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MEDA ANDRIJAUSKIENĖ

THE INFLUENCE OF EU INVESTMENT ON MEMBER STATES' INNOVATION PERFORMANCE

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MEDA ANDRIJAUSKIENĖ

ES INVESTICIJŲ ĮTAKA VALSTYBIŲ NARIŲ INOVACINĖS VEIKLOS REZULTATAMS

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CONTENTS

SUMMARY

This dissertation focuses on the influence of EU investment on the innovation performance of its member states. Whether we deal with the production of new goods, introduction of new production methods or innovative strategies in marketing and organisational methods, innovation is not merely a result of research and development (R&D) activities and previous knowledge stock as it is the governmental policy which sets the priorities for investment; thus it is equally important. Based on the need for systematic cooperation within European countries, a joint research and development initiative named the first *Framework Program* (FP) was launched in 1984. It had a budget of approximately 3 billion euros. It 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. Currently, Horizon 2020 has been assigned a budget of 80 billion euros. Nevertheless, despite the emphasis on the innovation-based growth and targeting of R&D, the innovation performance visibly differs across the member states with highly uneven and incoherent progress.

Besides R&D investment, the country-level potential for innovation is enhanced by the broader context in its national innovative capacity. Complex and reliable tools must be adopted to evaluate the set of factors affecting national innovation performance so that we could investigate the reasons which distort the magnitude of the influence of EU investment. Therefore, this research addresses the scientific problem: what is the influence of EU investment on its member states' innovation performance and how do we evaluate it? The object of the research is the influence of EU investment on its member states' innovation performance. The aim of the research 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. The research objectives are as follows:

1. To analyse the role and additionality effects of EU research and innovation investment.
2. To determine the current methods used in the evaluation of EU investment influence.
3. To analyse and specify the influence of national innovative capacity elements on shaping the national innovation performance and determine the current methods used in this context.
4. To present a methodology for the assessment of the influence of EU investment on its member states' innovation performance.
5. To evaluate the influence of EU investment on its member states' innovation performance by using the developed methodology.

The dissertation consists of an introduction, three main chapters, general conclusions, a list of references, and 43 annexes. The introduction presents the scientific problem, the relevance of the investigated issue, the aim, objectives, methodology, scientific novelty and practical significance of this research. The first chapter is composed of two sub-chapters. One of them discusses the European Union's FPs as an instrument for the development of its member states' innovation

performance. The evolution of the EU research and innovation policy (including the comparison of different FPs over time), demonstration of the additionality effects of R&D investment, and an overview of the methods for the assessment of the influence of EU investment are presented. The second sub-chapter describes the concept of the national innovative capacity and its role in the process of improving a specific country's innovation performance. At first, the R&I investment as an element of a country's innovative capacity are analysed. Further, other elements are overviewed. Finally, the national innovation performance as the output of a country's innovative capacity is analysed, and comparative analysis of the methods used in the assessment of national innovative capacity is introduced.

The second chapter is devoted to the development of a methodology for the assessment of the influence of EU investment on the member states' innovation performance. To begin with, the elements of national innovative capacity are identified along with their definitions and the justification for selection. Later on, national innovation performance indicators which would reflect both technological and non-technological innovative output as well as the output for commercialisation of innovation in a country are presented. Finally, a conceptual model is designed by including the variable of EU investment and the NIC elements identified in the previous sections. Furthermore, an empirical research scheme is introduced and the statistical methods for the evaluation are selected. On the grounds of the findings and insights, six scientific hypotheses are formulated.

The final chapter of this dissertation involves the implementation of the empirical model for the assessment of the influence of EU investment on the innovation performance of the member states. The research path consists of 7 steps: (1) unit root tests to check the stationarity of time series; (2) Granger causality tests with 5 lag values for the evaluation of Granger causality between the variables; (3) correlation, multicollinearity test, and OLS regression; (4) effect tests; (5) calculation of a long-run multiplier; (6) evaluation of EU investment influence disparities through different programming periods; and (7) evaluation of the influence of EU investment disparities across the member states.

Finally, a summary of the results along with the overall conclusions of the dissertation is presented at the end of the thesis. The reference list along with annexes is also provided. 5 scientific articles have been published on the topic of the dissertation. The results of the research have also been presented at 5 international scientific conferences.

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LIST OF ABBREVIATIONS AND TERMS

EC European Commission
EIS European Innovation Scoreboard
ERA European Research Area
EU European Union
EU-13 Group of 13 EU countries: Bulgaria (BG), Croatia (HR), Cyprus (CY), Czech Republic (CZ), Estonia (EE), Hungary (HU), Latvia (LV), Lithuania (LT), Malta (MT), Poland (PL), Romania (RO), Slovakia (SK) and Slovenia (SI)
EU-15 Group of 15 EU countries: Austria (AT), Belgium (BE), Denmark (DK), Finland (FI), France (FR), Germany (DE), Greece (EL), Ireland (IE), Italy (IT), Luxembourg (LU), Netherlands (NL), Portugal (PT), Spain (ES), Sweden (SE) and United Kingdom (UK)
FDI Foreign Direct investment
FE Fixed Effects
FP Framework Programme
FP6 Sixth Framework Programme
FP7 Seventh Framework Programme
FTE Full-time Equivalent
GDP Gross Domestic Product
H2020 Horizon 2020 Framework Programme
ICT Information and Communications Technology
IP Intellectual Property
IPR Intellectual Property Right
IS Information Society
KPI Key Performance Indicator
LM Lagrange Multiplier
LRM Long-run Multiplier
MS Member State
NIC National Innovative Capacity
NIP National Innovation Performance
OECD Organization for Economic Co-operation and Development
OLS Ordinary Least Squares
R&D Research and Development
R&I Research and Innovation
RE Random Effects
S&T Science and Technology
SMEs Small and Medium Enterprises
WIPO World Intellectual Research Organization
WoS Web of Science

INTRODUCTION

The relevance of the research topic

Science, technology and innovation have been widely acknowledged as the crucial determinants of economic growth since the critical contributions of J.A. Schumpeter and R.M. Solow. Being one of the most important stimuli for prosperity (Schwab, 2017), innovation creates benefits for both developed and developing economies (Dincer, 2019). For the more advanced countries, innovation takes a significant role in shaping further economic growth and sustainable development while, for the less advanced ones, it acts as a measure to reach the degree of achievements of more developed nations (Lee, Nam, Lee, & Son, 2016).

Whether we deal with the production of new goods, the introduction of new production methods or innovative changes in marketing and organisational methods, innovation is not merely a result of the research and development (R&D) activities and the previous knowledge stock as the governmental policy setting the priorities for investment is equally important. The countries which have mastered and improved the skills in this area succeed in the creation of very innovative and competitive economies (Veugelers, 2015; McCann & Ortega-Argiles, 2016). The importance of government interventions is also emphasised in the scientific studies of Perez-Sebastian (2015), Petrin (2018), Zang, Xiong, Lao & Gao (2019). Since the vast majority of enterprises are profit-seekers, they usually are not interested in investing with very basic or low-return innovation. Therefore, the role of effective governmental strategies and instruments for public financial support is essentially assistance not only in building the organisational R&D capabilities but also in promoting the industry-university-research cooperation, sharing R&D risks, and compensating market failures if innovation activities turn to have a negative impact.

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* (FP) was launched in 1984; it had a budget of approximately 3 billion euros. It was followed by a series of multi-annual FPs which were growing progressively in size, scope and broadening of focus on the new research fields: the 2nd FP (1987–1991) with 5.4 billion euros, the third FP (1990–1994) with 6.6 billion euros, the 4th RTD FP (1994–1998) with 13.2 billion euros, and the 5th FP (1998–2002) with 14.9 billion euros. In 2000, the European Council promoted the Lisbon strategy which was complemented by the Barcelona target in 2002 with the ambition for EU to become the most competitive and dynamic knowledge-based economy in the world. Therefore, the budgets of the 6th FP (2002–2006) and the 7th FP (2007–2013) increased to 19.3 billion euros and 55.9 billion euros, respectively. The latest research and innovation FP Horizon 2020 (2014–2020) was assigned a budget of 80 billion euros, and the initial Commission’s proposal (European Commission, 2020a) for the next FP Horizon Europe was 100 billion euros (yet, due to the COVID-19 crisis, the European Council (2020) decided to reduce the financial envelope for the FP to 75.9 billion euros).

In 2019, the EU's performance surpassed the United States, and the innovation gap separating the EU from the strongest innovators in the world – Japan, Canada and Australia – was reduced. Nevertheless, despite the focus on innovation-based growth and R&D targeting, the innovation performance strongly diverges across the member states with a highly uneven and incoherent progress (European Commission, 2019a). These differences in the scope of innovative outputs across the countries and regions require efforts of researchers and policymakers. Besides R&D investment, the country-level potential for innovation is enhanced by a broader context in its national innovative capacity. Complex and reliable tools must be adopted in order to evaluate the set of factors affecting national innovative performance and investigating the reasons which distort the overall influence of EU investment.

Scientific problem and the extent of its investigation

Every year, the member states are receiving a considerable amount of financial inflows from the common EU budget. Despite the initial presumptions that these additional investments should bring a positive and constructive effect on the national innovation performance, the currently available findings show that the results in the member states differ significantly. Side factors starting with the initial economic conditions, 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, can influence the degree of capabilities to use these funds efficiently so that they would bring the biggest impact possible. Nevertheless, an investigation of these factors in the context of the evaluation of the influence exerted by EU investment is fairly limited.

On top of that, scholars admit that most evaluations are oriented to micro-level analysis, such as the influence of individual projects on the innovative performance of a beneficiary. Hence, there is lack of research evaluating the influence of EU investment at the national level by employing cross-country analysis. Furthermore, according to Hottenrott, Lopes-Bento & Veugelers (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 run-time of the grant, typically, two to three years. In addition to this, it can be emphasised that empirical studies on the innovative output additionality are more limited than those focusing on input additionality, e.g., on the effect of government support for R&D on the recipient's own R&D investment (Petrin, 2018).

Finally, ardent debate is related to the innovative outputs of the national innovative capacity as the general tendency of the empirical research is to include only the 'traditional' technological innovative output. Among the most commonly used ones, there are patents, either in the form of the absolute number or their rate per million people, and the patent citation rate (Azagra-Caro & Consoli (2016), Furman, Porter, Stern (2002), Faber & Hesen (2004), Hu & Mathews (2008), Huang, Shih & Wu (2010), Santana, Mariano, Camioto & Rebelatto (2015), Wu, Ma & Zhuo (2017)). Nevertheless, the application of these indicators receives extensive critique. Firstly, patents are quite effective to capture innovation in manufacturing, but they cannot fully explain innovation in services (Janger, Schubert, Andries, Rammer & Hoskens, 2017). Secondly, not all innovation is patentable, and not every patent is used to create an innovation (Proksch, Haberstroh & Pinkwart, 2017). Therefore, in order to properly evaluate the national innovation performance, it is crucial to broaden the exceptionally prevalent focus on the technological innovative output, to include the non-technological innovative output, such as marketing and organisational innovations, and to integrate other types of intellectual property rights, such as designs and trademarks. Having in mind the above described scientific problems, the scientific problem of this dissertation is: what is the influence of EU investment on the member states' innovation performance and how do we evaluate it?

The object of the research is the influence of EU investment on the member states' innovation performance.

The aim of the research

To evaluate the influence of EU investment on the member states' innovation performance by using a redeveloped national innovative capacity framework and including technological, non-technological and commercial innovative output.

Research objectives

1. To analyse the role and additionality effects of EU research and innovation investment.
2. To determine the current methods used in the evaluation of EU investment influence.
3. To analyse and specify the influence of national innovative capacity elements on shaping the national innovation performance and determine the current methods used in this context.
4. To present a methodology for the assessment of the influence of EU investment on member states' innovation performance.
5. To evaluate the influence of EU investment on member states' innovation performance by using the developed methodology.

Research methods

Systematic and comparative analysis of the scientific literature was performed in order to identify the role of research, development and innovation investment as well as to determine other important elements of national innovative capacity (NIC) which shape a country's innovation performance. With this objective, the current valuation methods both for influence assessment and analysis of NIC were explored. The obtained knowledge was used for the development of the methodology for the assessment of the influence of EU investment on the innovation performance of the member states.

The collected data was used to test the validity of the research model. Before analysing the panel data, the unit root test was performed in order to test the stationarity of the time series. Later, Granger causality analysis was used in order to define Granger causal links between the analysed indicators while taking into the 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 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.

The statistical data was processed and analysed by using year 2019 version of *Microsoft Excel* and *Statistical Data Processing Package SPSS* version 21.0. In order to test the hypotheses, econometric analysis and modelling was performed by using *EViews 11*.

Scientific novelty and theoretical significance of the dissertation

Overall, the dissertation expands the findings of scientific literature on the evaluation of the influence of EU investment regarding the innovative output additionality at the member state level:

- The national innovative capacity framework by Furman *et al*. (2002) is redeveloped by including the additional elements to the original dimensions of the common innovation infrastructure, cluster-specific environment for innovation, and the quality of linkages along with the supplementing model with the dimensions of international economic activities, diversity and equality, and the legal and political strength.
- The proposed alternative methodology allows assessing not only the overall long-term influence of EU investment on the innovative performance of EU member states, but also the specificities of the countries' innovative capacities. At the same time, by including all the EU Framework programmes for research and innovation since the launch of the Lisbon Strategy, the conceptual model and an empirical research scheme help to calculate the fluctuations in influence at different programming periods. Finally, the differences in influence among the member states are also considered (the analysis includes the 27 current Member States and 1 former member, the United Kingdom).
- The proposed alternative methodology 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).

Possible practical application of the results

- EU policy makers may employ the research findings about 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.
- A possibility to compare the national innovative capacities across the member states may be used to ensure that the Union is solving the problem of convergence in the context of innovation performances.
- The influence evaluation processes are about collecting and examining the evidence to support the policy making. 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.

The structure of the dissertation

The volume of dissertation without annexes is 114 pages. It contains 38 tables and 5 figures. There are 172 references used in the thesis. The dissertation consists of an introduction, 3 main parts, and conclusions. The introduction presents the relevance of the research topic, the scientific problem and the extent of its investigation, the object, aim and objectives of the research as well as the employed methods of research, the scientific novelty and theoretical significance of the dissertation, and, finally, the possible practical application of the results. The first part of the dissertation is composed of two sub-parts devoted to the discussion on the European Union Framework programmes as an instrument for the development of the member states' innovations and the role of a country's innovative capacity in shaping the national innovation performance. The second part of the dissertation focuses on the development of a methodology for the assessment of influence of the EU investment on the member states' innovation performance. NIC and NIP elements are selected, the conceptual model is designed, and the empirical research scheme is presented. The third part of the dissertation is devoted to the assessment of the influence EU of investment on the innovation performance oif the member states. Finally, the findings of the dissertation are generalised with the conclusion section.

Approval of research results: 5 scientific articles have been published on the topic of the dissertation. The results of the dissertation research have been presented at 5 international scientific conferences. The PhD Candidate is a two-times laureate of the competition determining the most active doctoral students of Kaunas University of Technology (2016, 2019) and a two-times winner of the Research Council of Lithuania scholarship for academic achievements (2016, 2018).

Scientific articles:

1. Andrijauskiene, M. & Dumciuviene, D. (2019). Inward Foreign Direct Investment and National Innovative Capacity. *Engineering Economics*, 30(3), 339-348.
2. Andrijauskiene, M. & Dumciuviene, D. (2019). Import of Goods and Services as a Stimulus for a Better National Innovation Performance in EU Member states. *Ekonomista*, (5), 572-589.
3. Andrijauskiene, M. & Dumciuviene, D. (2018). National culture as a determinant of firms' innovative performance. *Forum Scientiae Oeconomia,* 2018 (6), 47-68.
4. Andrijauskiene, M. & Dumciuviene, D. (2017, October). Hofstede's cultural dimensions and national innovation level. In *DIEM: Dubrovnik International Economic Meeting* (Vol. 3, No. 1, pp. 189-205).
5. Keleckaite [Andrijauskiene], M. (2016). Improving the ex-post evaluation of NGOs' projects by involving the individual assessment of social and economic effectiveness. *Project management development-practice and perspectives*, 172-187.

International conferences:

1. Andrijauskiene, M. (2019). Import of Goods and Services as a Stimulus for a Better National Innovation Performance: Case of EU Member states. World Economy 2019: Learning from the Past and Designing the Future. SGH Warsaw School of Economics, 9-10 May, 2019, Warsaw, Poland.
2. Andrijauskiene, M. (2017). Hofstede's cultural dimensions and national innovation level. DIEM: Dubrovnik International Economic Meeting. 12-14 October, 2017, Dubrovnik, Croatia.
3. Andrijauskiene, M. & Dumciuviene, D (2016). The linkage between EU funds absorption, innovation and competiteveness: case of Baltic States // International scientific conference "Economics and Management", ICEM: Smart and Efficient Economy. Preparation for the Future Innovative Economy / Brno, Czech Republic, May 19–20, 2016.
4. Andrijauskiene, M. (2016). Improving the ex-post evaluation of NGOs' projects by involving the individual assessment of social and economic effectiveness // Project management development – practice and perspectives: 5th international scientific conference on project management in the Baltic countries, Riga, Latvia, April 14–15.
5. Keleckaite [Andrijauskiene], M. (2016). Negative effects of EU Structural Support. Case of Lithuania // 2nd Scientific Conference "Economy today. Interdisciplinary approach to contemporary economic challenges" / University of Lodz, Poland. March 11, 2016.

1. THEORETICAL ASPECTS OF THE INFLUENCE OF INVESTMENT ON NATIONAL INNOVATION PERFORMANCE

This chapter is composed of two sub-chapters. The first sub-chapter discusses the European Union framework programmes as an instrument for the development of the member states' innovation performance. The evolution of the EU research and innovation policy (including the comparison of different FPs over time) along with the demonstration of the additionality effects of R&D investment and an overview of the methods for the assessment of EU investment are presented. The second sub-chapter describes the concept of the national innovative capacity and its role in the process of improving the country's innovation performance. At first, R&D investment as an element of a country's innovative capacity is analysed. Further on, other relevant elements are overviewed. Finally, national innovation performance as the output of a country's innovative capacity is analysed, and comparative analysis of the methods used in the assessment of the national innovative capacity is introduced.

