanced networking and collaboration, the increased knowledge and scientific capabilities of the researchers, the prestige for participating universities and the overall reputation of the member states. Regarding benefits for the private sector, FP7 is claimed to lead to higher turnover (Alquézar Sabadie & Kwiatkowski, 2017), employment, productivity, and even resilience against the economic crisis (Rosemberg *et al*., 2016). Nielsen *et al.* (2017) also found many non-monetary benefits for SMEs, such as strategic collaboration, competitor monitoring, agenda-setting, and access to the new European and international markets.

On the contrary, according to Szücs (2018), who used difference-in-difference estimation on highly innovative patenting firms which were participating in FP7, the overall effect of participation in the programme is limited as no significant effects were observed on innovation indicators (i.e., patent counts and patent citations). According to DASTI (2015), Piirainen *et al.* (2018), Rosemberg *et al.* (2016), the traditional commercialisation outputs and impacts (e.g., new license agreements, spinoffs) are the areas scoring the furthest below FPs participant expectations. This illustrates the 'European paradox' of the successful promotion of R&D inputs in the light of the inability to transform these results into innovations and competitive advantages (particular issue is also mentioned in the works of Napiorkowski (2018), Radicic ane Pugh (2017), and Weresa (2018)).

The findings of the official Interim Evaluation of Horizon 2020 (European Commission, 2017) present evidence that the programme is already producing scientific and technological outputs and societal impacts. The scientific impact includes research competencies and the emergence of new technologies or science directions; better international and cross-sectorial collaboration for research and innovation. The innovation/economic impact embraces new job placements and a strengthened position of Europe's industrial competitiveness. Finally, the societal impact involves the input of R&I while considering global societal challenges and societal approval of science and innovative solutions. According to Čučković and Vučković (2018), who analysed the data on the total H2020 budget allocations to SMEs between 2014 and 2017, countries which received a more considerable amount of EU financial support scored better in the general innovation performance indicator. Napiórkowski (2018) adds that the program helped in producing innovative output, yet the efficiency of this success was heterogeneous across individual programs and countries.

Nevertheless, despite specific incentives and the implemented instruments, membership in the EU does not guarantee development towards an innovative knowledge society (Adam, 2014). The EU innovation gap with the world innovation leaders still exists, and differences between the performance of individual member states persist (European Commission, 2020a). On top of that, Napiorkowski (2018), who compared the effects of different EU FPs, learnt that not all programmes are equally efficient in achieving the innovative output (e.g., the total budget of the 7th FP showed no connection with the innovative output including commercial exploitation of R&D results, patent applications, etc.). This, according to Napiorkowski (2018) and Schuch *et al.* (2017), suggests that there might be a set of other factors determining the creation of the analysed output (e.g., the stock of human capital, the general economic policy at the level of member states, etc.). As indicated by Čučković and Vučković (2018, p. 120), "different empirical studies have not come to a conclusive answer on this research task, especially when it comes to determining the causality of impacts".

Therefore, in the processes of ex-post evaluation as well as the development of new innovation policies, it is crucial to assess a range of factors that may, directly and indirectly, alter the overall influence of EU investment. Information about the methods currently used for the assessment of EU investment influence can be found in the following section.

Overview of the methods for the assessment of the influence of EU investment

Despite a number of measures (for instance, Horizon 2020 Results Platform; Horizon dashboard; Europe 2020 Innovation Indicator; European Innovation Scoreboard), the official interim evaluation of Horizon 2020 (European Commission, 2017) states that it is still challenging to detect all the direct and indirect effects of such an inclusive programme which functions in the multi-faceted policy context. Therefore, as Schuch *et al*. (2017) remarked, FPs are evaluating their impact mainly just as the sum of the results of individual projects. According to Nepelski and Piroli (2018), most of the official evaluations of FPs are limited to the analysis of benefits to the participating organisations, such as profitability, employment change, or labour productivity (e.g., Barajas *et al*., 2012; Aguiar & Gagnepain, 2017), or the accounting for the scientific output and filed patent applications (as in European Commission, 2016), see Table 1.

The analysis of previous evaluations confirmed that most of them are oriented to micro-level analysis, such as the influence of individual projects on the innovative performance of a beneficiary. Hence, there is a lack of research evaluating the influence of EU investment at the national level by employing cross-country analysis. Furthermore, according to Hottenrott *et al.* (2017), public co-funding might influence the R&D efforts of the relevant institutions as well as their ability to innovate well beyond the duration of the supported project. Yet, most analyses focus on the period of the runtime of the grant, typically, two to three years. Finally, it can be accentuated that there is much more focus on innovative input additionality (e.g., on the effect of government support for R&D on the recipient's own R&D investment) rather than the innovative output additionality (e.g. new products, processes, novel marketing or organisational methods, high-tech products or exports of knowledge-intensive services).

Due to these reasons, the next chapter is devoted to the development of research methodology that would help to consider the 'broader environment' and the differences between the EU member states in the context of the long-term influence of FP on the national innovation performance.

Research methodology

A conceptual model for the evaluation of the influence of EU investment on the member states' innovation performance is illustrated in Figure 1. The motivation of this model is based on the original national innovative capacity (NIC) framework by Furman *et al*. (2002). However, due to a fast-changing nature of innovation, it was considerably modified by including additional elements to the initial dimensions of 1) common innovation infrastructure, 2) cluster-specific environment for innovation and 3) quality of the linkages and supplemented by such dimensions as international economic activities, diversity and equality, legal and political strength. Since at current form, it is applied to the situation in the European Union, the variable of EU investment is as well added in the model (see Figure 1).