1.1. European Union Framework programmes as an instrument for the development of the member states' innovation performance

In order to secure global competitiveness, EU applies a number of innovation funding actions. To start with, financial measures are undertaken to support R&I projects directed towards prototyping, piloting, testing, and demonstration of innovations. Furthermore, EU offers support for the deployment of innovative technologies into new markets or sectors. There are also means of support for innovative firms, such as support to business R&D investment or the creation of start-ups. Furthermore, exchange of knowledge and information is encouraged by networking, joint learning, and diffusion of lessons learned as well as best practices. Finally, financial measures are available for the improvement of innovation policymaking at the national or regional level (Rubio, Zuleeg, Magdalinski, Pellerin-Carlin, Pilati & Ständer, 2019).

In comparison to other EU initiatives, the framework programmes are assigned a budget for the support to innovation which has been steadily increasing every year. As it acts as one of the core instruments with the longest history in developing the member states' innovation performance, the following sections are devoted for the analysis of the evolution of the EU research and innovation policy (including the comparison of different FPs over time), demonstration of additionality effects of R&D investment, and an overview of the methods for the assessment of EU investment.

1.1.1. Evolution of EU research and innovation policy

The government policy targeting R&I encourages creation, dissemination and implementation of new solutions (Lewandowska, Rószkiewicz & Weresa, 2018). Support for innovative activities acts as a minimiser of possible risks and market failures (Bruno & Kadunc, 2019; Perez-Sebastian, 2015; Qu & Li, 2019), stimulates the increase of own R&D investment (Azagra-Caro & Consoli, 2016; Hottenrott *et al.*, 2017, Zang *et al.*, 2019), improves the environment of innovation (Ege Y. & Ege Y.A., 2019; Malik, 2020), and promotes innovation (Furman & Hayes, 2004; Hu & Mathews, 2005; Lewandwoska *et al.*, 2018). The countries which have mastered and improved the skills in the area of the most appropriate policy for R&I succeed in the creation of highly innovative and competitive economies (Aghion, 2016; Veugelers, 2015; McCann & Ortega-Argiles, 2016).

Since the innovation policy affects a variety of enterprises and institutions – firms, universities, research institutes, etc. – there is an increased range of measures used by the decision makers (Cunningham, Gök & Laredo, 2013; Ormala, Linshalm &Ploder, 2017; Petrin, 2018):

- Direct support (e.g., government programmes for subsidies, grants and loans);
- Indirect support (e.g., financial system instruments, such as tax deductions or tax credits);
- Regulations (e.g., legal regulations, standards, prohibitions).

Over the years, the innovation policy was transforming together with the changing and broadening concept of innovation – it went from the grounds of the linear model of innovation through the model of linked chains, and, later, to the network model while adhering to the innovation systems approach. The first-generation innovation policy had a linear perspective assuming that innovation is mainly the result of R&D; hence, it mostly focused on the science and science&technology community (Eurostat, OECD, 2005). As the linear model turned out to be unsuccessful in identifying the multiple links connecting the research, development, commercialisation and uptake of innovation (Weresa, 2018), a need for the next generation innovation policy emerged. System-wise perspective, interdisciplinarity, and the inclusion of the business community as an essential stakeholder in the two-way communication across different points in the innovation chain were the main elements of the second-generation innovation policy (Meissner, Polt & Vonortas, 2017). Nevertheless, three broad groups of features of the knowledge-based economy had considerable significance on the nature of innovation (Lengrand, 2002):

1) The rise of services and intangibles;
2) The ongoing rapid development of Information and Communication Technologies (ICT) and the Information Society (IS);
3) The new roles of knowledge, organisational learning and human resources.

Therefore, even though the chain-linked model seemed to solve the limitations of the linear model, the motivation for the third-generation innovation policy was raised. From the sole objective of economic growth, the 3rd generation innovation policy was supplemented with additional aspects, such as life quality and sustainable development. Furthermore, the civil society was integrated into the closed community of science, technology and business (Eurostat, OECD, 2005). According to Meissner *et al*. (2017), innovation started to be perceived as the outcome of the collaboration and interaction of a multitude and a variety of actors in the national innovation system. Moreover, the common aim shifted from the willingness to minimise the risks of impeding or undermining innovation activities into maximising the chances that the innovation policy will effectively support the innovation objectives.

Along with the general worldwide evolution of innovation policies, EU has also been developing a very ambitious innovation strategy with a funding system which should ensure its position of the global innovation leader. The key programs are denoted by the longest history of aiming to increase the direct involvement in innovation activities and thus to ensure the successful innovation performance and to close the innovation gaps are the framework programmes (Napiorkowski, 2018; Gouardères, 2020). In the 1980s, the investments of European countries were overlapping, product standards differed, and the competitiveness worldwide was relatively low (Kim & Yoo, 2019). Based on the need for a common and regular EU R&I policy and systematic cooperation within the member states, a joint research and development initiative named the first *Framework Program* (FP) was launched in 1984; it had a budget of approximately 3 billion euros (see Table 1). It was followed by an array of multi-annual FPs growing progressively in size, scope and broadening of focus on new research fields: the 2nd FP (1987–1991) increased to 5.4 billion euros, the third FP (1990–1994) went up to 6.6 billion euros, the 4th FP (1994–1998) rose to 13.2 billion euros, and the 5th FP (1998–2002) reached 14.9 billion euros.

Table 1. Comparison of EU Framework programmes from 1st to 5th. *Based on Bruno & Kadunc (2019); European Commission (2014); Kim & Yoo (2019).*

FP	Period	Budget	Main contents
1st FP	1984–1987	€ 3.3 billion	Incorporation of individual programmes; Funding the research for industry competitiveness.
2nd FP	1987–1991	€ 5.4 billion	Accentuating the European single market and research programme; Focus on industrial research.
3rd FP	1990–1994	€ 6.6 billion	Expansion of the ICT sector; Training and mobility of scientists.
4th FP	1994–1998	€ 13.2 billion	Participation of non-EU countries; Besides the areas of biotechnology, environmental research and telecommunications, increased support for research of social sciences and humanities.
5th FP	1998–2002	€ 14.9 billion	Differed considerably from its predecessors; Conceived to respond to the major socio-economic challenges; Concentrated on a limited number of multidisciplinary research areas.

In 2000, the European Council promoted the Lisbon strategy which was complemented by the Barcelona target in 2002 with the ambition for EU to turn into the most dynamic and competitive knowledge-based economy worldwide. Therefore, the budgets of the 6th FP (2002–2006) and the 7th FP (2007–2013) increased to 19.3 billion euros and 55.9 billion euros, respectively (see Table 2). In 2010, the initiative *Innovation Union* was launched by the European Commission. The focus was on removing obstacles to innovation (e.g., market fragmentation, skills shortages, and slow standard-setting): all the elements preventing the quick transfer of ideas to the market were targeted (European Parliament, 2010). Furthermore, through the development of partnerships among EU institutions, national and regional authorities and business entities, it was intended to change the way the public and private sectors collaborate.

Furthermore, when planning the instruments for HORIZON 2020, policy makers considered that private enterprises are not willing to invest in novelties for public and collective welfare due to very long developmental time frames. Instead, firms choose to retain their focus on incremental innovation, i.e., they seek to utilise the currently existing and available technology while increasing the value to the customer (e.g., features, design) within the already existing market (Cunningham *et al*., 2013). This situation induced the genesis of focus on grand societal challenges – the societal problems requiring changes in organisational practices and breakthrough innovations both in products and services. For this reason, the latest Framework programme for research and innovation, i.e., *Horizon 2020* (2014–2020) was assigned a budget of 80 billion euros. Horizon 2020 includes not only a greater budget and is denoted by radical simplification but also introduces more emphasis on innovation and societal challenges and is denoted by special attention to SMEs and gender equality. In 2021, the EU will step into the new programming period, along with the Commission's proposal of 100 billion euros for the mission-oriented *Horizon Europe* (European Commission, 2020a). Yet, due to the COVID-19 crisis, the European Council (2020) decided to reduce the financial envelope for Horizon Europe to 80.9 billion euros.

Table 2. A comparison of EU Framework programmes from the 6th FP to Horizon Europe. *Based on Bruno & Kadunc (2019); European Commission (2014a;b; 2015a;b; 2019b); Kim & Yoo (2019).*

FP	Period	Budget	Main contents
6th FP	2002–2006	€ 19.3 billion	Integrating and strengthening ERA; Policy-oriented research and leading technological edge topics; Research activities involving SMEs; International cooperation activities.
7th FP	2007–2013	€ 55.9 billion	Promotion of networking with 'third countries'; Strengthening the European industry; Focus on jobs and competitiveness; Expansion of nuclear research; Funding research infrastructures and mobility.
Horizon 2020	2014–2020	€ 80 billion	Convergence of R&I policies; Improving researchers' competences and skills; Empowering industrial leadership; Providing an extensive budget for SMEs; Ensuring public-private partnerships; Strengthening the role of social sciences and humanities.
Horizon Europe	2021–2027	€100 billion (initial) €80.9 (current)	Focus on high-quality knowledge, skills, and technologies; Strengthening the impact of R&I in developing and executing EU policies; Supporting the uptake of innovative solutions by industry and society; Promoting all forms of innovation and strengthening market deployment of contemporary solutions.

To sum up, EU is investing billions of euros in research and innovation. Nevertheless, Japan, Canada and Australia are still leading as the most innovative nations, and China is catching up fast (European Commission, 2019a). It is also important to mention that the performance strongly diverges across the member states with highly uneven and incoherent progress. According to Andrijauskiene & Dumciuviene (2018), although a half of EU enterprises are innovative, there exists visible disparity in R&D and non-R&D innovation investment, patent applications, design applications, and trademark applications. Furthermore, companies encounter the challenge of commercialising new or significantly improved products – innovation sales make up as little as 13.4% of the total turnover, and Europe is home to only 7 per cent of the world's leading technological companies (Archibugi, Filippetti & Frenz, 2020). Therefore, comprehensive evaluation of the influence of EU investment in research and innovation, together with the assessment of how other determinants of innovation work in this common context, is necessary.

1.1.2. Additionality effects of R&D investment

R&D investment can be considered as an imperative element in the overall investment since it is most likely to lead to new products, processes, or services (Archibugi *et al.*, 2020). According to Kubera (2018), Lewandowska *et al.*(2018), Méndez-Morales &Muñoz (2019), and Petrin (2018), the influence of the government support for R&D can be considered within different levels of additionality (see Figure 1). The examples of input additionality may be additional investments in gaining external knowledge, improving the infrastructure, obtaining new technology, etc. Output additionality can be expressed as new products, processes, novel marketing or organisational methods, growth in high-tech products or knowledge-intensive services exports, etc. External behaviour is additionally manifested when firms receive the funding, but, in doing so, they change the way they conduct research and innovate. Examples of this phenomenon include the captured intensity of new innovation cooperation or personnel training. Finally, the additionality effects on economic outcomes can be observed via productivity and economic growth.

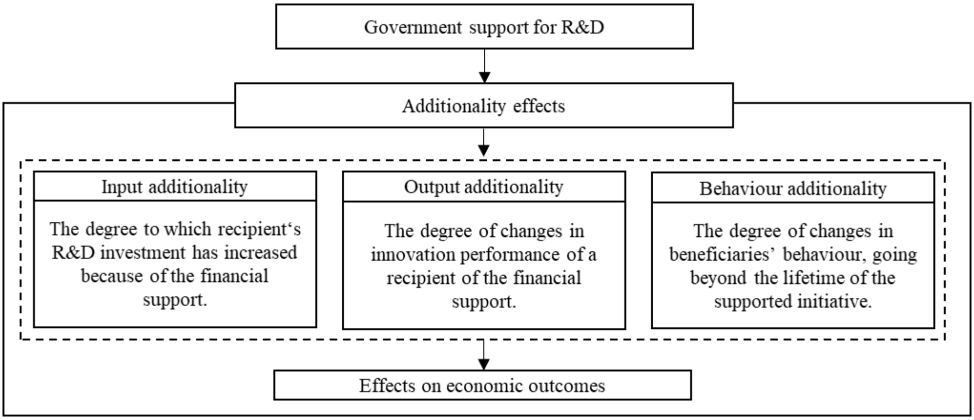

Figure 1. Additionality effects government support for R&D. *Based on Kubera (2018); Lewandowska et al. (2018); Méndez-Morales &Muñoz (2019); Petrin (2018).*

Most scientific works focus on the first level, i.e., the input additionality, that is, on the effect of the government financial support of R&D on institutions' (mostly, firms') own R&D investment (Czarnitzki & Hussinger, 2018; Cunningham *et al*., 2013; Petrin, 2018). Usually, empirical studies have been testing the crowding-in and crowding-out hypothesis (Huergo & Moreno, 2017; Orlic, Radicic & Balavac, 2019). Scholars analyse the determinants of private firms' participation in public R&D programmes or projects and then the effects of this participation on the firms' own R&D activities. Crowding-in can be explained as a positive effect of policy instruments which helps a firm mitigate market failures by reducing the share of costs of R&D investments (e.g., as in Huergo & Moreno (2017) who found out that the greatest crowding effect corresponds to EU grants, and that this influence is more than three times greater than the one of a loan)). Crowding-out, on the contrary, appears when a firm or a sector get accustomed to long-term subsidisation, and thus incentives for the search of efficiency are lost. In this situation, a firm/sector decides to simply substitute their own R&D investment with public subsidies, and, instead of using the additionality effect for the full potential to innovate, they perform at the same extent/level even if no subsidies were granted. According to Foray & Hollanders (2015), since the borders between the countries are becoming less and less important due to the globalisation, the increasing R&D subsidies will not be effective anymore if all the countries do so, and they will only cause the replacement of privately funded business R&D by the publicly funded R&D.

A number of scholars (Bronzini & Piselli, 2014; Bruno & Kadunc, 2019; Czarnitzki & Lopes-Bento, 2014; Cunningham *et al*., 2013; Grimpe, Sofka & Distel, 2017; Petrin, 2018; Radicic & Pugh, 2015) state that studies on R&D output additionality and/or the assessing effects on the macroeconomic level are much more limited than the studies on input additionality even though the results of this kind of research would be crucial for judging the influence of the government innovation policy.

The results of the research of the influence of the government's R&D investment on the output additionality of the beneficiary are mixed as different researches show positive, negative or insignificant effects. For instance, Herrera & Sanchez-Gonzalez (2013) discovered that in Spain SMEs increased the sales of the products which were new to the firm, and large firms expanded their sales of the products which were new to the market after being subsidised. Aguiar & Gagnepain (2017) analysed the causal effect of the 5th Framework Programme on the firms' performance. On the grounds of their findings, they claim that participation in FP raised labour productivity by at least 44.4%. The results of Czarnitzki &Lopes-Bento (2014) suggest that the funding receivers in Germany were more active in patenting. Furthermore, those recipients filed more valuable patents than those in the counterfactual situation of getting no public subsidies. Bronzini & Piselli (2014) investigated the R&D subsidies programme in Italy and learnt that there was a positive effect on the amount of patent applications, especially for smaller companies. This support also increased the probability of applying for a patent. Radicic & Pugh (2015) counted that the estimated effects of innovation support programmes are complimentary, typically increasing the likelihood of innovation and the success of commercialisation by about 15%. A negative effect was described in the study of the Czech Republic firms by Zemplinerova & Hromadkova (2012). Their analysis showed that access to subsidies had a significant but negative influence on the innovative output (patents in the case of their research). According to the authors, this outcome "may throw a shadow on the efficiency of the supported firms and hence on the provision of subsidies to firms R&D" (Zemplinerova & Hromadkova, p.488, 2012).

Some findings, on the other hand, are mixed, and it depends on the variables that the scholars choose to put into the models. For example, Baesu, Albulescu, Farkas & Drăghici (2015) admit that R&D investments have a negative effect on both patent applications and granted patents, but, for trademark applications, R&D investment is an important explanatory variable. Besides, Radicic & Pugh (2015) found positive effects for the propensity to apply for patents, but there were no additionality effects on innovation sales. Radicic & Pugh (2017, p. 497) describe these effects as "European paradox – success in promoting R&D inputs but not commercialization." Other significant findings were presented by Lewandowska *et al*. (2018). They found out that there are huge differences among the countries from the CEE region regarding the effects of EU funding for innovation. Moreover, one of the most striking results of the research was that EU financial support affected the output additionality (i.e., innovations) in none of the 13 selected EU countries from the CEE region.

The main insights can be twofold: 1) that there is relatively little research on R&I investment output additionality; and 2) that the findings are mixed. The results of the second insight might be influenced by a variety of circumstances. Output additionality appears to be established when government support is combined with other favourable factors, such as the recipient's openness and capabilities (Cunningham *et al.*, 2013). Output additionality may also be influenced by the strength of networks of different innovation actors, such as public institutions, universities, research organisations and private companies (Proksch *et al*. (2017)). Therefore, the influence of EU investment, as the core of this study, and the 'broader environment' which can mitigate the effect of the public support on national innovation performance is empirically investigated in Section 3.

Additionality effects of EU FP6, FP7 and HORIZON 2020 framework programmes according to the previously performed evaluations

The European Commission is responsible for the constant monitoring and evaluation of EU programmes (European Commission, 2020b). Evaluations, as a systematic process, helps in the understanding of how the program does or does not address the problem of interest. Furthermore, the evaluations act as a library for sharing the promising practices and lessons learnt with all the stakeholders and provide estimations of the programme's impact regarding its original goals. Also, it plays an important 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. Ex-ante evaluations are usually undertaken as an aid in the priority setting before the project or programme is initiated. It documents the needs to be addressed, the results to be obtained, and the feasibility of the planned programme. Interim evaluations are performed in the middle of the intervention. They document the progress of the programmes, the efficiency of the usage of resources, the relevance, coherence with other instruments, and the added value for EU (European Commission, 2017a). Finally, ex-post evaluations are undertaken to assess actual impacts 'on the ground' and to generate information which is useful for the selection, planning and management of future programs. They focus on the results and the contribution of the programme and assess whether the public funds have been used efficiently.

The ex-post evaluation of FP6 (European Commission, 2010) focused on the results generated at the level FP6 thematic priorities (e.g., genomics and biotechnology for health; IS technologies; nanotechnologies, new production processes and products; aerospace; food quality and safety; sustainable development, etc.) and the effects on the beneficiaries. As the results of the evaluation show, FP6 generated an added value for the EU and contributed towards industrial competitiveness, network externalities, and knowledge infrastructure (European Commission, 2010; Simmonds, Stroyan, Brown & Horvath, 2010). Furthermore, it improved the researchers' mobility and internationalised the research teams. FP6 also aided the integration of the new Member states into the European Union. On top of that, it was found out that it was the companies that were the ones which benefited most from the increased knowledge and networking. At the same time, the universities and institutes' incentives were hardly affected by the Framework programme despite being substantial beneficiaries. According to the expert group which was in charge of the ex-post evaluation of FP6, there was "a significant deficit in understanding of the effects of the FP over time and on the wider context (including institutions; disciplines and technologies; industry; society at large; policy)" (European Commission, 2010, p. 61). Hence, one of the recommendations to the Commission was to extend the evaluation culture substantially, to measure and present the impacts of the framework programmes.

A few attempts have been made to add some insights to the official studies on EU FP6 evaluation. For instance, Fisher, Polt & Vonortas (2009) analysed the effects of FP5 and FP6 on innovation at the firm level and stated that firms usually perceive the added value of European funding 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. One of the most relevant findings by Fisher *et al*. (2009) is that, for SMEs, as opposed to large companies, the participation in FP helps to demonstrate more positive results in terms of product and process innovation. In 2016, Bondonio, Biagi & Stancik (2016) prepared the first EU funding (i.e., FP6 and FP7) impact study based on the firm-level micro-data in multiple countries. Scholars used counterfactual analysis of seven EU member states – Austria, France, the United Kingdom, Hungary, Germany, Italy, and Spain. There was no evidence found that FP6 and FP7 have additional effects on employment, sales or added value (in comparison with the firms receiving only national funding). Nevertheless, analysis of national and EU funding effects showed them to be equally relevant in fostering the firms' product innovation. Moreover, European Union funding exhibited even higher correlation with process innovation.

The assessment of the added value and the economic effects of the EU Framework programmes (European Commission, 2017b) showed that FP7 projects acted as a crucial point of financial resources and international research expertise. Furthermore, by reducing the research and financial risks, it helped in leveraging additional flows from national/regional and private sources (for each 1 EUR funded by EC, other participant organisations contributed with around 0.74 EUR). By using econometric modelling, experts (European Commission, 2017b) calculated that FP7 will have substantial long-term economic effects, i.e., the effect on GDP was estimated at around 38.8 billion euros, and the contribution to employment is forecast to be ~123,000 additional jobs per year by 2023, of which, 42,000 will be jobs in the field of research.

The official ex-post evaluations of FP7 (Fresco, Martinuzzi, Anvret, Bustelo, Butkus, Cosnard, & Nedeltcheva, 2015; European Commission, 2016) concentrated on the assessment of the programme's effectiveness, efficiency, relevance, coherence, and the added value to the EU. The analysis showed that:

- FP7 involved leading international scientific and technological talent as well as prompted the collaboration and networking between the different sectors.

- FP7 was particularly useful in strengthening scientific excellence – according to the European Commission (2017b), EU FPs research teams are approximately 40% more likely to be granted patents or to produce patent applications than the teams in the control group.
- FP7 cost savings for participants were 551 million EUR bigger compared to FP6.
- FP7 invested more than 28.7 billion EUR in 7,873 projects, which helped in coping with such societal challenges as food safety, climate change, migration, or radicalisation.
- FP7 worked consistently with other EU initiatives, such as the Structural Funds. However, according to the European Commission (2016a), more significant synergies could have been developed.
- FP7 resolved cross-border challenges which could not be addressed by member states alone. FP ensured complementarity (i.e., only a small number of projects would have been implemented without it).

In 2018, Piirainen, Halme, Aström, Brown, Wain, Huovari & Boekholt (2018) prepared a study which examined the benefits of participating in the EU FPs (FP6 and FP7 in particular). Apart from the core investigation object – the added value of FPs to Finland – they also analysed the secondary data from the previous national evaluations in Austria, Denmark, Ireland, Netherlands, Sweden, and Norway. To begin with, the enhanced networking and collaboration was the most frequently reported effect of the participation in the framework programmes (Arnold, Åström, Boekholt, Brown, Good, Holmberg,... & van der Veen, 2008; Boekholt, 2009, Biegelbauer, Dinges, Wang, Weber, Ploder, Polt,... & Gassler, 2018; DASTI, 2015; Rosemberg, Wain, Simmonds, Mahieu & Farla (2016). Surveys and interviews disclosed that FPs promoted opportunities for the formation of international networks and also had a positive effect on the increased knowledge and scientific capabilities of the researchers, the prestige for participating universities and the overall reputation of the member states (Arnold *et al*., 2008; Piirainen *et al*., 2018; Rosemberg *et al*., 2016). This effect is also proved by Ryan & Schneider (2016) who were studying the effects of EC funding in Denmark. They found out that Danish research funded by FP7 (especially, the European Research Council and Marie Curie grants) had greater effects than the research funded by Danish national sources.

In terms of the effects on the private sector, the companies which participated in FP7 claimed that this participation led to the positive effects on their levels of turnover (Alquézar Sabadie & Kwiatkowski, 2017), employment, productivity, and even resilience against the economic crisis (Rosemberg *et al*., 2016). The results of the assessment conducted by Nielsen, Farla, Rosemberg, Simmonds & Wain (2017) regarding the FPs influence show that companies, especially SMEs, also derive many non-monetary benefits, 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). Furthermore, an interesting finding was that the quality of academic institutions plays a vital role as the more highly-ranked were the universities, the greater the benefits of SMEs cooperation with them were. What is more, Alquézar Sabadie & Kwiatkowski (2017) found out that, in general, the influence of FP7 on the participating firms is positive, but there are major differences in terms of countries and sectors. Moreover, 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 brings us back to 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. This issue was also mentioned in the works of Napiorkowski (2018), Radicic & Pugh (2017), and Weresa (2018). In general, as Čučković & Vučković (2018) observe, although many individual studies confirmed that the participation of SMEs in EU FPs could have a significant positive effect on some aspects of innovation performance, the final results are also determined by the internal factors (such as the quality of skills and knowledge of the market, national regulatory environment, etc.).

The findings of the official Interim Evaluation of Horizon 2020 (European Commission, 2017b) present evidence that the programme is already producing scientific and technological outputs and societal impacts. The expected impact of Horizon 2020 was divided into the following 3 categories:

- Scientific impact (research competences and the emergence of new technologies or science directions; better international and cross-sectorial collaboration for research and innovation);
- Innovation/Economic impact (new job placements due to the diffusion of innovation; growth and investment; a strengthened position of Europe's industry competitiveness);
- Societal impact (input of research and innovation while considering global societal challenges; societal approval of science and innovative solutions).

Čučković & Vučković (2018) analysed the data on the total H2020 budget allocations to SMEs in the period of 2014–2017 and the data on the summary innovation index. They confirmed that the countries which received a more considerable amount of EU financial support scored better in the general innovation performance indicator. An early assessment of the H2020 initiative by Napiórkowski (2018) also highlighted that the program helped in producing innovative output, yet the efficiency of this success was heterogeneous across individual programs and countries.

The European Commission (2017c) exhibits growing interest in the programme – the increase in the number of applications is considerably higher than in the FP7 (65% more applications per year; 131% increase in the number of applications from the private sector). Nevertheless, with the growing interest of applicants, there exists 'a long tail' of financially unsupported and denied projects – the statistics of the success rates led the European Commission to the conclusion that Horizon 2020 was underfunded by around €60 billion (European Commission, 2017c). This constitutes not only an unmet 3% EU R&I investment target but also a waste of time and financial resources of the applicants and a loss of high level R&I in Europe.

Rubio *et al*. (2019) emphasised that EU innovative public-private partnerships ought to be systemised, and that the impact direction should be enhanced with a clear link to the missions. It can be stated that this issue was not tackled over the years – as early as in 2015, Veugelers, Cincera, Frietsch, Rammer... & Leijten (2015) accentuated Horizon 2020's inability to reach out to the young and fast-growing innovative companies even though this programme was performing exceptionally well in attracting universities, research organisations, researchers and already established innovative companies. According to Adam (2014), despite specific incentives and the implemented instruments, membership in the EU does not guarantee development towards an innovative knowledge society – the EU innovation gap with the world innovation leaders still exists, and differences between the performance of individual member states persist (European Commission, 2019a). Renda (2015) indicated that innovation is increasingly less related to R&D investment as it can have many forms which do not entail the traditional industrial R&D process, it occurs in various sectors, and, in a lot of cases, it requires little or no resources (for example, in the case of social innovation). Schuch *et al*. (2017) also admitted that EU FPs should recognise innovation as something more than the established technology. Veugelers (2015) proposed that the innovation policy mix in EU countries remains fairly untargeted. As authors state, on average, 90 percent of the policies do not focus on particular sectors or technological areas and do not take into account the primary, secondary and tertiary sectorial distribution in the member states; hence, they stimulate uneven and incoherent effects from the policy which should 'just fit it all'.

According to Weresa (2018), one of Europe's major flaws lies in its inability to transform the gained skills and the results of technological research into innovative solutions and competitive advantages. Napiorkowski (2018), who compared the effects of different EU research framework programmes, 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.).

Looking at the level of MS, Fazekas, Chvalkovska, Skuhrovec, Tóth & King (2013), Paun (2015), Startiene, Dumciuviene & Stundziene (2015) give arguments that, in the case of the low quality of public institutions, weak national legal systems and fragile anticorruption services, politically allocated EU investments create more bureaucracy and frauds than the actual economic growth. Liargovas, Petropoulos, Tzifakis & Huliaras (2015) remark that the lack of coordination between the EU and the national agencies managing EU financial flows extends to the project overlaps and the duplication of activities which work for the same purposes. Furthermore, the misallocation of resources and rush in absorbing the financial support can lead not only to unproductive project activities but also distort the overall motivation of the beneficiaries to invest. As Jureviciene & Pileckaite (2013) and Archibugi *et al*. (2020) emphasised, in most cases, the companies which do not win projects and remain without EU investment still choose to implement their original ideas, however, even at a smaller cost than they initially required from the funding bodies. What is more, according to Varga & Sebestyén's (2016) findings regarding EU-13 investigation, the financial flows from FPs turn into substitutes for funding from national sources, and only peripheral districts with lower level knowledge infrastructures get the real FP benefits since innovation is stimulated via the transfer of external knowledge. On the contrary, no evidence for the core regions of the EU-13 was found on the positive impact of innovation related to FP participation.

According to Čučković & Vučković (2018), the net effects of the EU funding for innovation are complicated to quantify precisely. These effects rely on many factors at the firm, industry and national level, and "different empirical studies have not come to a conclusive answer on this research task, especially when it comes to determining the causality of impacts" (Čučković & Vučković, 2018, p. 120). 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 which may, directly and indirectly, alter the overall influence of EU investment. More information about the methods used for the assessment of EU investment influence can be found in the following section.

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

According to the European Commission (2017d), the evaluations and performance audits should consider the causality and the magnitude of effects in order to assess the extent to which policy interventions create the expected effects, or whether there are other exogenous factors which influence the outcomes and lead to (un)intended consequences. Evaluations are expected to go beyond the assessment of what has happened, and consider why something has occurred and, if possible, how much has changed as a consequence (i.e., evaluations seek quantification of change). During the last few years, counterfactual impact evaluation has been increasingly perceived as a convenient tool which helps in gathering reliable results (as in Bondonio *et al*., 2016; European Commission (2018); Szücs (2018).

While evaluating the FP6 (2002–2006), the European Commission (2010) indicated that a significant evaluation challenge is related to the diversity of the programmes' goals and the disparities between the available data across the countries, sectors and topics of the programme. Despite a number of measures (for instance, Horizon 2020 Results Platform; Horizon dashboard; Europe 2020 Innovation Indicator; European Innovation Scoreboard (European Commission, 2013; 2019a; 2020c,d)), the official interim evaluation of Horizon 2020 (European Commission, 2017b) 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 & 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, Huergo & Moreno, 2012; Aguiar & Gagnepain, 2017), or the accounting for the scientific output and filed patent applications (as in European Commission, 2016b). While monitoring provides a flow of data to track the performance against the plan, evaluation is used for strategic reasons in order to identify the real effects of the programme. However, despite important contributions to the base of evidence, evaluations are far less commonplace than the simple monitoring and are not applied comprehensively to the policies and programmes across Europe (European Commission, 2017a).

One of the attempts to analyse the innovation gaps in the EU member states and to link them with low EU-13 participation and success rates in the Framework Programmes was made by the European Parliament (2018). Eleven hypotheses were constructed, and more than a half of them were confirmed. Some of the most important findings include the fact that EU-13 organisations, in general, have lower participation per million inhabitants, per FTE researcher and active organisation in FP proposal submissions, i.e., they are less active than EU-15. Furthermore, proposals involving organisations from EU-13 are more likely to be rejected due to their low administrative/institutional quality. Finally, these countries have weaker connections to the collaboration network. Another critical conclusion was that, in 2008, the Innovation Index of the EU-13 was approximately 40% lower than the EU-15. In 2015, after having participated in FP7, the size of the gap continued to be the same. Thus, the European Parliament (2018) claims that the Framework Programme did not result in EU-13 catching up with EU-15.

What concerns the national evaluations, it can be noted that even though some of the evaluators employ bibliometrics (e.g., Rosemberg *et al*., 2016; Ryan & Schneider, 2016), evaluations at the member-state level (e.g., Arnold *et al*., 2008; Boekholt, 2009; Rosemberg, Wain, Simmonds, Mahieu & Farla, 2016; Biegelbauer *et al*., 2018) 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. According to Piirainen *et al*. (2018), for the bulk of official national evaluations, only secondary data analysis and evidence from participant/expert surveys and interviews are used.

As it can be seen in Table 3, experts and scholars are using a variety of different methods for the ex-post evaluation of EU investment starting from meta-evaluations which can be described as aggregate findings from a series of evaluations, continuing with case studies, interviews, surveys, focus groups, statistical/bibliometric analysis, and econometric modelling. These methods are employed for accessing, generating and analysing the data which is later transformed in order to structurise and explore interventions and to draw the conclusions. According to the European Commission (2018), the selection of the methods is entirely dependent on the purpose and timing of the evaluation, the objectives of the policy intervention, the nature of the specific policy questions, the availability of the data and information, and other associated factors.

Table 3. Methods used in the FPs assessment studies (FP6, FP7, H2020)

Method	Source
Meta-evaluation	Biegelbauer *et al.* (2018); European Commission (2010; 2016b; 2017b); European Parliament (2018); Rubio *et al.* (2019); Van den Besselaar, Flecha & Radauer (2018).
Case study	Arnold *et al.* (2008); European Commission (2016b; 2017b); Fisher *et al.* (2009); Nielsen *et al.* (2017).
Interview	Arnold *et al.* (2008); Biegelbauer *et al.* (2018); Boekholt (2009); European Commission (2010; 2016b; 2017b; 2018); European Parliament (2018); Fisher, Chicot, Domini, Misojic, Polt, Turk & Goetheer (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 (2016b; 2017b; 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 (2016b); 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 (2016); Fresco *et al.* (2015); European Commission (2014c; 2017b; 2018); Nielsen *et al.* (2017); Szücs (2018); Weresa (2018).
Bibliometric analysis	Arnold *et al.* (2008); Boekholt *et al.* (2009); European Commission (2014c; 2017b); European Parliament (2018); DASTI (2015); Fresco *et al.* (2015); Rosemberg *et al.* (2016); Ryan & Schneider (2016).

Nevertheless, the variety of evaluation approaches increases the risk of lacking coherence. This situation may also weaken the controllability and reduce the impacts (e.g., in the interim evaluation of Horizon 2020, the impact of the pillar ‘Excellent Science’ was mainly represented as an increase of the scientific output measured by publications, citations and careers, while in the pillar of ‘Industrial Leadership’, it was focused on the positive effects on growth and competitiveness (Schuch *et al.*, 2017)). Furthermore, evaluations of FPs usually include participant, project, sector, cross-sector or programme level of measurements. Hence, there is lack of research evaluating the effects on the macro-level – according to Biegelbauer *et al.* (2018), evaluations at the level of member states are infrequent. Also, monitoring should go beyond the measuring activities (Schuch *et al.*, 2017) as the influence of the innovation policies is strongly shaped not only by the framework programme conditions but also by the broader environment (Veugelers *et al.*, 2015). Therefore, alternative approaches should be proposed which "do not immediately focus on the impacts themselves, but at the conditions that generate impact, factors that make the impact more likely to occur: 'pathways' to impact" (Van den Besselaar *et al*., 2018, p. 7).

Besides the complicated decision of the proper selection of a method for the influence assessment, not only scholars but also experts which are assigned to official evaluations face more methodological challenges, for instance, the time lag issue, aggregation, the lack of data or benchmarks as well as other challenges listed in Table 4.