For the output indicators of national innovation performance, it was decided to represent three groups of innovative outputs instead of using only patents:

1. Technological innovative output (i.e., various forms of patent applications (Law *et al.*, 2018; Ryan & Schneider, 2016; Varga & Sebestyén, 2017) and SMEs introducing product and process innovations (Čučković & Vučković, 2021));
2. Non-technological innovative output (i.e., trademark and design applications (Baesu *et al.*, 2015) along with SMEs introducing marketing or organisational innovations (European Commission, 2020a; Stojčić *et al.*, 2020));
3. Commercialisation of innovation (i.e., innovation sales (Napiorkowski (2018) and exports of high-tech products and knowledge-intensive services (European Commission, 2020a)).

Having in mind the results of the scientific literature analysis, a conceptual model shall be used to check the following hypotheses:

H1: *EU investment has a positive long-term influence on the member states' national innovation performance expressed by the technological innovative output.*

H2: *EU investment exerts a positive long-term influence on the member states' national innovation performance expressed by the non-technological innovative output.*

H3: *EU investment does not have a long-term influence on the member states' national innovation performance expressed by the commercialisation of innovation.*

H4: *The influence of EU investment on the member states' innovation performance depends on the programming period.*

H5: *The magnitude of the influence of EU investment is different across the member states.*

Figure 2 represents an empirical research scheme for the evaluation of the influence EU of the investment on the innovation performance of the member states.

A total of 53 variables were included in the investigation (11 dependent variables for national innovation performance; 14 variables for common innovation infrastructure; 7 variables for cluster-specific innovation environment; 5 variables for the quality of linkages; 3 variables for international economic activities; 3 variables for diversity and equality; 4 variables for legal and political strength; 5 variables for general socio-economic conditions; and 1 variable for EU investment). The full list of independent variables, their definitions and sources (Eurostat, 2020; Property Rights Alliance, 2019; Web of Science, 2019; World Bank, 2019; World Intellectual Property Organisation (WIPO), 2020) can be found in Table 2, while the full list of dependent variables, their definitions and sources (Eurostat, 2020; European Patent Office, 2020) can be found in Table 3.

The panel dataset for 28 EU Member states was compiled with the most recent available data from 2000 to 2018 (*note: since the United Kingdom left the Union only on February 1, 2020, it was included in the analysis*). The data were processed by using the year 2019 version of Microsoft Excel and the Statistical Data Processing Package SPSS, version 21.0, whereas statistical and econometric analysis was performed by using EViews 11 University Edition for Windows.

Results

To begin with, unit root tests were applied in the analysis. The values of differences were applied for variables that turned out to be not stationary (Min, 2019; step 1 in Figure 2). Later on, Granger causality and correlation tests (as in Čučković & Vučković, 2018; Lewandowska *et al.*, 2018) helped in finding out which NIC elements may act as factors which influence the national innovation performance and have to be entered into the regression models (step 2 and step 3 in Figure 2).

Continuing with the regression analysis, the Lagrange multiplier was applied to check whether the model should include any of the effects (LM:

p(cross-section) and LM: p(time) in the tables). If the results showed the need for the effect, the Hausman specification test, which helps in choosing between the random-effects model and the fixed-effects model, was applied (p (Hausman test) in the tables). Regression model's goodness-of-fit is reflected by adjusted R squared (Min, 2019; step 4 in Figure 2).

Table 4–Table 6 depict the autoregressive distributed lag models (as used by Ege & Ege, 2019) which were employed in the calculations of the long-term influence (Min, 2019) of EU investment. GLS weights were used for all these calculations. A feasible GLS specification was chosen correcting for heteroscedasticity and contemporaneous correlation. It is important to emphasise that the lagged values of the EU FP variable are analysed and interpreted only while counting the long-run multiplier (LRM) that shows the effect on $E(Y_t)$ of a maintained unit increase in X_t for all the included periods (Min, 2019; see Table 7–Table 9).

For the evaluation of the role and significance of the independent variables in shaping the member states' innovation performance, the values without eu_fp lags are compared in order to keep a sufficient degree of freedom (Min, 2019).

The influence of EU investment on the member states' national innovation performance expressed by the technological innovative output

The results indicated in Table 7 show that EU investment had small, but positive, influence on total national patent applications (LRM: 0.03), patent applications by the higher education sector (LRM: 0.08), and the introduction of new or significantly improved products and processes by SMEs (LRM: 3.22). This means that if EU investment is permanently increased by one unit, then, after 7 years, total national patent applications will have changed by 0.03 units, after 6 years, applications by higher education sector will have changed by 0.08 units, and, after 7 years, product and process innovations will have changed by 3.22 units.

The most significant positive influence of EU FPs was captured when evaluating patent applications by the business sector (LRM: 15.45). The results of these favourable effects on enterprises might reflect the benefits of growing and more substantial focus on them in the EU R&I policy.

On the other hand, there is small, but negative, short-term influence of EU investment on patent applications by the government sector (LRM: -0.12). One of the assumptions which might explain this result can be related to the regulation quality of governments and the practical distribution of EU investment for innovation. As the public sector is usually characterised as less efficient than the private sector, illogical investment decisions, political unconcern, and even low qualification in project management can influence the degree of capabilities to use this money efficiently.

The influence of EU investment on the member states' national innovation performance expressed by the non-technological innovative output

Although at the core of the EU R&I policy strong concentration on the technological output is still observed, it was expected that, with the general level of innovativeness, EU member states would also experience the positive influence on the non-technological innovative output. As Table 8 demonstrates, there is strong positive influence of EU investment on trademark applications (LRM: 25.99), as well as positive, but less strong, influence on the introduction of new organisational or marketing innovations (LRM: 0.61). Nevertheless, the results show a small negative effect on design applications (LRM: -0.94). One of the assumptions why the influence is negative can be related to the topics, aims and objectives of the funded projects. If the results are constantly oriented to other types of intellectual property (e.g., trademarks or patents), it might be the reason why the empirical model shows negative influence on design applications. Other reasons may lie behind the member states' and FP's specificities. Therefore, the following steps of the empirical analysis will help identify the possible influence variations over time and across the countries.