Table 4. Methodological challenges of the evaluation of EU Framework programmes. *Author's contribution based on Bruno & Kadunc (2019); European Commission (2016b; 2017b); Fisher et al. (2018); Schuch et al. (2017); Van den Besselaar et al. (2018)*

Challenge	Description
Variety of approaches	The array of approaches increases the risk of missing coherence, reducing controllability, and cutting down the impacts.
Attribution/ contribution problem	Organisations are not innovating in isolation, but in the context of a broader environment, which also can positively or negatively influence the final R&I results.
Aggregation	KPIs are developed for specific parts of the FP but not for the programme in its entirety. Furthermore, KPIs differ from FP to FP; hence, the results cannot be comparable over time, and the process of aggregation is complicated.
Lack of focus on different type of effects	Monitoring should also consider and propose mitigation actions for the potential negative effects. As for this moment, they are only rarely addressed.
Time lag issue	Most of the results of R&I activities can only be captured in the longer term. Therefore, it is crucial to decide on the realistic timeframe for the effects of the programme.
Lack of benchmarks	In terms of the size, coverage and depth, there is no programme similar to FP, thus it makes benchmarking difficult.
Lack of data	Monitoring gaps are involved due to the lack of data beyond the programme's lifetime.

The attribution/contribution problem stems from the contextual circumstances. Beyond the project funding, also, other projects and factors may positively or negatively influence the activities of the programme's beneficiaries and the diffusion and uptake of the results. Another methodological challenge is related to aggregation. According to the Directorate General for Research and Innovation (DGRI, 2015), reliable indicators of results are limited, and the individual indicators vary by discipline and sector. In the study "Mainstreaming Innovation Funding in the EU Budget" by Rubio *et al*. (2019), there are several recommendations formulated for the improvement of the monitoring and evaluation processes of the next Multiannual Financial Framework for 2021–2027. The authors of the study propose that the Commission should search for possibilities of the introduction of innovation tracking methodology so that the financial flows from the EU budget to support to innovation could be tracked properly.

According to the European Commission (2017d), indirect effects of R&I programmes can be just as significant as the direct ones. As for this moment, besides the positive effects, other types (e.g., negative; intended and unintended; direct, indirect and systemic) are only rarely addressed. What is more, many years may be required to comprehensively cover all the spectrum of these effects (European Commission, 2016b). For instance, innovations in the ICT sector are usually closer to the market, while vaccine development (which requires trial and error in the R&I process) can take more than ten years. Therefore, when evaluating the performance of innovation policies, the appropriate amount of time lags need to be taken into account.

Horizon 2020, as well as the next FP (Horizon Europe), are the most extensive scientific and technological programmes in the world; therefore, benchmarking with other countries outside the EU is nearly impossible. This makes the monitoring and evaluation processes even more complicated since KPIs, methods and approaches cannot be 'borrowed' from other programmes. Finally, the evaluators, as it is very common in research, face the problem of data availability. Bruno & Kadunc (2019) remark that, due to the current digitalisation processes, data collection should be simplified, and, hence, data should become easier to access in the near future.

All in all, it can be emphasised that "there is no gold standard in the methodologies and indicators to be used for the evaluation of R&I programmes" (Bruno & Kadunc, 2019, p. 63), and "there is no ideal method which would apply to all possible Commission initiatives" (European Commission, 2017d, p. 26). Nevertheless, ex-post evaluations should serve as a library for the learnt lessons, which helps in identifying the key drivers and barriers responsible for the success or failure of a specific policy.

The effects of R&I programmes do not develop in a vacuum – each member state has its own specificities which may positively or negatively alter the overall influence of EU investment. These specificities include but are not limited to diverse national R&I strategies and funding mechanisms (Fisher *et al.*, 2018), the regulatory, legislative and political context, or the degree of availability of human capital (Bruno & Kadunc, 2019). Considering this 'broader environment' and the differences between the 28 EU member states (i.e., the 27 current member states plus 1 former member state, the United Kingdom) in the context of the influence of FP on the national innovation performance is crucial. However, although this evidence would be crucial for judging the effectiveness of both EU and national policies, the analysis of previous evaluations confirmed that there is lack of cross-country macro-level research assessing the influence of FPs on the member states' innovation performance. Therefore, the next sub-chapter of the dissertation is devoted to the analysis and specification of the concept of national innovative capacity and its role in shaping the national innovation performance.

1.2. Country's innovation performance and the role of national innovative capacity

As Van den Besselaar *et al*. (2018) proposed, it is crucial not to look instantly at the influence of the R&I programmes. At first, the conditions and factors which may alter the final effects have to be considered. Therefore, Section 1.2. is dedicated to the analysis of a country's potential to improve its national innovation performance.

The concept of the national innovative capacity (NIC) framework was initially introduced by Furman *et al*. (2002) and 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). As the object of this dissertation is the influence of EU investment on the member states' innovation performance, Section 1.2.1. describes the significance of R&D investment in the context of a country's innovative capacity. Meanwhile, Section 1.2.2. continues with other important elements of NIC, including international economic activities, equality, legal strength, etc.

Section 1.2.3. describes the problem of the variety of forms of innovation and the fact that 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). For this reason, the section covers the debate about the indicators which are efficient in capturing different types of innovation. In Section 1.2.4., an overview of the methods used in the assessment of the national innovative capacity is provided.

1.2.1. R&D investment as an element of a country's innovative capacity

Over time, a substantial amount of scientific research has been dedicated to the question of how country-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 preconditions for the dissemination and implementation of the results of innovative activities in practice.

A number of researchers (e.g., Andrijauskiene & Dumciuviene, 2019a;b); Azagra-Caro & Consoli (2016); Malik (2020); Proksch *et al*. (2017); Santana *et al*. (2015); Veugelers (2017); Wu *et al*. (2017)) admit that out of a wide variety of different models used to examine this 'broader environment', the model devised by Furman, Porter and Stern (2002) still remains the most appropriate model for use both at the national level and for cross-country analysis. Even though it suffers from certain limitations which have been tried to overcome by researchers over the years (see below in the analysis of the scientific research based on the NIC model), it is still the most comprehensive national innovative capacity framework (Proksch *et al*., 2017). Moreover, the "NIC framework converges the prior theories in the area of innovation <…> overcomes the drawbacks of other theories <…> (Malik, 2020, p.

5) and “has synthesised what determines an economy’s ‘innovation capacity’ ” (Veugelers, 2017, p. 5) by focusing on a “set of factors that affect innovation at a country level, rather than considering only a few factors” (Malik, 2020, p. 5).

In 2002, motivated by the differences in R&D productivity across the countries, Furman, Porter, and Stern introduced the original NIC framework. This framework was initially built as based on the following ground theories:

- The new ideas-driven endogenous growth theory by Romer (1990) with an assumption that the growth of the country’s knowledge stock and its innovation dynamics depends on the size of the research sector and its productivity; i.e., an increase of the number of researchers leads to the permanent increase in the total factor productivity TFP growth rate;
- The cluster-based theory of the national industrial competitive advantage by Porter (1990) features an assumption that whether firms invest on the basis of new-to-the-world innovation depends on the microeconomic environment in which they are competing. Therefore, innovative dynamics relies on the strength of the linkages between the common innovation infrastructure and the specific cluster (e.g., a vibrant university system or established funding sources for new enterprises may encourage the uptake of new technologies);
- The national innovation systems theory by Nelson (1993) which drives the collection of national policies, institutions and relationships that influence the extent of the country-specific innovative output.

According to Furman *et al*. (2002, p. 89), the “national innovative capacity is 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, Furman *et al*. chose international patents and international patents per million of the population as the variables of innovative output.

What concerns the NIC drivers (inputs), three distinct areas were included in the model (see Figure 2): the quality of the common innovation infrastructure, the quality of the cluster-specific innovation environment, and the quality of linkages.

- *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 the scientific and technical skills devoted to the production of new technologies (S&T personnel), the R&D personnel, the R&D investment, the expenditures on higher education, IPR protection, openness to international competition, and stringency of antitrust policies.
- *Cluster-specific environment for innovation* defines cluster-specific circumstances and investments. This dimension includes two variables: private R&D investment and specialisation, 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 commercialised technological innovation, only patents which belong to chemical, electrical and mechanical patents classes were taken into account. Furthermore, the

element of interrelationship and knowledge spillovers between the clusters is also represented in the framework (see the dashed lines in Figure 2).

- *Quality of linkages* between the common innovation infrastructure and industrial clusters is revealed by the university R&D performance and the strength of the venture capital markets. According to the authors, if the domestic linkages between institutions are weak, industries can fail to exploit the opportunities of the upstream scientific and technical activity, and it may spill over to the foreign countries.

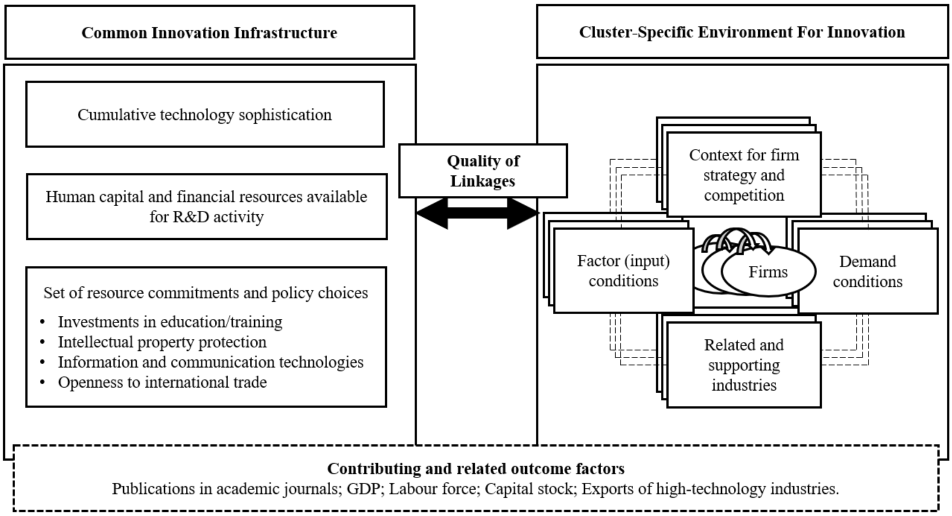

Figure 2. National innovative capacity framework. *Author's contribution based on Furman, J. L., Porter, M. E., & Stern, S. (2002).*

As for the contributing and related outcome factors, Furman *et al*. (2002) used publications in academic journals, gross domestic product (GDP), labour force, capital stock, and share of exports in high-technology industries.

The results of the analysed variables of the 17 OECD countries showed that, except for the size of population, stringency of antitrust policies and the availability of the venture capital, all the above-mentioned variables of the three NIC framework dimensions were positively significant. To be specific, in the context of the common innovation infrastructure, the results revealed that GDP per capita, the patent stock, the S&T personnel, the R&D investment, the openness to international trade and investment, the IPR protection, and the expenditures on higher education are significant. The analysis of the quality of the linkages showed that, while the strength of the venture capital markets had no effect, there was visible relevance of the high percentage of R&D performed by universities. In fact, it had the most positive effect on the national innovative output, i.e., patents. Finally, in the construct of cluster-specific environments, both variables – private R&D investment and specialisation – were significant.

As one of the main conclusions, Furman *et al.* (2002) implied that the public policy plays the crucial role in shaping a country's national innovative capacity.

Nevertheless, besides simple investments in R&D resources, human capital, favourable cluster circumstances, stimulation of innovation incentives, and the quality of linkages are impartially relevant. Therefore, further analysis shall be devoted to the critical role of R&D investment (which, in the original model, belonged to the dimension of the common innovation infrastructure) as well as to other determining factors of the national innovation performance. Since this doctoral thesis concentrates on the country-level (national) innovative capacity which demands a broader set of social, institutional and economic variables, all the studies which maintained focus purely on the firm level were rejected from the analysis in this section. The evaluation of the development and usage of the NIC framework is presented in the timeliness-based manner.

In 2004, Furman & Hayes (2004) used the NIC framework not only to analyse the factors which determine the overall long-run improvements in the innovation outputs but also to investigate how the less innovative countries can catch up the more innovative ones. For the sake of comparison, they categorised the set of the 29 OECD members into four groups based on historical information about their levels of innovative capacity: 1) leading innovator countries; 2) middle-tier innovator countries; 3) third tier innovator countries, and 4) emerging innovator countries.

By using some of the variables of NIC, Furman & Hayes (2004) created two indices: 1) the Investment Index which reflects the country-level investment in R&D and human capital, and the growth of the knowledge stock, and 2) the Policy Index which includes expenditures on education, openness to the international trade and investment, private and public R&D investment. The scholars found out that even though the innovation-oriented policy is important, but a more considerable part of variation and catch-up across the countries could have been explained by the elements of the investment index. This result suggests that country-level investments had stronger influence on the relative levels of innovative capacity. Finally, one of the most striking findings was that the variable of openness was negative and significant in their model, which illustrated that the countries which increased their openness to the international trade over time generated fewer patents. The authors claimed that “this may be an artefact of EU integration” (Furman & Hayes, 2004, p. 1343).

Faber & Hesen (2004) used the model developed by Furman *et al*. (2002) and tested it with 14 EU countries. In addition to patents, they added the sales of product innovations as another dependent variable. One of the most distinct results was that private R&D investment does not commit significantly to patent attainment and product innovation sales on the national level. According to the authors, this effect suggests that non-R&D investment by firms on innovation activities is the investment which stimulates innovations in the products which are introduced to the market.

Hu & Mathews (2005) adopted the NIC framework for five countries from East Asia, specifically, Republic of China (Taiwan), Korea, Singapore, Hong Kong and China, whereas none of them was included in the original study of Furman *et al*. (2002). The scholars additionally introduced a variable of public R&D investment and learnt that it has a significant role in the process of building the innovative capacity at the national level. Other findings were similar to those of Furman *et al*. (2002) – i.e., that the level of inputs devoted to R&D is one of the critical factors in determining the innovative output, and the only difference was that, for the latecomer East Asian economies, there was a smaller number of national factors which actually mattered. In fact, they gained much more from the accumulated knowledge capacity worldwide (the patent stock), described as "a pool of knowledge from which all latecomer countries draw in order to accelerate their catch-up" (Hu & Mathews, 2005, p. 1340).

Three years later, Hu & Mathews (2008) extended their earlier work conducted on the East Asian countries and presented the first study on China. The NIC framework again served as the basis for their methodology, but the authors broadened their focus on the six chosen sectors and their contributions to NIC: (1) universities; (2) public research institutes; (3) state-owned enterprises; (4) private enterprises; (5) FDI ventures; and (6) individuals. Moreover, even though in the previous studies these scholars were using patents as a proxy for the innovative output, this time they adhered to the position that "patents can vary enormously in their importance or value, thus simple patent counts are unlikely to capture the full force of the innovative output of the sector" (Hu & Mathews, 2008, p. 1470). Hence, beside the 'traditional' usage of the number of patents, the patent compound growth rate and the patent intensity in particular sectors, they supplemented the variables of the national innovative output with the forward patent citation rate, the backward patent citation rate, the average patent citation frequency, the technology cycle time, and the science linkage indicators.

The results of the empirical investigation by Hu & Mathews (2008) showed that five variables were positively significant (i.e., international openness, business R&D, university R&D, specialisation in the chemical sector, and antitrust policy). Altogether, private R&D and university R&D arose as the two strongest factors in China's national innovative capacity. On the contrary, and, quite surprisingly, among the six variables which exerted negative influence on the innovative output, there was a variable of the patent stock which, in the previous studies of Furman *et al*. (2002), Hu & Mathews (2005), showed a completely different direction. Hu & Mathews (2008) pointed out that this effect was caused by the insufficiency of China's previous technical knowledge. Also, the inefficiency or inadequacy in the alignment of public R&D investment and the lack of researchers may have played a role there. Other adverse variables were public R&D, protection of intellectual property rights, specialisation in the segment of electronics, and the availability of venture capital. The negative impact of IP protection and the venture capital was explained by the fact that, at the given time, China had the latecomer economy status and strict regulations on financial resources. Lastly, the scholars noted that the interactions and correlations between the variables yield contrasting effects at the different stages in building the national innovative capacity.

In 2009, Krammer (2009) performed a study on the innovation in transition economies from Eastern Europe and the former Soviet Union. This study empirically explored the main drivers of the national innovative output which was proxied by patents by using the identified regional differences (such as the historical heritage or technological specialisation). It was found out that IPR protection and inflows of foreign investment and trade increase the propensity significantly to patent. The scholar also discovered that, in the economies from Eastern Europe and the former Soviet Union, private R&D determines the variation in the patenting rates. These results went in line with the researches by Furman *et al*. (2002) and Furman & Hayes (2004). Moreover, the obtained results showed that governmental R&D is not only significant in the model (as in Hu & Mathews, 2005), but it even outperforms the influence of business R&D investment thus highlighting that the former is actually the primary driver of innovation.

In 2010, Huang *et al*. reconstructed the national innovative capacity framework by putting more emphasis on the global network context. Huang *et al*. (2010) used the approach that countries can obtain innovation technology via two preeminent ways:

- By enforcing national technology development and innovation capacity – the scholars used 8 elements from the original NIC framework as local effects (GDP per capita, GDP, total R&D personnel, R&D investment, openness, higher education expenditure, industry R&D investment and university R&D investment);
- By acquiring foreign advanced technologies via international technology diffusion. For this part, Huang *et al*. (2010) chose to employ the trade flows and FDI as the international diffusion of embodied technology. Next, they engaged patent citations as a proxy for disembodied technology diffusion.

By using network autocorrelation models and regression analysis, Huang *et al*. (2010) concluded that the empirical results of their study which examined 42 countries – including both developed and developing ones – did not support the findings of Furman *et al*. (2002) as the effects of GDP per capita, R&D personnel, openness and private R&D investment were not consistent with the original NIC study. The scholars tried to explain this contradicting result by the fact that Furman *et al*. (2002) focused only on the developed countries with advanced infrastructures and robust cluster-specific environments, hence, the findings are not applicable to the determinants of the new-to-the-world innovation production all over the world. Furthermore, Huang *et al*. (2010) confirmed that the national innovative capacity is not exclusively influenced by the local effects but is also determined by the position in the global network and international cooperation.

In 2011, these authors continued their work (Huang, Shih, Wu, 2011) and found out that the "embodied technology is more rigid to knowledge spillover and more strongly influences productivity changes than does national innovative capacity <…> disembodied technology is less rigid to knowledge spillover and increases domestic technological knowledge able to be adopted for innovation, and affects technical change" (Huang *et al*., 2011, p. 252). These results again prove the importance of the international economic activities in the context of national innovation performance and that the model of national innovative capacity should include these variables.

Castellacci & Natera (2013) introduced the concept of the dynamics of national innovation systems. They revealed that the dynamics are driven by the innovative, scientific, and technological input (innovative capability variables) as well as infrastructures, international trade, and human capital (absorptive capacity factors). The scholars used similar variables to Furman *et al*. (2002) and supplemented the model with the perspectives of quality of institutions and the governance system (by using the Corruption Perception Index) as well as social cohesion and economic inequality (by using the GINI Index). The variable of public R&D was causally linked to the publications, but it did not directly affect patents. Private R&D, on the other hand, turned out to be crucial in the process of creating the technological innovative output.

The flexibility and adaptability of the NIC framework was also demonstrated by Santana *et al*. (2015). The scholars used a data set of BRICS (Brazil, Russia, India, China) and G7 (Canada, France, Germany, Italy, Japan, UK, the United States of America) in order to analyse the efficiency of these countries so that to translate their NIC into economic, environmental and social development. Yet, Santana *et al*. (2015) employed merely several key elements of the framework variables proposed by Furman *et al*. (2002) and Hu & Mathews (2008), i.e., public R&D and patent stock for the common innovation infrastructure and private R&D for the environment of industrial clusters. They emphasised that the social dimension which would represent health and education is also undoubtedly relevant. Hence, they added the life expectancy and the means of schooling years (the two most frequently used variables of the Human Development Index, according to the authors). By using panel data regressions, data envelopment analysis, triple index and clusterisation, Santana *et al*. (2015) demonstrated that the efficiency of national innovative capacity differs across developed and developing countries. For example, China presented similar numbers in variables related to the national innovation capacity as compared to the United States of America, but its low social and economic indicators resulted in low average efficiency. On the contrary, even though the European countries (France, Germany, Italy and UK) did not invest much in R&D, they displayed high mean efficiency rates, which shows that they were able to reverse their inputs into high outputs.

In 2016, Azagra-Caro & Consoli presented a paper which directly focused on the European Union countries. By using a sample of ~600,000 patents in the period of 1990–2007, this paper analysed the effect of cross-organisational interactions on country-specific factors of knowledge flows (expressed as the number of backward citations in patent data). The results suggested that the public-private collaboration has a moderating impact since public institutions act as the generators of scientific knowledge. At some point, these results were in line with the findings of Furman *et al*. (2002); nevertheless, the approach of looking at the role of public-private cooperation was different. This positive and significant effect was proved by showing that the number of citations increases when companies co-apply for patents with universities and/or government bodies (Azagra-Caro & Consoli, 2016). According to the scholars, the analysis also showed fairly counterintuitive results of Higher Education R&D – although not significant, it still had the negative sign. Azagra-Caro & Consoli (2016) explained this might mean that high shares of Higher Education R&D simply do not show the strength of universities, but rather the industrial and applied orientation instead. They justified this argument by showing a positive correlation between the share of business funding of university R&D and a negative correlation of the percentage of university R&D corresponding to the basic research. What is more, it was suggested that the composition of R&D by the institutional sector (funding and expenditure) also matters for their innovative output expressed as knowledge flows.

Motivated by lack of the application of comparative methods in the national innovative capacity research stream, Proksch *et al*. (2017) applied the NIC framework for the fuzzy-set analysis of 17 European countries. Proksch *et al*. (2017) thus remarked that the original model by Furman *et al*. (2002) involved several limitations which they tried to overcome by using a slightly different approach:

- Even though the majority of indicators were quantitatively assessed, Furman *et al*. (2002) used qualitative data for the openness for international trade and investment, the strength of IP protection, the stringency of the antitrust policies, and venture capital performance.
- Only two variables were employed for the analysis of cluster-specific environment and quality of linkages. Hence, Proksch *et al*. (2017) included newly created businesses as an additional indicator for the quality of the linkages construct.

In their conclusions, the scholars advocated the view that different innovation strategies can come out with the same result (patents); hence, in their opinion, nations could select the most suitable one based on their preconditions. For example, it was observed that the UK needs more vital high-tech specialisation, Ireland should focus on a higher share on education expenditures and venture capital, or that Italy and Spain lack private R&D funding and journal publications.

One of the latest studies by Doran, McCarthy & O'Connor (2018) analysed the importance of NIC for competitiveness and growth in nineteen OECD countries. By obtaining the data from the global competitiveness report, the scholars used the same three sub-indexes as originally used in Furman *et al*. (2002), i.e., the common innovation infrastructure, cluster-specific innovation environment, and the quality of linkages. However, the variables differed. As a proxy for a country's common innovation infrastructure, they used the variable 'Institution' (a combined measure for contract and law enforcement and corruption) and the variable 'Macroeconomic environments' (a measure for the stability of a country's macroeconomy). As a proxy for the cluster-specific environment for innovation, the scholars employed the variable 'Quality of the national business environment' (a comprised measure from the survey data). To proxy for the quality of linkages, Doran *et al*. (2018) used the variable 'Percentage of BERD' (measured by the proportion of business R&D out of the total R&D within the nation); in the framework of Furman *et al*. (2002), this variable was included in the section for cluster-specific innovation environment. Finally, the proportion of the population involved in R&D and the previous patent stock were considered as two control factors. Although the scholars determined a significant positive correlation between the sub-indexes and the final output, one of the most important findings of the study was that a country's innovative potential (i.e., NIC) does not always automatically translate into innovative results (i.e., patent applications). For instance, Finland, which was found to have the highest level of national innovation capacity, was not the leading patent applicant. On the contrary, USA, despite the constant falling in the rankings, was found to have the highest patent applications per capita for any country considered. Nevertheless, these results may depend on the selection of the NIC factors – Doran *et al*. (2018) picked only four of them, while three of which were aggregate indexes derived from survey data.

In general, it can be stated that R&I investment is an essential element in the national innovative capacity; the vast majority of the above-analysed studies used at least one of the R&D variables and found it to be significant in stimulating innovative outputs:

- Total R&D investment: Furman *et al*. (2002); Furman & Hayes (2004); Hu & Mathews (2005); Huang *et al*. (2011).
- Public R&D: Faber & Hesen (2004); Furman & Hayes (2004); Hu & Mathews (2005); Krammer (2009).
- University R&D: Furman *et al*. (2002); Hu & Mathews (2005); Proksch *et al*. (2017)
- Private R&D: Castellacci & Natera (2013); Doran *et al*. (2018); Faber & Hesen (2004); Furman *et al*. (2002); Furman & Hayes (2004); Hu & Mathews (2005; 2008); Krammer (2009); Proksch *et al*. (2017).

However, innovation is not determined only by R&D investment (Renda, 2015), and it can be more than the established technology (Meissner *et al*., 2017; Schuch *et al*., 2017), it does not necessarily involve a traditional industrial R&D process (Halkos & Skouloudis, 2018; Renda, 2015), and does not necessarily have to be commercialised (Eurostat, OECD, 2018). For these reasons, it is proposed to redefine the NIC definition by Furman *et al.* (2002, p. 89) ("national innovative capacity is the ability of a country to produce and commercialize a flow of innovative technology over the long term") to the NIC definition as an environment and conditions which determine the national level ability to carry out innovative activities and to create innovations.

In order to redevelop the original NIC framework by Furman *et al*. (2002) and to add the latest insights from the scientific literature, Section 1.2.2. includes analysis of studies by scholars whose research was dedicated to the macro-level determinants of innovation.

1.2.2. Other elements of a country's innovative capacity

Not only researchers but also policy makers admit that the "R&D indicator had certain limitations to serve as the main indicator to monitor improvements of the EU in becoming the most competitive innovative society <…> and <…> relying only on one input indicator might result in overrating unproductive R&D investment" (Janger *et al*., 2017, p. 30). Having in mind the research gaps indicated in the scientific literature which was reviewed in the previous sections, Section 1.2.2. shall synthesise other important country-specific elements which were scientifically proven to be critical determinants of the national innovation performance. The original NIC dimensions of 'common innovation infrastructure', 'cluster-specific environment for innovation' and 'quality of linkages' were redeveloped and supplemented with the results of other scholars whose research was dedicated to the determinants of the national innovation performance. In addition to this, an original NIC framework was enhanced by three dimensions, namely, 'international economic activities', 'diversity and equality', and 'legal and political strength'.

Common innovation infrastructure

A country's common innovation infrastructure includes a range of overarching factors which foster innovation in the economy as a whole. To begin with, the knowledge stock, as a pool of knowledge, accumulates the competitive advantages of a nation (Doran *et al*., 2018; Furman *et al*., 2002; Furman & Hayes, 2004; Proksch *et al*., 2017; Santana *et al*., 2016). This specific knowledge may be diverse, or it may be focused on a few specialist areas (Filippetti & Guy, 2020).

Secondly, according to Wu *et al*. (2017, p. 506), "the common innovation infrastructure also encompasses national resource commitments that broadly affect innovation incentives and R&D productivity." As a study by Carvalho N., Carvalho, L., & Nunes (2015) confirmed that, apart from private R&D and a percentage of innovative firms, public R&D is the most important determinant of the innovative performance at the national level. Nevertheless, as Veugelers *et al*. (2015) emphasised, the EU suffers from a 'systemic' failure which involves the financing system. This issue is highly noticeable in the EU-13, where lower R&D investment leads to lower innovation performance (European Parliament, 2018).

According to Hudec (2015), the division of labour between universities, private industries and government (the so-called Triple Helix) across countries differs significantly. Hence, thirdly, an essential element of the innovation capacity is the quality of a country's labour force (Veugelers, 2017). Not limited to R&D personnel or doctoral graduates, a skilled nation can absorb the latest technologies (Castellacci & Natera, 2013; Rodríguez-Pose & Wilkie, 2019) and create efficient production methods as well as innovative products (Krammer, 2009). Therefore, according to Proksch *et al*. (2017), one way to ensure the growing levels of the innovative output is to ensure a high education level for the country's population. For instance, Sannikova, Dobele, A. & Dobele, M. (2016), who analysed the effects of lifelong education on the competitiveness of countries, found out that lifelong education makes the most robust and most positive effects on a country's competitiveness both during the innovation-driven and the efficiency-driven stages.

In this context, the academic quality of universities plays a significant role (Szücs, 2018). According to Cirera & Maloney (2017), countries need to shift their policy away from R&D-centered initiatives and give more attention to human capital factors. Academic institutions raise the stock of human capital by educating the workforce. Plus, it concentrates on training scientists and engineers who have a direct role in the innovation process by being the originators of new ideas and innovative products through R&D (Datta, Saad & Sarpong, 2019). As the European Parliament (2018) indicates, the governments of the member states should be responsible for supporting the career development of talented academicians and raising the quality of the national research performance. Nevertheless, judging by the average citation impact per publication and the presence of the rankings of national universities, the findings of the European Parliament (2018) revealed visible disparities amongst the member states, especially between the EU-15 and EU-13 categories. The issue of academic quality was also discussed in the work of Rodríguez-Navarro & Narin (2018) who obtained the results showing that the European Union gap in innovation performance can be at least partially attributed to the lagging-behind performance in a lot of science fields. One of the solutions to this problem is a strong scientific collaboration network. As the European Parliament (2018), Proksch *et al*. (2017) and Szücs (2018) propose, having a large number of international publications belongs to the alternative ways which positively influence the national innovative outputs.

The final discussed element of the common innovation infrastructure is the use of ICT. According to Renda (2015), ICT is key to the future of innovation. In the era of high technologies, such as virtualised production and 3D printing, a country which has not yet developed an ICT-friendly environment will be excluded from the most thriving global value chains (Renda, 2015). The European Parliament (2018) also implies the necessity of national public investments in ICT networks since it acts as an enabler of innovation in the sectors of manufacturing and services. It is also crucial to note that the importance of ICT usage was also considered in the works of Ege, A. and Ege, A.Y. (2019), Filippetti *et al*. (2017) and Lee *et al*. (2016). According to Ege, A. and Ege, A.Y. (2019), access to the internet is a significant contributor to an innovation-friendly environment.

To conclude, there is a range of overall country-level factors which stimulate innovation, including R&D and education policy, the quality of the labour force in the different segments of the Triple Helix, the strength of research institutions, and the diffusion of ICT.

Cluster specific environment for innovation

Clusters can stimulate innovation, and competitiveness within regions and countries (Doran *et al*., 2018), thus a cluster-specific environment for innovation is a core component in the national innovative capacity framework. As outlined by Furman *et al*. (2002), it defines cluster-specific circumstances and investments. Apart from Furman *et al*. (2002) who positioned business R&D investment at the core of their NIC concept, a number of other scholars (e.g., Castellacci & Natera (2013), Doran *et al*. (2018), Faber & Hesen (2004), Hu & Mathews (2005; 2008), Krammer (2009), Proksch *et al*. (2017)) proved that private R&D investment is a significant element in the process of improving the national innovation performance of not only catching-up but also leading countries. As Veugelers (2017) emphasises, low scores on this indicator may identify deficits in R&D capabilities in the business sector.

On the other hand, innovation may arrive through activities which do not require research and development. Moreover, according to Lhuillery, Raffo & Hamdan-Livramento (2017), R&D represents only about one-third of the 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 the market research or training related to the introduction of new products or processes (European Commission, 2019a).

According to Castellani, Piva, Schubert & Vivarelli (2019, p. 280) who compared R&D and productivity in the US and the EU, "industrial composition might affect the overall aggregate outcome since technological opportunities and appropriability conditions are very different across industries." Castellani *et al*. (2019) observed that R&D intensive manufacturing and service industries are under-represented in the European economy if compared to the US. Furthermore, the EU was identified as having a lower capacity to transform corporate R&D investment into productivity gains (a situation called the *European paradox*, as indicated in the previous sections of this dissertation). Foray & Hollanders (2015, p. 215) also claimed that "countries with high shares of R&D-intensive industries almost automatically perform better in patent applications," therefore, the EU needs more long-term oriented policies to provoke structural change towards R&D-intensive sectors.

To sum up, business investment directed towards innovation, as well as the concentration of sector-specific expertise, can determine both the type of innovative outputs and the magnitude of the national innovation performance.

Quality of linkages

The creation and diffusion of knowledge and innovation is an essential part of a country's national innovative capacity. Therefore, linkages between the sectors contribute to the system as a whole. To begin with the universities, they produce skilled graduates for the labour market and act as an easily accessible source of research both for industry and other sectors. Moreover, university R&D investment has been found to have a significant positive impact on innovative outputs (Furman *et al*., 2002; Hu & Mathews, 2008; Proksch *et al*. (2017). Furman *et al*. (2002) claimed that if the domestic linkages between institutions are weak, companies may not be able to exploit the potential of opportunities to innovate, and this might have a spillover effect to foreign countries. Although collaboration between firms and universities increases productivity (Cunningham & Link, 2015) and leads to a higher likelihood of commercialisation of R&D results (Hewitt-Dundas, Gkypali & Roper, 2017), according to Veugelers *et al*. (2015), EU experiences structural weakness, i.e., lack of interaction between industry and higher education institutions. In fact, as little as 11.2% of SMEs collaborate with public research institutions or other firms (Andrijauskiene & Dumciuviene, 2018).

The estimations by Jaklič, Damijan, Rojec & Kunčič (2014) who analysed the importance of innovation cooperation for the innovation activity of firms in Slovenia confirm that, apart from R&D investment, innovation cooperation is the most significant factor in the prospect for firms to innovate. This also goes in line with the results from a study by Nepelski & Piroli (2018) which examined the innovation potential of EU-funded research projects. It was concluded that in explaining the innovative output of a project, the design of a collaborative consortium is even more important than the level of R&D input. For example, universities often reported partnership with firms as an essential process to bring their innovations to the market (Nepelski & Piroli, 2018). Renda (2015, p. 22) held the same 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." Therefore, the results of the official evaluation of business R&D grant schemes by the European Commission (2018) are not surprising – the participants expressed their request for strong university-industry partnership and technology transfer to be further stimulated in Europe.

Other elements presenting the quality of linkages are venture capital (Faber & Hesen, 2004; Proksch *et al*., 2017) and new business density (Proksch *et al*., 2017). What concerns the venture capital, it is a type of investment provided to small business or startup companies which, in the investor's eyes, show long-term growth potential. Therefore, venture capital helps in sharing the R&D costs and risks, hence stimulating innovation. New business density, meanwhile, can reflect another vital stage of innovation cycle: new ventures may encourage and increase the opportunity of the commercialisation of new products or processes. According to Proksch *et al*. (2017), it shows the dynamism of industry performance in an innovative economy.

To sum up, a nation seeking to improve its national innovation performance has to increase the amount of interaction between different institutions and ensure that the quality of these linkages is at the appropriate level.

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, such as international trade and foreign investment, are also important for the national innovative capacity. The results of the research performed by Andrijauskiene &Dumciuviene (2019 a;b); Baesu *et al*. (2015); Bloom, Draca, & Van Reenen (2016); Filippetti, Frenz, and Ietto-Gillies (2017); Furman *et al*. (2002); Furman & Hayes (2004); Huang *et al*. (2010); Law, Lee & Singh (2018); Lee *et al*. (2016); Malik (2020); Proksch *et al*. (2017); Schneider (2005); Tebaldi & Elmslie (2013); Veugelers (2017); Wu *et al*. (2017) show that national innovative capacity is not exclusively determined by local effects, e.g., R&D investments, but is also influenced by the global network position and international cooperation.

International economic activities are broadly classified into two types: international trade and foreign direct investment (Wu *et al*., 2017). Because of exchange, international economic activities yield increased opportunities for information sharing (Huang *et al*., 2010; Castellacci & Natera, 2013). Therefore, direct learning from the experience of a foreign country and employing the already advanced services or products invented abroad facilitate international knowledge and technology diffusion.