The influence of EU investment on the member states' national innovation performance expressed by the commercial innovative output

As it was described previously in the literature review, EU member states endure the so-called European paradox of the successful promotion of R&D inputs, accompanied by the inability to transform these results into commercial benefits. Therefore, it was decided to empirically test whether EU investment has long-term influence on the member states' national innovation performance expressed by the commercialisation of innovation.

The results in Table 9 indicate that, as it was expected, EU investment does not have significant influence on the sales of innovations. Moreover, it has small, but negative, long-term influence on the exports of hi-tech products (LRM: -0.23) and knowledge-intensive services (LRM: -0.47). Several of the assumptions why the analysis presents this kind of results might be that the member states encounter the 'crowding-out effect' of the EU Framework programmes, or else the investment simply targets other points of the innovation performance. Further underlying factors may be related to the different influence of EU FPs over time or beneficiaries' NIC. As these results represent the tendencies for the entire region, the following steps of the empirical analysis will help in looking at a closer picture.

EU investment influence disparities during different programming periods

By using OLS regression models and including dummies for separate framework programmes, a comparison was made (see the key statistics in Table 10). It is important to note that, due to lack of data of dependent variables, patent_gov was not included in the analysis since it was impossible to compare the results during more than one programming period. For the same reason, there was no opportunity to check the results of the influence of all individual FPs on dependent variables. The abbreviation for 'not available' in the tables — n.a. — indicates this issue and is further described as one of the research limitations.

Regardless, to begin with the technological innovative output, there was no difference in the influence between the individual Framework Programmes on the product and process innovations. Further results indicate that only the financial flows from the FP6 were effective in achieving positive results (influence respectively on patent: 0.229*; on patent_higher_ed: 0.049**). Moreover, in comparison with FP6, FP7 had a negative effect on the total patent applications (as well as H2020), patent applications by the business sector, and applications by the higher education sector.

These results may have at least a twofold explanation. The first explanation could be related to the already mentioned crowding-out effect, when firms and institutions accustom themselves to long-term subsidisation and lose the incentives for the search of efficiency. Another implication could be connected to the fact that each of the programming periods had more and more beneficiaries, both looking from the point of view of the participant institutions and of the countries which joined the EU in 2004, 2007, and 2013. Due to historically having lower national innovative capacity to produce technological innovation, EU–13 countries are likely to distort the final results of the influence of EU investment.

Continuing with the non-technological innovative output, the results indicate that there were no differences between the influence of FP7 and H2020 on the trademark and design applications. It is important to note that H2020 had positive effects on marketing and organisational innovations if compared to FP7. One of the assumptions why H2020 manifests optimistic outcomes is that the current programme is providing a substantially bigger budget for SMEs and is strengthening the role for social sciences and humanities thus promoting non-technological forms of innovation.

Lastly, for the national innovation performance of the member states, which is presently expressed by the commercialisation of innovation, there were no differences captured between the influences of individual framework programmes.

EU investment influence disparities across the member states

As it was indicated in the previous steps of the empirical analysis, the final influence of EU investment can be affected by the individual member state's environment and conditions which determine the national level ability to carry out innovative activities and to create innovations. The stepwise regression model was used in order to find out the member states which experience different influence of EU investment if compared to the influence on the entire region (key statistics are presented in Table 11–Table 13).

Table 11 presents evidence that, throughout the analysed time period, the influence of EU investment on the total patent applications was negative in Finland (-0.69*) and Germany (-2.20***), while it was positive in Luxembourg (0.33**). Continuing with the business patent applications, negative effects were captured in Sweden (-4.48***), Denmark (-3.42***) and Austria (-2.47***), which means that even though the general long-term influence on the whole European Union was positive (LRM: 15.45), these specific countries experienced the opposite effect.

Further results indicate that more prominent negative influence of EU investment on government patent applications, if compared to the whole region (LRM: -0.12), was experienced by the Netherlands (-0.66***), France (-1.02***), and Finland (-0.29***). In addition to this, Belgium underwent a negative effect on patent applications filed by higher education institutions (-0.32***), while the long-term influence on the region was small, but positive (LRM: 0.08). The final analysed indicator of the technologic innovative output is product and process innovations. It has already been proven that, in this context, EU FPs showed positive long-term influence for the entire EU (LRM: 0.11) but, as the results in Table 11 demonstrate, the investment had even higher effect on particular countries: Lithuania (2.34**), Portugal (0.72***), Greece (0.72***), Finland (0.32**), and Estonia (0.78***).

As there are differences between the magnitude of the influence of EU investment across the observed countries, the future research could also involve qualitative case analysis which could help to find the underlying factors regarding each country's NIC.

Table 12 illustrates the disparities of the influence of EU investment across the member states when national innovation performance is expressed as non-technological innovative output. In the context of design applications, the entire European Union was influenced uniformly, without any differences across the countries. On the contrary, the influence on Cyprus (4.21***) and Malta (15.92**) trademark applications was positive, but smaller if compared to the general long-term influence (LRM: 25.99). Finally, a contrasting result was captured on the marketing and organisational innovations in the Czech Republic (-1.52*) because the long-term influence of EU investment was small, but positive, for the whole region (LRM: 0.61).