Trade openness and flow of trade across borders is linked to leading innovations in numerous ways. Trade openness boosts markets in client countries. This situation motivates exporters to improve the level of resources and innovate so that they would be able to compete with national and international firms (Bloom *et al*., 2016). The newly developed growth theories also imply that trade openness fosters the spillover of ICT and hence promotes innovation (Furman *et al*., 2002; Lee *et al*., 2016; Tebaldi & Elmslie, 2013). On the other hand, one of the most striking findings by Furman & Hayes (2004) was that the variable of openness was negative and significant in their model which illustrated that the countries which over the years had been increasing their openness to international trade generated fewer patents. The authors claimed that "this may be an artefact of EU integration" (Furman & Hayes, 2004, p. 1343).

Continuing with the import, Schneider (2005) and Filippetti *et al*. (2017) pointed out that even though it facilitates knowledge dissemination across countries (e.g., via reverse engineering, the acquisition of information about the importer's design, production or organisational methods), it may have a negative impact, especially in countries with poor knowledge and conditions for innovation. According to Archibugi *et al*. (2020), in order to handle the systemic challenges of the European innovation system, plans of investment in public research must be combined with a broader set of spheres and policies, such as attracting FDI. What concerns FDI, literature highlights mixed evidence related to its relationship to innovation (Andrijauskiene & Dumciuviene, 2019a; Malik, 2020). On the one hand, FDI can promote local producers to enhance their R&D efforts, which would lead to more prominent knowledge flows followed by innovation. On the other side, 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 which already are innovation leaders. Another critical point is that the inward FDI can cause brain drain and that the domestic R&D activities can be crowded out by inward foreign investment. This situation leads to an overall decline in the innovation output, e.g., patenting activities (Law *et al*., 2018).

The relationship between the international economic activities and national innovative outputs was illustrated by the empirical studies of Andrijauskiene & Dumciuviene (2019 a;b). It was found out that imports of goods and services play an essential role in boosting design applications, and, together with inward FDI, increase the number of trademark applications. Nevertheless, imports had a negative effect on patent applications, and there was no significant relationship between inward FDI and the above mentioned technological innovative output. To be more specific, imports of services turned out to provide a much higher positive effect on the amount of trademark and design applications than imports of goods. As it was outlined above, these results disclosed that the amount of patent applications strongly depends on private investment in R&D and employment in the high-tech sector but is slightly negatively influenced by the imports of goods and services. This proves that the international transmission of knowledge requires more than just trading goods, and that the importing country's absorptive capabilities can act as a critical factor in this situation.

The importance of the absorptive capacity is also considered in the research of Filippetti *et al*. (2017). They extended these findings with the conclusion that countries can benefit from inward FDI, yet these advantages do not apply to the countries with lower levels of absorptive capacity. According to Veugelers (2017), the absorptive capacity is determined by a lot of factors, for instance, by the degree of the highly educated and skilled workforce which promotes the pro-investment climate in a country. Hence, before putting effort into the use of international economic activities as a measure to benefit from knowledge spillovers, nations attempting to improve their innovation performance should first invest in local basics of absorptive capacity, such as human resources, physical infrastructure and R&D.

However, it can be concluded that the traditional approach of closed-system analysis may be criticised since a country's economic growth and innovative progress is also driven by its international economic activities.

Diversity and equality

"Countries may not be able to increase their rates of innovation simply by increasing the amount of money spent on R&D or infrastructure. They also may need to change the values of their citizens to those that encourage innovative activity" (Shane, 1993, p. 59). The values which are shared within a society play a unique role in motivating and encouraging its members to undertake innovative initiatives (Petrakis, 2016), and diversity leads to a bigger amount of ideas, variance in creativity, and innovation (Nepelski &Piroli, 2018). Hence, as EU countries are denoted by significant differences within their social norms, morals, values, traditions and behaviours, they may also affect the innovative capacity of their societies.

Empirical studies at both micro and macro level point out that cultural features can either stimulate or restrain innovation performance. For example, Al-Kalouti, Kumar, Garza-Reyes, Upadhyay & Zwiegelaar (2020) and Naranjo-Valencia, Jiménez-Jiménez & SanzValle (2016) point out that the organisational culture is a crucial determinant for the innovation capability of a firm as it lays the foundations for knowledge creation within the organisation, contributes towards the performance improvement, and stimulates creativity. According to Andrijauskiene & Dumciuviene (2018), the representatives of enterprises admit that socio-cultural determinants of innovation performance are important. However, they are less relevant than technological and economic determinants, but have been affirmed to be more significant than political, legal, and environmental ones. Therefore, companies have to improve their capabilities to exploit favourable market circumstances, quickly respond to challenges, manufacture improved or new products, and, above all that, implement the organisational innovation culture. Otherwise, they may be destined to fail.

Researchers investigating at the macro level also suggest that there exists significant relationship between a nation's culture and its degree of innovativeness (Andrijauskiene & Dumciuviene, 2017; Kaasa, 2013; Khan & Cox, 2017; Puia & Ofori-Dankwa, 2013; Petrakis, 2016; Prim, Filho, Zamur & Di Serio, 2017). According to Kaasa (2013), the outputs of innovation are directly connected to innovation inputs, such as R&D, but innovation processes are strongly determined by culture. Petrakis (2016) and Prim *et al*. (2017) also advocate the view that the competitive culture has cultural features which are more innovation-driven. Furthermore, the analysis of the relationship between culture and innovation (Andrijauskiene & Dumciuviene (2017)) suggests that societies with certain features have a potential to innovate. Some of these features include highly individualistic culture, willingness to demand justification for inequalities of power, feeling comfortable with uncertainty and risks, and placing a higher degree of importance on leisure time. According to Castellacci & Natera (2013, p. 582), "countries having a greater level of social cohesion and within-country income equality are in general characterized by a higher degree of trust and knowledge sharing, hence supporting the pace of diffusion and adoption of advanced knowledge within the country."

Therefore, it must be emphasised that countries seeking to advance their national innovation performance should try to reduce their corruption rates and pursue the equal distribution of power and trust in different hierarchical levels (Andrijauskiene & Dumciuviene (2017). Furthermore, it is important to shift the direction of policy so that the inhabitants of the country would be satisfied with their living conditions and health. On the other hand, for today's globalised world, it can be rather challenging to adapt to every part of the community living in a country. By using a cross-country data set of 113 countries, DiRienzo & Das (2015) emphasise that cultural diversity reflects the lack of unity, the difference in values and distrust, therefore weakening economic, political, and financial institutions and hampering country-level innovation.

Since the concept of culture involves social norms, morals, values, traditions and behaviours, the factors of diversity and equality are also at the core of factors affecting innovation (Bührer & Frietsch, 2020; Díaz-García, González-Moreno & Saez-Martinez, 2013; European Commission, 2015; Ege, A., Ege, A.Y., 2019; Ritter-Hayashi, Vermeulen & Knoben, 2019; Teruel, Parra & Segarra, 2013; Wu *et al*., 2017).

Bührer & Frietsch (2020) analysed the results of two German programmes with a target to increase the number and participation of female researchers. Bührer & Frietsch (2020) found out that an increased proportion of women in the science system brings considerable contribution to the nation's innovative outputs – citations and excellence rates are high for female authors. According to Bührer & Frietsch (2020, p. 1), this means that "more women in the science system not only brings about ‘gain in justice’, but also a concrete scientific benefit.” 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 industries which are technology-intensive. Therefore, according to Claudie Haigneré, the President of Universcience, a French centre teaching young people the value of scientific and technological discoveries, “integrating the gender dimension into basic and applied research encourages excellence in science, engineering, research and policy <…> It’s vital that this waste of talent is addressed if we are to boost European competitiveness and innovation” (European Commission, 2015, p. 39).

The balance between male and female employees is emphasised to be important at the enterprise level as well because gender-diverse teams increase the probability of innovating (Ritter-Hayashi *et al*., 2019; Teruel *et al*., 2013). Ritter-Hayashi *et al*. (2019) found out that gender diversity both at the firm owners’ level and the general workforece level has a positive effect on innovation. This proves that diversity enhances the knowledge stock because complementary ideas provide new combinations of benefits in creating the new products and processes.

In one of their latest works, Ege, A., & Ege, A.Y. (2019) developed a model for testing how four different categories of variables impact innovation. These categories consist of legal/regulatory, political and economic, social, and informatory categories. As a proxy for the social inclusiveness, the scholars chose the variable of the female labour participation rate. The obtained results confirmed that the participation of women in the labour force is the second most important factor (after the rule of law) which influences the innovative performance of European countries.

Continuing with the income (in)equality, it is worth elaborating on the reality that significant erosions in the incomes of a particular part of the population creates an environment full of uncertainties for not only those people who are facing the challenge of lower incomes, but actually for the society as a whole (Ege, A., & Ege, A.Y. (2019)). The results of the research by Jacobs (2016) illustrate this phenomenon – specifically, the rising inequality reduces innovative dynamism. It was found that the 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. Therefore, it can be concluded that the redistribution from the rich to the poor can positively affect both the innovative process and the innovative outputs.

Legal and political strength

As it was mentioned in the section discussing diversity and equality, in order to improve their national innovation performance, nations should reduce the corruption and bureaucracy rates, and ensure equal distribution of power and trust across different hierarchical levels.

Fairly often, with the objective to obtain EU support, businesses exploit gaps in the activities of public institutions – they falsify documents, e.g., they prepare fictitious contracts between partners or providers (Chlivickas & Švogžlys, 2016). According to Transparency International (2019), when assessing the spending of EU grants, it is not rare to observe goods acquired for 5 times the market price. For example, the price for a device a Hungarian medical centre bought from a Slovak company was 1.7 million euro (partly funded by EU funds), even though the purchase market price of the same device in Slovakia was 262,000 euros. Thus, it can be claimed that the actual rates of allocation, absorption and usage of EU financial measures can be affected by corruption. Misallocation of resources as a result of corruption was also mentioned in the work of DiRienzo & Das (2015) and Perez-Sebastian (2015). Scholars claim that corruption, together with bureaucracy, may cause the inability of the public sector to target R&D projects efficiently. Furthermore, corruption deteriorates the trust of innovators in the legal system, leads to a surge in risks (Dincer, 2019), and weakens the underlying fundamentals of the governing institutions which are necessary for higher levels of innovative activity within the country. As small increases in the penalties for corruption can result in large increases in product innovation (Veracierto, 2008); therefore, it is crucial to control this abuse of power while seeking a private gain because this damaging trend has a statistically significant negative effect on innovation (Akkoyunlu & Ramella, 2017; Dincer, 2019).

According to Zang *et al*. (2019), a nation may try to imitate innovation policies of others, but it still heavily depends on the abilities of its authorities whether these policies can meet the expected goals. Castellacci & Natera (2013), Law *et al*. (2018), and Malik (2020) claim that the countries which are denoted by high institutional quality are more innovative. Therefore, although there may be analogies in innovation strategies and policies of different regions, significant disparities in their national innovative capacity, and the final innovation performance can be detected. For instance, BGI Consulting (2018) provides annual progress assessment of innovation support services of the Ministry of the Economy and Innovation of the Republic of Lithuania. In 2018, they determined that, in comparison with other countries, the number of implementing and/or administering agencies in Lithuania is high, and their functions often overlap. Hence, the real innovation impact relies a lot on the regulatory quality of governments and the practical allocation of innovation support (Zang *et al*., 2019) since, besides corruption, bureaucracy and complex rules can present a significant barrier to innovation and new ideas (European Commission, 2015).

Rivera León, Simmonds, and Roman (2012) explain that there are internal, external and political factors which can act as an incentive or a barrier for innovation (see Figure 3).

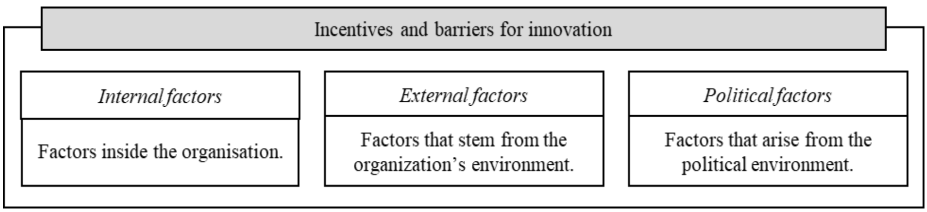

Figure 3. Types of factors acting as incentives and barriers for innovation.
Based on Rivera León, Simmonds and Roman (2012).

Internal factors within the organisation also affect innovation. The development of human resources, good leadership, quality and results-oriented management can foster innovation. On the contrary, lack of motivation and expertise of employees, lengthy bureaucratic procedures, an organisational structure based on institutions with overlapping functions, and complicated coordination can hamper innovative activities. External factors stem from the organisation's environment. They are more often seen as incentives rather than barriers (e.g., consumer involvement in the design of public services, cooperation, and attention to the requirements of citizens and businesses, and international dissemination of good practice create the environment which facilitates innovation). Political factors arise from the political environment. These can include public policy decisions, budget issues, politicisation of project selection, irrational funding of organisations, and the impact of newly adopted laws.

Corruption, politicised decisions, irrational funding and other 'shadow' activities can be ceased by proper legal and regulatory inclusiveness. Andrijauskiene & Dumciuviene (2017) suggest that one of the main features of a society with a high potential to innovate is the willingness to demand justification for inequalities of power. According to Ege, A., & Ege, A.Y. (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 & Das (2015), Ege, A., and Ege, A.Y. (2019), Furman *et al.* (2002), Hu & Mathews (2005; 2008), Hudec (2015), Krammer (2009), Malik (2020), Proksch *et al*. (2017), Wu *et al*. (2017), Zang *et al*. (2019). According to DiRienzo & Das (2015), 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. Trust in the government and the legal system is crucial if we seek to incentivise innovation. On the other hand, a study by Wu *et al*. (2017) illustrated that the strength of intellectual property rights correlates positively with the innovative capacity of the leading innovator countries, while the effect in the emerging innovator countries is negative. These findings were compatible with the previous work of Hu & Mathews (2005) and explained the different role of intellectual property protection institutions in patenting, which depends on the development of a country. For leading innovators, this protection encourages technological innovation and prompt economic growth in the long term. On the other hand, for the emerging innovators, these protections minimise the opportunity to copy the good practice and 'catch-up'.

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. As a lot of debate takes place about the nature and role of indicators which are most suitable to be employed as proxies for the country-level innovation outputs, or, in other words, the national innovation performance, the subsequent section is devoted to a comprehensive overview of the variables which were commonly used in the scientific literature analysed in Sections 1.2.1. and 1.2.2.

1.2.3. National innovation performance as the output of a country's innovative capacity

As the analysis of scientific literature conducted in Sections 1.2.1. and 1.2.2 demonstrated, the national innovative capacity can be generally defined as the broader environment and conditions which determine the national-level ability to carry out innovative activities and to create innovations. Therefore, the national innovation performance can be described as a country's innovative output. Table 5 illustrates the variables which are the most commonly used as a proxy for the national innovation performance. It should be noted that only the studies which took into account the country-level determinants were included in the analysis (both in Sections 1.2.3. and 1.2.4). The studies which focused mainly on the firm level were omitted (for instance, Jaklič *et al*. (2014)).

Table 5. Variables commonly used as a proxy for national innovation performance

Innovative output	Source
Patents granted	Baesu *et al*. (2015); Carvalho *et al*. (2015); Castellaci and Natera (2013); Faber & Hesen (2004); Filippetti and Guy (2020); Franco & Leoncini (2013); Furman *et al*. (2002); Hu & Mathews (2005; 2008); Huang *et al*. (2010); Krammer (2009); Law *et al*. (2018); Lee *et al*. (2016); Puia & Ofori-Dankwa (2013); Wu *et al*. (2017); Zang *et al*. (2019).
Patent applications	Andrijauskiene & Dumciuviene (2019a;b); 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 &Sebestyén (2016).
Patent citations	Azagra-Caro & Consoli (2016); Hu & Mathews (2008).
Global Innovation Index	DiRienzo & Das (2015); Kaasa (2013); Khan & Cox (2017); Prim *et al*. (2017).
European Innovation Scoreboard index	Andrijauskiene & Dumciuviene (2017); Ege, A. and Ege, A.Y. (2019).
Trademarks granted	Puia & Ofori-Dankwa (2013).
Trademark applications	Andrijauskiene & Dumciuviene (2019a;b); Baesu *et al*. (2015)
Design applications	Andrijauskiene & Dumciuviene (2019a;b).
Sales of new products or/and services	Carvalho *et al*. (2015).
Total factor productivity	Filippetti *et al*. (2017).
Labour productivity	Filippetti *et al*. (2017).
R&D investment	Kaasa (2013).
Exports of high-tech products	Andrijauskiene & Dumciuviene (2019b).
Scientific and technical journal articles	Castellaci and Natera (2013).

Innovation can "have various forms (product, market, process or social innovation), derived from diverse sources (closed vis-à-vis open innovation) and pertain to different scopes of change, i.e. disruptive, incremental or reapplied innovation" (Halkos & Skouloudis, 2018, p. 292). Nevertheless, despite the importance of the non-technological dimension, the formal technological and economic aspects of innovation have been taken into account in a far greater number of analyses (see Table 5). Furthermore, a lot of researchers use a popular approach to measure the output of innovative capacity by using patents as a proxy. They generally argue that:

- Patent is the only evident indicator of inventive activity with a well-grounded universality (Foray & Hollanders, 2015; Furman *et al*., 2002, Hu & Mathews, 2005; 2008; Malik, 2020; Zang *et al*., 2019).

On the contrary, despite the frequency of the usage of patents as the output of NIC, this strategy has received a considerable amount of critique:

- The popular view of innovation as invention or patenting fails to capture the larger part of the innovation process (Cirera & Maloney, 2017);
- Not every patent is used to generate innovation (Proksch *et al*., 2017);
- Use of patents as an output promotes the bias towards technology-driven sectors because the propensity to patent differs significantly depending on the sector (Janger *et al*., 2017);
- Not all innovative solutions are granted the right of a patent (Wu *et al*., 2017);
- "The use of traditional tools creates an innovation gap so that actual innovation is higher than measured innovation, and the more economies are service-based, the wider the innovation gap" (De Liso & Vergori, 2017, p. 126).