Results in Table 13 show that, throughout the Union, there were no disparities in terms of the influence of EU investment on exports of knowledge-intensive services. On the other hand, even though the general long-term influence on the exports of high technology products was negative (LRM: -0.47), the United Kingdom felt the opposite positive effect (0.32**). It is also important to note that the variable of sales of innovation were not included in the analysis since no influence of EU investment — neither short nor long term — was found in the 5th step of our empirical analysis, see Table 6.

To sum up, the results of the empirical investigation show that:

H1: *EU investment has positive long-term influence on the member states' national innovation performance expressed by the technological innovative output* can be partially confirmed with one exception of influence on government patent applications (LRM -0.12).

H2: *EU investment exerts positive long-term influence on the member states' national innovation performance expressed by the non-technological innovative output* can be partially confirmed with one exception of influence on design applications (LRM -0.94).

H3: *EU investment does not have long-term influence on the member states' national innovation performance expressed by commercialisation of innovative output* can be partially confirmed by proving the absence of influence on the sales of innovations.

H4: *The influence of EU investment on the member states' innovation performance depends on the programming period* can be partially confirmed because the influence of individual EU FPs varied for the technological innovative output expressed by patent applications as well as for the non-technological innovative output expressed by marketing and organisational innovations.

H5: *The magnitude of the influence of EU investment is different across the member states* can be partially confirmed since there were disparities of the influence of EU investment among the countries for nine dependent variables out of 11.

Discussion

Overall, this article expands the scientific literature findings on the evaluation of the influence of EU investment regarding the innovative output additionality at the member state level. According to Čučković and Vučković (2021, p. 33), "country-level analyses can provide insight into the specifics of the important non-R&I factors that drive the innovation performance and growth of that country". As every member state has its peculiarities, firstly, the national innovative capacity framework by Furman *et al.* (2002) was redeveloped significantly. The mentioned specificities include, but are not limited to, diverse national R&I strategies (Fisher *et al*., 2018), the regulatory, legislative and political context (Law *et al*., 2018), and culture or values which are shared within a society (Halkos & Skouloudis, 2018; Khan & Cox, 2017). Therefore, the additional elements to the original dimensions of the common innovation infrastructure, cluster-specific environment for innovation, and the quality of linkages were added along with the supplementing model with the dimensions of international economic activities, diversity and equality, and the legal and political strength.

To continue with, the proposed alternative methodology allows assessing the overall long-term influence of EU investment on the innovative performance of EU member states and the specificities of the countries' innovative capacities. The results reflecting mainly positive influence of EU investment both on the technological and non-technological innovative output go in line with the conclusions of the Interim evaluation of Horizon 2020 (European Commission, 2017) and the latest studies by Čučković and Vučković (2021), Grabowski and Staszewska-Bystrova (2020), and Stojčić *et al.* (2020). Stojčić *et al.* (2020) and Grabowski and Staszewska-Bystrova (2020) found out that SMEs that obtained support from the EU FP funds delivered a substantial number of innovations (including product, process, marketing, and organisational ones). Similar results were shown by Čučković and Vučković (2021), who proved that Horizon 2020 budget allocations to SMEs helped in recording larger amount of product and process innovations. Regarding the commercialisation of innovation, none of the chosen variables in our study (i.e., innovation sales and exports of high-tech products and knowledge-intensive services) were positively affected by the EU investment. These results prove that the 'European paradox' still exists; the challenge of the inability to transform innovations into commercial success was also highlighted and discussed by Napiorkowski (2018), Radicic and Pugh (2017), and Weresa (2018).

The developed conceptual model and an empirical research scheme also helped calculate the fluctuations in influence at individual programming periods since the launch of Barcelona target in 2002. Effects varied in the context of patent applications and marketing and organisational innovations, where the seventh framework programme (FP7) was found to be the least effective one. Other scholars who compared different EU FPs as well learnt that not all the programmes are equally 'productive' in achieving the innovative output. For example, the Napiorkowski (2018) study showed no connection between the total budget of the FP7 and the innovative output, including commercial exploitation of R&D results and patent applications. Szücs (2018) also claimed that the overall effect of participation in FP7 is limited as no significant effects were observed on firms' patent counts and patent citations.

According to Biegelbauer *et al.* (2018), evaluations of the effects of FPs at the level of member states are scarce and infrequent, plus, as noted by Rosemberg *et al.* (2016), they tend to rely on selective case studies, descriptive statistics, or simple comparative statistical analysis without any effort to investigate the reasons behind the gathered results. It is important to emphasize that this research considers the differences in EU investment influence among the 27 current EU member states and 1 former member, the United Kingdom. To the authors' knowledge, there were only several previous attempts to make such type of cross-country analysis. Still, these scholars agree that the EU investment effects on the innovative outputs are heterogeneous across the countries (e.g., Alquézar Sabadie & Kwiatkowski, 2017; Čučković & Vučković, 2021; Lewandowska *et al.*, 2018; Napiórkowski, 2018; Varga & Sebestyén, 2017) and one of the leading tendencies in their results shows that EU–13 member states do not experience such positive effects as the 'old' member states do. Our research, vice versa, proves that, if compared to the whole region, only the Czech Republic (that belongs to the EU–13) felt negative effects of EU FPs, and only in the case of marketing and organisational innovations. In addition to that, the results show that member states, such as Finland, Denmark, Sweden, Germany, Austria, Netherlands, Belgium, and France, may already feel the crowding-out effect of the Framework programmes.

Finally, our proposed methodology fills in the research gap regarding the usage of different innovative outputs in the context of national innovation performance. According to one of the latest extensive literature analyses conducted by Dziallas and Blind (2019), 74% of the analysed research papers within the timeframe of 1980–2015 applied technological innovation indicators of the manufacturing industry (e.g., patents). However, innovation can be more than the established technology (Meissner *et al*., 2017; Schuch *et al*., 2017), and it does not necessarily involve a traditional industrial R&D process (Halkos & Skouloudis, 2018). Moreover, patents cannot fully explain innovation in services (Janger *et al*., 2017), not all innovation is patentable, and not every patent is used to create innovation (Proksch *et al*., 2017). As Dziallas and Blind (2019) indicate, although a recent shift from the manufacturing to the service industry was captured, this number still remains relatively low. Therefore, the proposed methodology in this study includes not only the substantially more used 'traditional' industry innovation indicators (i.e., patents as well as product and process innovations), but also the service sector-based and non-technological forms of innovations (i.e., trademarks, designs, marketing and organisational innovations), as well as the commercialisation of innovation (i.e., innovation sales, exports of high-tech products, and knowledge-intensive services).

Conclusions

The possible practical application of the results is definite. EU policy makers may employ the research findings of the real influence and intended/unintended effects of the FPs. These insights may serve in the designing process of the specific instruments and the future innovation policies, which would bring the maximum benefit for the society and economy. The research also gives a possibility to compare the national innovative capacities across the member states that may be used to ensure that the Union is solving the problem of convergence in the context of innovation performances. Finally, at the member states' level, a comparison of the distinguished components of the redeveloped NIC framework may help the national governments identify the areas for improvement.

At the same time, it is important to mention several research limitations. Firstly, there was the challenge of a time-frame linked with the shortage of certain data availability. It includes the dependent variables that represent the sectoral distribution of patent applications, the dependent variables which were extracted from the Community Innovation Survey that is carried out every two years and limited data availability of the longer-term indicators of Horizon 2020. Secondly, there always exists a potential bias related to the selected evaluation methods. A reader must have in mind that the direct interpretation and comparison of the results must be careful in those cases where the variables are expressed in different units.

To conclude, a conceptual model, along with the empirical research scheme, helped to extend the empirical evidence on the influence of EU investment on the member states' innovation performance. The judgement and comparison both over time and across the countries were ensured in order to detect the potential influence variations and the reasons lying behind the detected trends. To supplement this research in the future, qualitative comparative case studies could be applied to bring valuable insights about the underlying factors between the values of each member state.

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Annex

Table 1. Methods used in the FPs assessment studies (FP6, FP7, H2020)

Method	Source
Meta-evaluation	Biegelbauer *et al.* (2018); European Commission (2010; 2016); European Parliament (2018); Rubio *et al.* (2019); Van den Besselaar *et al*. (2018).
Case study	Arnold *et al.* (2008); European Commission (2016; 2017); Fisher *et al.* (2009); Nielsen *et al.* (2017).
Interview	Arnold *et al.* (2008); Biegelbauer *et al.* (2018); Boekholt (2009); European Commission (2010; 2017; 2018); European Parliament (2018); Fisher *et al.* (2018); Fresco *et al.* (2015); Nielsen *et al.* (2017); Rubio *et al.* (2019); Simmonds *et al*. (2010).
Questionnaire survey	Biegelbauer *et al.* (2018); DASTI (2015); European Commission (2016; 2017; 2018); European Parliament (2018); Fisher *et al.* (2009); Fisher *et al.* (2018); Simmonds *et al*. (2010); Rosemberg *et al.* (2016).
Focus groups	Arnold *et al.* (2008); Biegelbauer *et al.* (2018); European Commission (2018).
Descriptive statistics	Alquézar Sabadie & Kwiatkowski (2017); Arnold *et al.* (2008); European Commission (2016); European Parliament (2018); Fresco *et al.* (2015).
Cluster analysis	Fresco *et al.* (2015); Napiorkowski (2018).
Correlation analysis	Alquézar Sabadie & Kwiatkowski (2017); Čučković & Vučković (2018); Fisher *et al.* (2009); Fresco *et al.* (2015); Napiorkowski (2018).
Econometric modelling	Aguiar and Gagnepain (2017); Barajas *et al*. (2012); Bondonio *et al*. (2016); DASTI (2015); Varga & Sebestyén (2017); Fresco *et al.* (2015); European Commission (2017; 2018); Nielsen *et al.* (2017); Szücs (2018); Weresa (2018).
Bibliometric analysis	Arnold *et al.* (2008); Boekholt *et al.* (2009); European Commission (2017); European Parliament (2018); DASTI (2015); Fresco *et al.* (2015); Rosemberg *et al.* (2016); Ryan & Schneider (2016).

Table 2. Definitions and sources of data for independent variables

Code	Definition	Source
rd	Research and development investment (% of GDP). All R&D investment plus gross fixed investment for R&D performed within a country during a specific year, whatever the source of funds.	Eurostat (2020)
public_rd	Intramural R&D investment in the public sector (% of GDP).	Eurostat (2020)
edu_exp	Total public investment on education as % of GDP, for all levels of education combined.	Eurostat (2020)
rd_fte	Total R&D personnel and researchers by all sectors of performance, as % of total employment – numerator in full-time equivalent (FTE).	Eurostat (2020)
rd_fte_gov	R&D personnel and researchers in the government sector, as % of total employment – numerator in full-time equivalent (FTE).	Eurostat (2020)
rd_fte_bus	Total R&D personnel and researchers in the business enterprise sector, as % of total employment – numerator in full-time equivalent (FTE).	Eurostat (2020)
doc_grad	New doctorate graduates per 1,000 population, aged 25–34.	Eurostat (2020)