According to Meissner *et al*. (2017), as innovation is much more than technology, there cannot be one single adequate measurement to capture its multiplicity of features. Consequently, in the process of choosing the most appropriate measurements of innovation outputs, a country's specialisation must be considered. One of the options can be to take into account whether the nation specialises in services or manufacturing, as proposed by Janger *et al*. (2017). Even in the context of EU funding, Archibugi *et al*. (2020) noticed that the modern economy should no longer rely on financing the 'champions' in manufacturing (e.g., the automotive sector), and that the important role of services, and knowledge-intensive services in particular, should be much more carefully addressed at the policy levels. Thus, the measurement of the NIC output should include not only patents or their citation rate but also other elements of intellectual property, e.g., trademarks and design applications (Huang *et al*., 2010).

According to the European Commission (2018a) and Flikkema, De Man & Castaldi (2014), when identifying the origin of goods and services, the trademark is an imperative innovation indicator for the service sector. As the results of the study by Flikkema *et al*. (2014) confirmed, trademarks allow not only better measurement of innovation in services, but they also reveal multiple types of innovation, including non-technological ones. On the other hand, although trademarks, in general, are the most extensively used IPR across various economic sectors and firms (Castaldi, 2018), van den Besselaar *et al*. (2018) indicate that they are a much-undervalued type of IP in the empirical research of innovation.

Another type of IP which, in comparison with patents, is much under-researched in the context of innovation performance, is the design. Product and industrial design typically involves significant levels of scientific input (Sunley, Pinch, Reimer & Macmillen, 2008). However, according to Apostolos, Yeoryios & Maria (2017), despite the growing recognition of this IP, only a few studies attempted to use this variable as innovative output or quantify its contribution to the performance of a company or to the national economic growth.

Several studies also employed sales or exports of new products and/or services (respectively, Carvalho *et al*., 2015 and Andrijauskiene & Dumciuviene, 2019b); also, a number of scientific articles (e.g., Castellaci and Natera, (2013)) researched the total factor productivity, labour productivity (Filippetti *et al*., 2017), and the total R&D investment (Kaasa, 2013) as proxies for the innovative output. In addition to the above mentioned indicators, scholars tend to use the international innovation ranks (e.g., the European Innovation Scoreboard (EIS) and the Global Innovation Index (GII)) as the output of the country-level innovation performance (e.g., DiRienzo & Das (2015); Ege, A. and Ege, A.Y. (2019); Khan & Cox (2017); Prim *et al*. (2017)). Nevertheless, according to Foray & Hollanders (2015), indexes, such as EIS, may act as a tool to notify policy makers, yet they cannot be employed in an isolated manner as not all the crucial factors and conditions influencing the national innovation performance are observable within this framework. Moreover, as the experts of the European Commission themselves assert, the results of the overall summary index are not comparable over time (hence, the obtained values cannot be used in panel data analysis). The reasons behind this are that the external sources from which the data were extracted change from report to report, and the time period covered in the reports can be different, and, finally, the set of indicators varies as well (European Commission, 2019a).

It can be concluded that a considerable number of different indicators have been used when analysing the drivers and gains of the national innovative capacity. By starting with the origins – patents – scholars supplemented the models with a broader range of possible variables which may be used as a proxy for the national innovative output (i.e., the national innovation performance). It has to be emphasised that in the context of NIC, there still exists a general tendency to include only the ‘traditional’ technological innovative output. Therefore, in order to properly evaluate the national innovation performance, it is crucial to broaden the exceptionally prevalent focus on the technological innovative output to the non-technological innovative output, such as marketing and organisational innovations, and integrate other types of intellectual property rights, such as designs and trademarks.

1.2.4. Overview of the methods used in the assessment of national innovative capacity

Methods for the evaluation of the national innovative capacity largely vary. The most widespread way in the empirical designs is based on correlation and OLS regression models (e.g., Doran *et al*., 2018; Filippetti *et al*., 2017; Franco & Leoncini , 2013; Furman *et al*., 2002; Huang *et al*., 2010; Wu *et al*., 2017; Zang *et al*., 2019, etc.), see Table 6. Further alternatives include network autocorrelation models (e.g., Huang *et al*., 2010), fixed and random effects models (e.g., Baesu *et al*., 2015; Malik, 2020), and cluster analysis (e.g., Prim *et al*., 2017; Santana *et al*., 2015).

Table 6. Methods used in the context of National Innovative Capacity research

Method	Source
Correlation	Azagra-Caro & Consoli (2016); Filippetti and Guy (2020).
OLS regression models	Andrijauskiene & Dumciuviene (2019a;b; 2017); Baesu *et al*. (2015); Carvalho *et al*. (2015); DiRienzo & Das (2015); Doran *et al*. (2018); Ege, A and Ege, A.Y. (2019); Faber & Hesen (2004); Filippetti and Guy (2020); Filippetti *et al*. (2017); Franco & Leoncini (2013); Furman *et al*. (2002); Halkos & Skouloudis (2018); Hu & Mathews (2005); Huang *et al*. (2010); Kaasa (2013); Khan & Cox (2017); Krammer (2009); Lee *et al*. (2016); Malik (2020); Puia & Ofori-Dankwa (2013); Prim *et al*. (2017); Rodríguez Pose and Wilkie (2019); Schneider (2005); Wu *et al*. (2017); Zang *et al*. (2019).
Network autocorrelation models	Huang *et al*. (2010)
Fixed and random effects models	Baesu *et al*. (2015); Filippetti and Guy (2020); Lee *et al*. (2016); Malik (2020); Rodríguez Pose and Wilkie (2019); Schneider (2005); Zang *et al*. (2019).
General method of moments (GMM)	Franco & Leoncini (2013); Law *et al*. (2018); Malik (2020).
Cluster analysis	Kaasa (2013); Prim *et al*. (2017); Santana *et al*. (2015).
Stochastic frontier analysis (SFA)	Franco & Leoncini (2013).
Neuro-fuzzy model	Proksch *et al*. (2017).
Autoregressive distributed lag model	Ege, A., & Ege, A.Y. (2019).
Vector error correction model	Castellacci & Natera (2013).
Data envelopment analysis	Santana *et al*. (2015).
Negative binomial estimation	Azagra-Caro & Consoli (2016).
Granger causality	Castellacci & Natera (2013).
Factor analysis	Filippetti *et al*. (2017).

Scholars have also used the general method of moments (e.g., Law *et al*., 2018; Malik, 2020), Granger causality tests (Castellacci & Natera, 2013) exploratory qualitative comparative analysis based on Boolean algebra and the fuzzy-set theory (Proksch *et al*., 2017), negative binomial estimation (e.g., Azagra-Caro & Consoli, 2016), and the vector error correction model (Castellacci & Natera , 2013).

As it was indicated in Section 1.1.3., there is lack of cross-country macro-level research which would assess the influence of the EU Framework programmes on the member states' innovation performance while taking into the account the broader environment and conditions which determine the national level ability to carry out innovative activities and to create innovations. Therefore, the usage of a redeveloped NIC model is proposed.

To sum up the results of Section 1.2., we emphasise that the original NIC definition which included strictly technological innovations and the process of their commercialisation must be redefined into "environment and conditions that determine national level ability to carry out innovative activities and to create innovations." Moreover, as innovations are based on complex processes involving diverse backgrounds, knowledge, and experiences, more surrounding elements than simply R&D investment have to be taken into account, such as the common innovation infrastructure, cluster-specific environment for innovation, the quality of linkages, international economic activities, diversity and equality, and legal and political strength. Furthermore, as there exists a tendency to include only the 'traditional' technological innovative indicators as the output, it is of crucial importance to broaden the exceptionally prevalent focus and, on top of that, to employ non-technological innovative outputs, such as marketing and organisational innovations, and to integrate other types of intellectual property rights, such as designs and trademarks. In addition to the lack of cross-country macro-level research in the context of EU investment, most of the official assessments are limited to the analysis of direct benefits to the participating organisations by using such qualitative methods as survey, focus groups, or interviews. Moreover, another issue is related to the fact that national evaluations are fragmented; therefore, it is difficult to judge and compare evidence at the macro level. Finally, the FP result indicators vary from report to report, thus a comparison in a timely manner is complicated. For these reasons, by using the results of the analysis outlined in the previous sections, an alternative methodology for the assessment of the influence of EU investment on the member states' innovation performance is presented in Section 2.

2. METHODOLOGY FOR THE ASSESSMENT OF INFLUENCE OF THE EUROPEAN UNION INVESTMENT ON THE MEMBER STATES' INNOVATION PERFORMANCE

This section is devoted to the development of a methodology for the assessment of the influence of EU investment on the member states' innovation performance. To begin with, the elements of the national innovative capacity are identified along with their definitions and the justification for their selection. Later on, national innovation performance indicators which would most efficiently reflect both technological and non-technological innovative output as well as the commercialisation of innovation in a country are presented. Finally, the conceptual model is designed by including the variable of EU investment and the elements identified in Sections 2.1. and 2.2. along with the developed scheme of empirical research.

2.1. Selection of national innovative capacity indicators

A country's common innovation infrastructure includes a range of different factors fostering innovation in the economy as a whole. There is substantial agreement that the national innovation performance greatly depends on the expenditures which are directly related to innovative processes. Therefore, 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, is a part of the common innovation infrastructure. This dimension also consists of variables representing the scientific skills devoted to the development of new or significantly improved products and processes, i.e., the R&D personnel and new doctorate graduates. According to Bilbao-Osorio & Bilbao (2018), upgrading a country's science base is vital to prompt and accelerate the scientific excellence and to foster the development as well as the adoption of innovations. Hence, other variables include the quality of scientific research institutions, scientific publications among the top 10% most cited publications worldwide, and the number of international scientific publications (i.e., with at least one co-author based abroad).

In addition, countries, where people can build on previous knowledge, tend to produce a higher innovative output (Proksch *et al*., 2017). Even though the above listed scholars along with Doran *et al*. (2018), Furman *et al*. (2002), Hu & Mathews (2005; 2008), Krammer (2009) and Wu *et al*. (2017) used the patent stock as a proxy for the knowledge stock since this dissertation focuses on both technological and non-technological innovative outputs, it was still decided to form a composite construct. By using factor analysis, a construct was formed from the stock of granted patents, the stock of granted trademarks and the stock of granted designs from 2000 to 2018.

Other variables of the 'common innovation infrastructure' dimension are the employees possessing tertiary education *(note: Faber & Hesen (2004) and Carvalho et al. (2015) used a slightly different variable of the average years of education of employees*) and the participation of the country residents in life-long learning. The latter indicator reflects the constant improvement of knowledge, skills, and competence (European Commission, 2019a), hence, increase of the potential to innovate while the former aspect generally indicates the quality of the human capital in a country. Finally, having in mind that the current time requires ICT-friendly environment, the variable of ICT access is included in this dimension (*note: Ege, A. and Ege, A.Y., 2019, Filippetti et al., 2017 and Lee et al., 2016 used a slightly different variable of 'internet users'*). The variables, their codes and sources are represented in Table 7, while the full definitions of the variables can be found in Table 16.

Table 7. Elements of the dimension 'Common Innovation Infrastructure'

Variables	Code	Source
National R&D investment	rd	Azagra-Caro & Consoli (2016); Baesu *et al*. (2015); Castellacci & Natera (2013); Ege, A. and Ege, A.Y. (2019); Faber & Hesen (2004); Filippetti and Guy (2020); Filippetti *et al*. (2017); Furman *et al*. (2002); Hu & Mathews (2005; 2008); Huang *et al*. (2010); Khan & Cox (2017); Krammer (2009); Malik (2020); Proksch *et al*. (2017); Zang *et al*. (2019).
Public sector R&D investment	public_rd	Andrijauskiene & Dumciuviene (2019b); Baesu *et al*. (2015); Carvalho *et al*. (2015); Castellacci & Natera (2013); Faber & Hesen (2004); Franco & Leoncini (2013); Hu & Mathews (2005; 2008); Krammer (2009); Rodríguez Pose and Wilkie (2019); Santana *et al*. (2016).
Government expenditures on education	edu_exp	Andrijauskiene & Dumciuviene (2019a); Baesu *et al*. (2015); Faber & Hesen (2004); Filippetti and Guy (2020); Furman *et al*. (2002); Hu & Mathews (2005; 2008); Huang *et al*. (2010); Krammer (2009); Proksch *et al*. (2017); Wu *et al*. (2017).
R&D personnel and researchers	rd_fte rd_fte_gov rd_fte_bus	Baesu *et al*. (2015); Doran *et al*. (2018); Faber & Hesen (2004); Furman *et al*. (2002); Hu & Mathews (2005; 2008); Huang *et al*. (2010); Lee *et al*. (2016); Proksch *et al*. (2017).
New doctorate graduates	doc_grad	European Commission (2019a).
Knowledge stock	knowledge_ stock	Doran *et al*. (2018); Furman *et al*. (2002); Hu & Mathews (2005; 2008); Krammer (2009); Proksch *et al*. (2017); Wu *et al*. (2017).
Quality of scientific research institutions	quality_ scientific	Halkos & Skouloudis (2018).
Scientific publications	int_co_pub pub_top10	Filippetti *et al*. (2017); Franco & Leoncini (2013); Furman *et al*. (2002); Hu & Mathews (2005); Hudec (2015); Proksch *et al*. (2017); Wu *et al*. (2017).
Employees having a tertiary education	employees_ edu	Faber & Hesen (2004); Carvalho *et al*. (2015)

Life-long learning	long_learning	European Commission (2019a).
ICT access	ict	Ege, A. and Ege, A.Y. (2019); Filippetti *et al.* (2017); Lee *et al*. (2016).

The following NIC dimension is 'Cluster specific environment for innovation'. It defines sectorial circumstances and investments which lead to innovation. A number of scholars (see Table 8) claim that private R&D investment acts as the engine of innovation performance because the exploitation of the scientific and technological opportunities leads to launching own created products and processes which improve the profitability and competitiveness. On the other hand, according to the European Commission (2019a), many firms, especially in the services sector, innovate via non-technological forms of innovation, hence, non-R&D inputs are of growing importance (Lhuillery *et al*., 2017).

In order 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. To cover and distinguish among potentially more innovative sectors, two additional variables were selected to supplement the model. The first one of them is the share of the high-tech sector, while the other element is the share of the knowledge-intensive 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 (2019a), these areas have a higher likelihood to be more innovative since people, government, educational institutions and enterprises are located closer to each other; therefore, it simplifies the process of knowledge diffusion.

Table 8. Elements of the dimension 'Cluster-specific environment for innovation'

Variables	Code	Source
Private sector R&D investment	private_rd	Andrijauskiene & Dumciuviene (2019a;b); Doran *et al*. (2018); Halkos & Skouloudis (2018); Hudec (2015); Faber & Hesen (2004); Franco & Leoncini (2013); Furman *et al*. (2002); Hu & Mathews (2005; 2008); Huang *et al*. (2010); Krammer (2009); Proksch *et al*. (2017); Rodríguez Pose and Wilkie (2019).
Business sector non-R&D innovation investment	non_rd	European Commission (2019a).
Share of the high-tech sector	sector_hitech	Andrijauskiene & Dumciuviene (2019b); European Commission (2019a).
Share of the knowledge-intensive services sector	sector_kis	European Commission (2019a); Hudec (2015).
Share of the industry and services sectors	sector_industry sector_services	Filippetti and Guy (2020); Filippetti *et al*. (2017); Rodríguez Pose and

		Wilkie (2019).
Urban population	pop_urban	Wu *et al*. (2017); Zang *et al*. (2019).

According to Furman *et al*. (2002), a country seeking to improve its national innovation performance must strengthen the domestic linkages between institutions. To begin with, as higher education institutions constitute a crucial part of networking in the Triple Helix (politics, business and science), university R&D investment is defined as another determinant of innovation performance according to the NIC approach. As it was already indicated in Section 1.2.2., the venture capital helps in sharing the R&D costs and risks thus stimulating innovation. It should be pointed out that both of the previously mentioned variables were used in the original NIC framework, i.e., university R&D investment and the strength of venture capital markets (*note: this dissertation uses a slightly different variable, i.e., the venture capital as a percentage of GDP).* In order to represent the public-private collaboration, a variable of public-private co-authored research publications was used. The cooperation between companies is proxied with a variable of a percentage of innovative SMEs collaborating with others out of all SMEs. Lastly, new business density was selected as a reflection of the (dis)encouraging environment for entrepreneurs. According to Proksch *et al*. (2017), new ventures increase the opportunity of the commercialisation of innovations.

Table 9. Elements of the dimension 'Quality of linkages'

Variables	Code	Source
Higher education institutions' R&D investments	higher_ed_rd	Azagra-Caro & Consoli (2016); Faber & Hesen (2004); Furman *et al*. (2002); Hu & Mathews (2005; 2008); Huang *et al*. (2010); Krammer (2009); Proksch *et al*. (2017); Rodríguez Pose and Wilkie (2019).
Venture capital	venture_cap	Carvalho *et al*. (2015); Faber & Hesen (2004); Furman *et al*. (2002); Hu & Mathews (2005); Proksch *et al*. (2017); Wu *et al*. (2017).
Public-private sector collaboration	public_private_ collab	Halkos & Skouloudis (2018).
Innovative SMEs' collaboration	inno_smes_collab	Carvalho *et al*. (2015); Faber & Hesen (2004).
New business density	new_business	Proksch *et al*. (2017).

As it was indicated in Section 1.2.2., trade openness motivates exporters to advance their resources and create innovation 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, beside exports, other international economic activities, such as imports and inward FDI, stimulate direct learning from the experience of a foreign country thus facilitating knowledge and technology diffusion. Therefore, this dimension was supplemented with two additional variables, i.e., imports of goods and services, and inward FDI.

Table 10. Elements of the dimension 'International economic activities'

Variables	Code	Source
Exports of goods and services	exports	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).
Imports of goods and services	imports	Andrijauskiene & Dumciuviene (2019a;b); Filippetti *et al*. (2017); Krammer (2009); Schneider (2005); Zang *et al*. (2019).
Inward foreign direct investment	fdi	Andrijauskiene & Dumciuviene, D. (2019a); Filippetti *et al*. (2017); Halkos & Skouloudis (2018); Hudec (2015); Krammer (2009); Law *et al*. (2018); Malik (2020); Schneider (2005); Wu *et al*., 2017.