Table 2. Continued

Code	Definition	Source
knowledge_stock	Cumulative variable formed from the granted patents stock, the granted trademarks stock, and the granted designs stock (from 2000 until 2018). Method to be used: factor analysis.	WIPO (2020)
quality_scientific	Quality of scientific research institutions, 1–7 (best).	World Bank (2019)
int_co_pub	Number of scientific publications with at least one co-author based abroad (where 'abroad' is non-EU for the EU-28).	Eurostat (2020)
pub_top10	Scientific publications among the top 10% most cited publications worldwide (percentage of the total scientific publications of the country).	Web of Science (2019)
employees_edu	Employees with tertiary education, aged 15–74, % of total employees.	Eurostat (2020)
long_learning	Participation rate of adults aged 25–64 in education and training, also referred to as life-long learning.	Eurostat (2020)
ict	The ICT index is used as a composite index which weights three ICT indicators (assigning 33.(3)% to each): (1) Percentage of individuals using the Internet; (2) Fixed (wired)-broadband Internet subscriptions per 100 inhabitants; and (3) Active mobile-broadband subscriptions per 100 inhabitants.	World Bank (2019)
private_rd	Intramural R&D investment in the business sector (% of GDP).	Eurostat (2020)
non_rd	Non R&D innovation investment. The sum of total innovation investment for enterprises, excluding intramural and extramural R&D investment, as % of the total turnover.	Eurostat (2020)
sector_hitech	Employment in high-technology sectors, as % of the total employment.	Eurostat (2020)
sector_kis	Employment in knowledge-intensive services, as % of the total employment.	Eurostat (2020)
sector_industry	Employment in the industry sector, as % of the total employment.	Eurostat (2020)
sector_services	Employment in the services sector, as % of the total employment.	Eurostat (2020)
pop_urban	Urban population (% of total population).	World Bank (2019)
higher_ed_rd	Intramural R&D investment in the higher education sector (% of GDP).	Eurostat (2020)
venture_cap	Venture capital (% of GDP).	Eurostat (2020)
public_private_collab	Number of public-private co-authored research publications. Publications are assigned to the country/countries in which the business companies or other private sector organisations are located.	Web of Science (2019)
inno_smes_collab	Innovative SMEs collaborating with others (% of SMEs).	European Commission (2020a)
new_business	New business density (new registrations per 1,000 people aged 15–64).	World Bank (2019)
exports	Total exports of goods and services, percentage of the gross domestic product (GDP).	Eurostat (2020)

Table 2. Continued

Code	Definition	Source
imports	Imports of goods and services (% of GDP).	World Bank (2019)
fdi	Inward foreign direct investment (% of GDP).	World Bank (2019)
multiculture	Cultural diversity – foreign country or stateless population, % of the total population.	Eurostat (2020)
poverty	People at risk of poverty or social exclusion, % of the population.	Eurostat (2020)
gender_equality	Female share of employment in the senior and middle management (%).	World Bank (2019)
corruption	Corruption perception index. Originally, the score of 0 represents a very high level of corruption, whereas the score of 100 represents a very clean (i.e., totally corruption-free) country. Instead, the reversed ranking (Excel RANK.AVG function) was chosen as an option for regression models thus meaning that the higher is the rank, the more corrupt the country is.	Eurostat (2020)
legal_political	Strength of the legal and political environment – judicial independence, rule of law, political stability. 1–7 (best).	World Bank (2019)
bureucracy	Time required to start a business (days).	World Bank (2019)
ipr	Protection of intellectual property rights, patent protection, copyright protection.	Property Rights Alliance (2019)
gdp_capita	Gross domestic product, euro per capita.	Eurostat (2020)
pop	Population, millions of inhabitants as of January 1 of a specific year.	Eurostat (2020)
labour_force	Labor force – employment and activity, millions of persons aged from 15 to 64.	Eurostat (2020)
healthy life	Healthy life years in the absolute value at birth – males and females. It is defined as the number of years that a person is expected to continue to live in a healthy condition.	Eurostat (2020)
working life	The duration of working life.	Eurostat (2020)
eu fp	EU investment targeting science, research, development and innovation and channelled through the Framework Programmes during the programming periods of 2002–2006, 2007–2013, and 2014–2020, euro per capita.	European Commission (2020b)

Table 3. Definitions and sources of data for dependent variables

Code	Definition	Source
patents	Patent applications to the EPO by priority year, per million inhabitants. The geographic origin is based on the country of residence of the first applicant listed on the application form (the first-named applicant principle).	Eurostat (2020) European Patent Office (2020)

Table 3. Continued

Code	Definition	Source
patent_bus	Patent applications to the EPO by priority year by the institutional sector (Business), per million inhabitants. The geographic origin is based on the country of residence of the first applicant listed on the application form (the first-named applicant principle).	Eurostat (2020)
patent_gov	Patent applications to the EPO by priority year by the institutional sector (the Government sector), per million inhabitants. The geographic origin is based on the country of residence of the first applicant listed on the application form (the first-named applicant principle).	Eurostat (2020)
patents_ higher_ed	Patent applications to the EPO by priority year by the institutional sector (the Higher education sector), per million inhabitants. The geographic origin is based on the country of residence of the first applicant listed on the application form (the first-named applicant principle).	Eurostat (2020)
smes_pp	The share of SMEs (10–249 employees) which introduced at least one product innovation or process innovation either new to the enterprise or new to their market, as % of all enterprises. Product innovation: the market introduction of a new or significantly improved goods item or service with respect to its capabilities, user friendliness, components, or sub-systems. Process innovation: the implementation of a new or significantly improved production process, distribution method, or supporting activity.	Eurostat (CIS data)
trademark	European Union trade mark (EUTM) applications per million inhabitants. The geographic origin is based on the country of residence of the first applicant listed on the application form (the first-named applicant principle).	Eurostat (2020)
design	Community design (CD) applications per million inhabitants. The geographic origin is based on the country of residence of the first applicant listed on the application form (the first-named applicant principle).	Eurostat (2020)
smes_mo	The share of SMEs (10–249 employees) which introduced at least one new organisational innovation or marketing innovation, as % of all SMEs. Organisational innovation: a new organisational method in the enterprise's business practices (including knowledge management), workplace organisation or external relations which has not been previously used by the enterprise. Marketing innovation: the implementation of a new marketing concept or strategy which differs significantly from the enterprise's existing (currently employed) marketing methods and which has not been used before.	Eurostat (2020)
inno_sales	Sales of new-to-market and new-to-firm innovations, as % of turnover.	Eurostat (2020)
exports_ hitech	High-tech exports – exports of high technology products as % of the total product exports.	Eurostat (2020)
exports_kis	Knowledge-intensive services exports as % of the total services exports.	Eurostat (2020)

Table 4. Regression models: Technological innovative output

	patent	patent_ bus	patent_ gov	patent_ higher_ed	smes_ pp
c	40.81	-108.96	60.93***	0.33	-48.7*
dep. var.(-1)	0.46***	1.28***	0.82***	1.11***	1.47***
dep. var. (-2)	-	-	-0.52***	-0.28***	-1.10***
dep. var. (-3)	-	-	-	-	0.61***
dep. var. (-4)	-	-	-	-	-0.27***
higher_ed_rd	0.19**	-	-	-	-
corruption	-0.01**	-	-	-	-
edu_exp	-	18.62***	-	0.02**	-
quality_scientific	-	-	0.13**	-	-
knowledge_stock	-	14.64**		-	-
pop_urban	-0.07	-	0.79**	-	1.13***
eu_fp	-0.01	-0.47	-0.08**	0.01	0.03
eu_fp(-1)	0.43***	-0.63	-	0.09***	0.03
eu_fp(-2)	0.46***	-0.49	-	0.03	0.01
eu_fp(-3)	-0.09	-1.51***	-	-0.07**	-0.24***
eu_fp(-4)	-0.33	-1.30***	-	-0.08	0.06
eu_fp(-5)	0.27	-	-	0.17***	0.02
eu_fp(-6)	-0.02	-	-	-0.12***	-0.06
eu_fp(-7)	-0.69***	-	-	-	0.14**
Adj. R^2	0.99	0.96	0.91	0.91	0.98
LM: p (cross-section)	0.00	0.00	0.00	0.11	0.00
LM: p (time)	0.11	0.43	0.73	0.00	0.51
p (Hausman test)	0.00	0.00	0.00	0.00	0.00
Model	FE	FE	FE	FE	FE

****p<0.01 **p<0.05 *p<0.1, dep. var. means dependent variable, d() means first differences.*

Table 5. Regression models: Non-technological innovative output

	trademark	design	smes_mo
c	-46.81	83.11	7.22**
dep. var. (-1)	0.94***	0.83***	1.55***
dep. var. (-2)	-	-0.23***	-0.97***
dep. var. (-3)	-	-	0.49***
d(public_private_collab)	-14.97***	-	-
gender_equality	1.40**	-0.14	-
rd_fte_bus	20.50	18.00**	-
working_life	-	0.21***	-
rd_fte	-	-	1.25**
eu_fp	1.67***	-0.40	-0.08*
eu_fp(-1)	1.41**	0.32	0.06
eu_fp(-2)	0.66	0.23	-0.05
eu_fp(-3)	-1.37**	0.60	-0.04
eu_fp(-4)	-1.04	0.37	0.04
eu_fp(-5)	0.47	-0.23	0.11**
eu_fp(-6)	0.27	0.04	-
eu_fp(-7)	0.45	-0.16	-
eu_fp(-8)	-1.07**	-0.24	-
eu_fp(-9)	-	-0.03	-
eu_fp(-10)	-	-0.86**	-

Table 5. Continued

	trademark	design	smes_mo
Adj. R^2	0.97	0.98	0.98
LM: p (cross-section)	0.00	0.00	0.49
LM: p (time)	0.44	0.07	0.00
p (Hausman test)	0.00	0.03	0.00
Model	FE	FE	FE

****p<0.01 **p<0.05 *p<0.1, dep. var. means dependent variable, d() means first differences.*

Table 6. Regression models: Commercialisation of innovation

	inno_sales	exports_hitech	exports_kis
c	8.25**	-2.24	-4.32
dep. var. (-1)	1.43***	1.15***	0.97***
dep. var. (-2)	-1.33***	-0.36***	-
dep. var. (-3)	1.03***	-	-
dep. var. (-4)	-0.54***	-	-
imports	0.11**	-	-
sector_services	-	6.59**	-3.10
venture_cap	-	3.44**	-
d(multiculture)	-	77.58***	-
ict	-	-	0.79**
eu_fp	-0.01	0.10***	-0.08
eu_fp(-1)	0.00	-0.06	-0.11*
eu_fp(-2)	0.00	-0.08**	-0.06
eu_fp(-3)	0.02	0.01	0.24***
eu_fp(-4)… eu_fp(-10)		*not significant*	
adj. R^2	0.91	0.92	0.98
LM: p (cross-section)	0.00	0.00	0.23
LM: p (time)	0.31	0.86	0.63
p (Hausman test)	0.00	0.19	-
Model	FE	RE	OLS

****p<0.01 **p<0.05 *p<0.1, dep. var. means dependent variable, d() means first differences.*

Table 7. Long-run multiply of EU investment influence on the innovation performance of member states: Technological output

Long-term influence of EU investment / Innovative output	Positive	Negative	No influence/ Insignificant
patent	0.03	-	-
patent_bus	15.45	-	-
patent_gov	-	-0.12	-
patent_higher_ed	0.08	-	-
smes_pp	3.22	-	-

Table 8. Long-run multiply of EU investment influence on the innovation performance of member states: Non-technological output

Long-term influence of EU investment / Innovative output	Positive	Negative	No influence/ Insignificant
trademark	25.99	-	-
design	-	-0.94	-
smes_mo	0.61	-	-

Table 9. Long-run multiply of EU investment influence on the innovation performance of member states: Commercialisation of innovation

Long-term influence of EU investment / Innovative output	Positive	Negative	No influence/ Insignificant
inno_sales	-	-	X
exports_hitech	-	-0.23	-
exports_kis	-	-0.47	-

Table 10. Influence of individual EU Framework programmes on the innovation performance of member states

EU FP / Innovative output	FP6	FP7	H2020	F-stat.	Adjusted R^2
patent	0.244*	-0.342***	-0.299**	0.000	0.998
patent_bus	0.271	-0.554*	n.a.	0.000	0.953
patent_higher_ed	0.049**	-0.052**	n.a.	0.000	0.877
smes_pp	n.a.	0.012	-0.016	0.000	0.974
trademark	n.a.	0.346	-0.224	0.000	0.973
design	n.a.	-0.247	0.079	0.000	0.978
smes_mo	n.a.	-0.020	0.080**	0.000	0.976
inno_sales	n.a.	0.005	-0.005	0.000	0.906
exports_hitech	-0.016	0.027	0.020	0.000	0.914
exports_kis	n.a.	-0.021	-0.002	0.000	0.982

Table 11. EU investment influence disparities across the member states (Technological innovative output)

Technological innovative output	Significant differences of estimates for the whole region	Adjusted R^2
Patent	FI: -0.69*; LU: 0.33***; DE: -2.20***	0.99
Patent_bus	SE: -4.48***; DK: -3.42***; AT: -2.47***	0.96
Patent_gov	NL: -0.66***; FR: -1.02***; FI: -0.29**	0.87
Patent_higher_ed	BE: -0.32***	0.87
smes_pp	LT: 2.34**; PT: 0.72***; EL: 0.72***; FI: 0.32**; EE: 0.78***	0.97

****p<0.01 **p<0.05 *p<0.1*

Table 12. EU investment influence disparities across the member states (Non-technological innovative output)

Non-technological innovative output	Significant differences of estimates for the whole region		Adjusted R^2
	YES	*NO*	
Trademark	CY: 4.21***; MT: 15.92***	-	0.98
Design	-	X	0.97
smes_mo	CZ: -1.52*	-	0.97

****p<0.01 **p<0.05 *p<0.1*

Table 13. EU investment influence disparities across the member states (Commercialisation of innovation)

Commercialisation of innovation	Significant differences of estimates for the whole region		Adjusted R^2
	YES	*NO*	
Exports_hitech	UK: 0.32**	-	0.94
Exports_kis		X	0.98

****p<0.01 **p<0.05 *p<0.1*

Figure 1. Conceptual model for the evaluation of the influence of EU investment on the innovation performance of member states

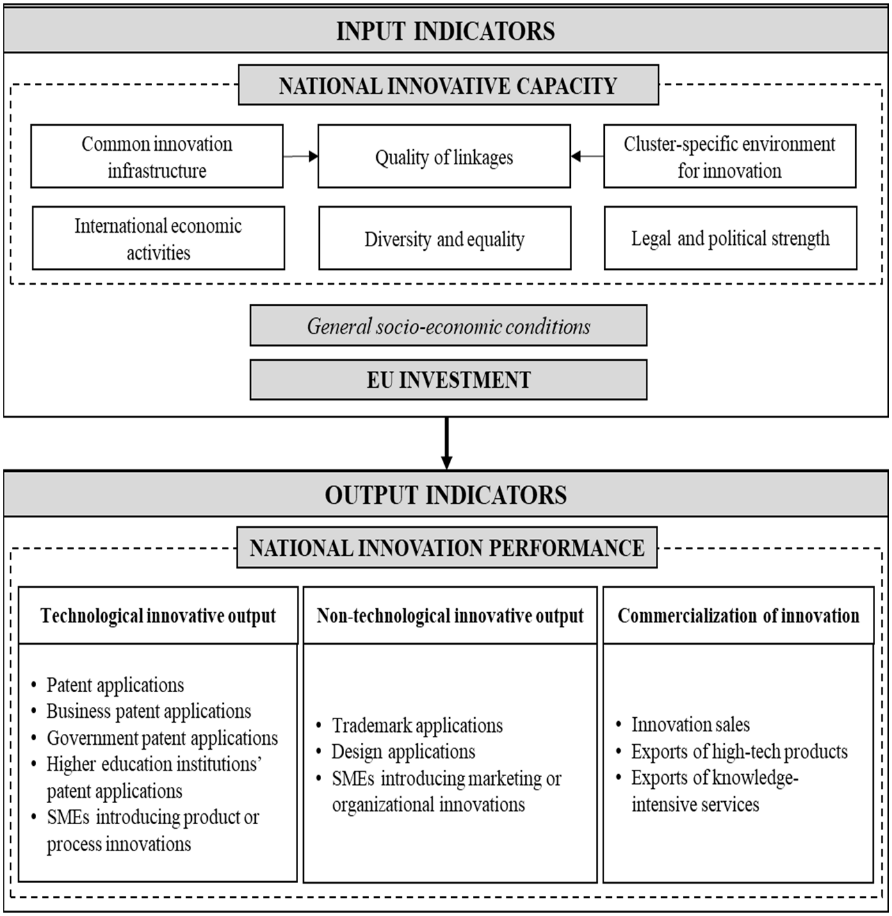

Figure 2. Empirical research scheme for the evaluation of the influence of EU investment on the innovation performance of member states