The importance of cultural diversity is discussed in the works of DiRienzo & Das (2015), Halkos & Skouloudis (2018), Puia & Ofori-Dankwa (2013), and Zang *et al*. (2019). On the other hand, indicators used this index as a proxy for varied cultural diversity. For instance, Zang *et al*. (2019) used GINI, while DiRienzo & Das (2015) employed three indexes: Ethnic, Linguistic and Religious Fractionalisation Indexes. Puia & Ofori-Dankwa (2013), meanwhile, used the Greenberg diversity index which reflects the amount of active languages in a country (*note: this dissertation uses a direct measure of the foreign country population as a percentage of the total population to reflect the cultural diversity of a nation*).

What is more, poverty is also discussed in the paper by DiRienzo & Das (2015). These scholars used the GINI index as a variable for income inequality (*note: this dissertation uses the measure of people at risk of poverty or social exclusion as a percentage of population*). Finally, in line with the results of Andrijauskiene & Dumciuviene (2017), as well as Ege, A. and Ege, A.Y. (2019) and Wu *et al*. (2017), it was decided to include the element of gender equality, which is reflected by the share of females in the senior and middle management; see Table 11.

Table 11. Elements of the dimension 'Diversity and equality'

Variables	Code	Source
Cultural diversity	multiculture	DiRienzo & Das (2015); Halkos & Skouloudis (2018); Puia & Ofori-Dankwa (2013); Zang *et al*. (2019).
Poverty level	poverty	DiRienzo & Das (2015).
Gender equality	gender_equality	Ege, A. and Ege, A.Y. (2019); Wu *et al.* (2017).

Table 12 illustrates the selected elements for the NIC dimension 'Legal and political strength'. The corruption perception index was employed in the analysis in order 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 totally corruption-free country, a reversed ranking (the Excel RANK.AVG function) was chosen as the option for regression models, which currently means that the higher is the rank, the more corrupt the country is. The importance of the strength of the legal and political environment is discussed by Ege, A. and Ege, A.Y. (2019); Halkos & Skouloudis (2018); Wu *et al*. (2017); Zang *et al*. (2019). This variable, when used as a proxy, is a combined variable which includes judicial independence, the rule of law, and political stability in a country.

Furthermore, the European Commission (2015) states that, beside corruption, bureaucracy and complex rules may turn into a significant barrier halting new ideas and innovation. One of the sub-indices which Law *et al*. (2018) employed was the bureaucratic quality. To simplify this measure, this dissertation employs World Bank's data on the number of days required to start a business in order to reflect the bureaucracy level in a country. Finally, since innovators have to be ensured that their intellectual property is well protected, the last element of the dimension 'Legal and political strength' is the strength of the protection of intellectual rights. This variable was used by a number of authors, including Furman *et al*. (2002); Faber & Hesen (2004); Proksch *et al*. (2017); Wu *et al*. (2017) and others, as listed in Table 12.

Table 12. Elements of the dimension 'Legal and political strength'

Variables	Code	Source
Corruption level	corruption	Castellacci & Natera (2013); DiRienzo & Das (2015); Malik (2020).
Legal and political environment	legal_political	Ege, A. and Ege, A.Y. (2019); Halkos & Skouloudis (2018); Wu *et al*. (2017); Zang *et al*. (2019).
Business registration procedures	bureucracy	Law *et al*. (2018).
Protection of intellectual property rights	ipr	Faber & Hesen (2004); Furman *et al*. (2002); Hu & Mathews (2005; 2008); Krammer (2009); Proksch *et al*. (2017); Schneider (2005); Wu *et al*. (2017).

In order to minimise the omitted variable bias, several socio-economic variables were selected. As presented in Table 13, it includes GDP per capita to create the image of a nation's relative prosperity and socioeconomic development. Also, the number of inhabitants (population) and labour force represents the critical mass of potential innovators; also, it may affect the participation in EU FPs due to 'internal' networks in a member state (European Parliament, 2018). Since the living conditions and health may influence the inhabitants' capabilities to innovate, based on the results of Andrijauskiene & Dumciuviene (2017), it was decided to include these variables as well.

Table 13. Elements of the dimension 'General socio-economic conditions'

Variables	Code	Source
GDP per capita	gdp_capita	Azagra-Caro & Consoli (2016); Carvalho *et al*. (2015); Castellacci & Natera (2013); Faber & Hesen (2004); Franco & Leoncini (2013); Furman *et al*. (2002); Halkos & Skouloudis (2018); Hu & Mathews (2005; 2008); Huang *et al*. (2010); Law *et al*. (2018); Lee *et al*. (2016); Malik (2020); Proksch *et al*. (2017).
Population	pop	Furman *et al*. (2002); Hu & Mathews (2005; 2008); Krammer (2009); Proksch *et al*. (2017); Wu *et al*. (2017).
Labour force	labour_force	Furman *et al*. (2002); Hu & Mathews (2005); Proksch *et al*. (2017).
Healthy life years	healthy_life	Based on the findings of Andrijauskiene & Dumciuviene (2017).
The duration of working life	working_life	Based on the findings of Andrijauskiene & Dumciuviene (2017).

In order to conclude this sub-section, it must be emphasised that, by employing the insights of other scholars who performed empirical research on the topic of the national innovative capacity, the original framework by Furman *et al*. (2002) was redeveloped in order to reflect 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 three additional dimensions, i.e., 'international economic activities', 'diversity and equality', and 'legal and political strength'. It is also important to note that the indicators were selected in a manner so that they would bring quantitative results and a possibility to make trustworthy cross-country and over-time comparisons.

The following Section 2.2. is devoted to the selection of national innovation performance indicators which could be characterised not only as the outputs of NIC but also expand the current exceptional focus on the technological side of innovation.

2.2. Selection of national innovation performance indicators

According to Martin (2016, p. 434), a certain type of innovations exists which "have been ignored or are essentially invisible in terms of conventional indicators." This type is identified as 'dark innovation' or 'hidden innovation' and may include such examples as innovations based on design, branding or software. Moreover, one of the latest extensive literature analyses conducted by Dziallas & Blind (2019) raises another scientific concern related to the commonly used innovation variables: 74% of the analysed research papers within the timeframe of 1980–2015 applied technological innovation indicators of the manufacturing industry. Although a recent shift from the manufacturing to the service industry was captured, this number still remains relatively low (Dziallas & Blind, 2019). The overview of the variables which are commonly used as a proxy for national innovation performance showed the same tendencies (see Section 1.2.3.). Therefore, since no single measurement is adequate to capture various forms of innovation and its features (Meissner *et al*., 2017), and since it is important to consider whether a country specialises in services or manufacturing (Janger *et al*., 2017), there were three groups of innovative outputs selected, see Table 14. The breakdown by type was based on the Oslo Manual 2018 (OECD, 2018) and the EIS Methodology Report (European Commission, 2019a).

The first group of outputs which were included in the methodology for the evaluation of EU investment influence on the member states' NIP is the technological innovative outputs. This group contains total patent applications, as well as patent applications in different triple Helix segments, i.e., business, government and higher education (the justification and sources for selection can be found in Section 1.2.3. while the full definitions of the variables are presented in Table 17). Furthermore, the share of SMEs introducing product or process innovations is chosen as an additional variable to reflect the technological innovation. The rationale of taking SMEs is due to them being the dominant type, on average accounting for 99% of the enterprise sector (Čučković & Vučković, 2018).

The second group of national innovation performance indicators is the non-technological innovative outputs: trademark applications, design applications, and the share of SMEs introducing marketing or organisational 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, 2018a; Flikkema *et al*., 2014), and, secondly, it is a highly undervalued type of IP in the empirical research of innovation (Dziallas & Blind, 2019; van den Besselaar *et al*., 2018). As emphasised in the studies of Lhuillery *et al*. (2017) and Apostolos *et al*. (2017), there is also a lower amount of interest in using design as an indicator of innovation. This might be explained by the fact that, in general, most economies observe more patent and trademark applications than design applications (World Intellectual Property Organisation (WIPO), 2014)). Nevertheless, according to a WIPO report from 2019 (WIPO, 2019), 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. These reasons lead to a concern that more scientific focus should be paid to the option to use designs as innovation performance indicators. According to the European Commission (2019a), a lot of firms, especially in the services sectors, innovate through other non-technological forms of innovation, for instance, through marketing or organisational innovations. Therefore, the third variable of the group of non-technological innovative outputs is the share of SMEs introducing marketing or organisational innovations; see Table 14.

Table 14. Variables used as a proxy for national innovation performance

Type	Innovative output	Code	Definition
Technological innovative outputs	Patent applications	patent	Total patent applications to the European Patent Office (EPO) by priority year, per million inhabitants.
	Business patent applications	patent_bus	Patent applications to the EPO by priority year by business sector, per million inhabitants.
	Government patent applications	patent_gov	Patent applications to the EPO by priority year by the government sector, per million inhabitants.
	Higher education institutions' patent applications	patent_higher_ed	Patent applications to the EPO by priority year by the higher education sector, per million inhabitants.
	SMEs introducing product or process innovations	smes_pp	SMEs introducing product or process innovations, % of all enterprises.
Non-technological innovative outputs	Trademark applications	trademark	European Union trade mark (EUTM) applications, per million inhabitants.
	Design applications	design	Community design (CD) applications, per million inhabitants.
	SMEs introducing marketing or organisational innovations	smes_mo	SMEs introducing marketing or organisational innovations, % of all enterprises.
Commercialisation of innovation	Innovation sales	inno_sales	Sales of new-to-market and new-to-firm innovations, % of turnover.
	Exports of high technology products	exports_hitech	Exports of high technology products, % of total product exports.
	Knowledge-intensive services exports	exports_kis	Knowledge-intensive services exports, as % of total services exports.

The last group of outputs reflects the commercial part of innovation. The motif to include this part of indicators into the methodology for the evaluation of EU investment influence on the member states' national innovation performance is indicated in Section 1.1.2. A number of scholars, e.g., Napiorkowski (2018), Piirainen *et al*. (2018), Radicic & Pugh (2017), Rosemberg *et al*. (2016), and Weresa (2018) noted that European Union Framework programmes 'suffer' from the European paradox of the successful promotion of R&D inputs in the context of the inability to transform these results into commercial benefits. 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 due to seeking to find out the possible reasons why EU investment does not always help in boosting innovation sales.

It should be noted that there is a time gap between the application process and the issue of IPR. Therefore, the use of the data of applications instead of granted IPRs provides a more timely account of innovative activity (Schneider, 2005), and it is entirely suitable for cross-country comparative econometric analysis (Rodríguez Pose and Wilkie, 2019). The same logic is applied to patent, design, and trademark variables. Furthermore, in order to account for the varying size of the member states, IPR applications per capita are calculated.

To sum up this sub-section, it can be noted that three groups of national innovation performance indicators are selected to include into the model which would help with the evaluation of the influence of EU investment. The first group of outputs is the technological innovative outputs – these are patent applications from different sectors and product and process innovations introduced by SMEs. Having in mind the gap both in the scientific and practical literature, the second group of national innovation performance indicators is the non-technological innovative outputs, i.e., trademark applications, design applications, and marketing and organisational innovations introduced by SMEs. Finally, since a substantial amount of debate is related to the ability of the EU to commercialise the innovative processes and products, the final group of outputs reflects the commercial part of innovation. The next Section (2.3.) focuses on the presentation of a conceptual model which has been designed to evaluate the influence of EU investment on its member states' national innovation performance, the introduction of the hypotheses, and the description of the logics of the selected statistical methods in order to test them (i.e., the empirical research scheme).

2.3. Conceptual model and empirical research scheme

The overview presented in Section 1.1.3. revealed that there is shortage of research which would consider the context of the member states' innovative capacity when evaluating the influence of EU investment on research and innovation. Moreover, national evaluations are fragmented; hence, this issue complicates the judgement and comparison of evidence across the countries. In addition to this, the indicators of the Framework programmes vary from report to report, thus a comparison in a timely manner is also difficult. Finally, according to the European Parliament (2018), there are no accessible data making it possible to investigate the effects of FPs either at the level of the separate blocks (for instance EU-13 or EU-15) or at the individual member state level.

Having these issues in mind, a conceptual model has presently been proposed to cover the specificities of the member states' NIC (see Table 7 through Table 13) and the potential variations between the influence of the EU Framework Programmes (see Table 15).

Table 15. Variable used as a proxy for EU investment

Code	Definition	Source
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 (2020e)

A conceptual model for the evaluation of the influence of EU investment on the member states' innovation performance is illustrated in the figure below (see Figure 4). The input indicators include the elements from the dimensions of a redeveloped NIC framework (i.e., common innovation infrastructure; cluster-specific environment for innovation, quality of the linkages; international economic activities; diversity and equality, and legal and political strength) and the variable of EU investment (as defined in Table 15 above).

The output indicators representing the national innovation performance contain three groups of innovative outputs:

1. Technological innovative output (i.e., various forms of patent applications and SMEs introducing product and process innovations);
2. Non-technological innovative output (i.e., trademark and design applications along with SMEs introducing marketing or organisational innovations);
3. Commercialisation of innovation (i.e., innovation sales and exports of high-tech products and knowledge-intensive services).

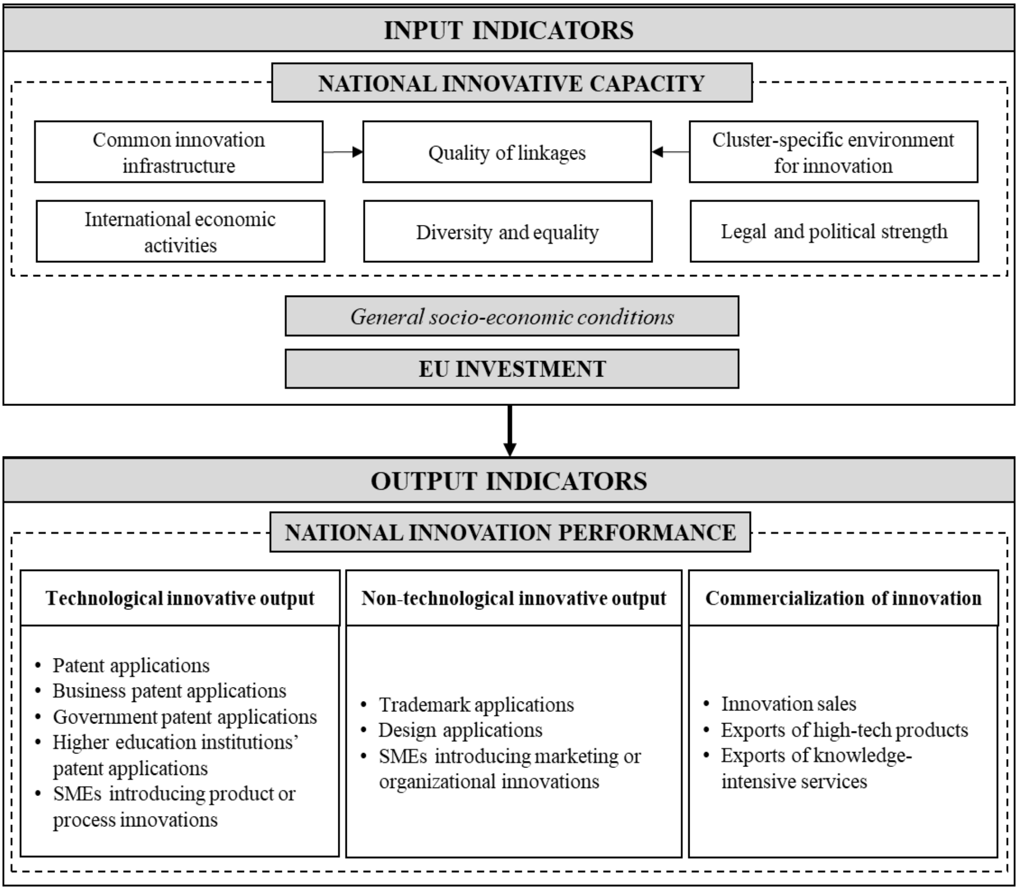

Figure 4. Conceptual model for the evaluation of the influence of EU investment on the innovation performance of member states.

Having in mind the results of the scientific literature analysis presented in the first part of this dissertation, a conceptual model for the evaluation of the influence of EU investment on the innovation performance of the member states shall be used in order to check the following hypotheses:

- **H1:** There is Granger causal relationship between the national innovative capacity and the national innovation performance.
- **H2:** EU investment has positive long-term influence on the member states' national innovation performance expressed by the technological innovative output.
- **H3**: EU investment exerts positive long-term influence on the member states' national innovation performance expressed by the non-technological innovative output.
- **H4:** EU investment does not have long-term influence on the member states' national innovation performance expressed by commercialisation of innovation.

- **H5**: The influence of EU investment on the member states' innovation performance depends on the programming period.
- **H6:** The magnitude of the influence of EU investment is different across the member states.

As it was mentioned in Section 1.1.3., most of the official assessments of EU FPs are limited to the analysis of direct benefits to the beneficiaries by using such qualitative methods as a survey, focus groups, or interviews. Therefore, there is a rationale for using the econometric techniques which would help in identifying a range of factors which may alter the overall influence of EU investment.

It must be pointed out that the insights from the above presented works of scholars who performed research on the benefit of NIC involves not only the theoretical basis for the analysis of conditions determining the national level ability to create innovations, but also provides the empirical 'know-how'. As it was indicated in Section 1.2.4., various types of regression analysis (simple regression, OLS, the inclusion of fixed or random effects, etc.) are the most frequently used methods which have been proven to be well-applicable for the analysis of this context.

Since the empirical part of the dissertation considers all the EU member states via the time frame of nineteen years from 2000 to 2018, observations about different cross-sections across the time period and the member countries are made via panel data analysis.

Figure 5 below represents an empirical research scheme for the evaluation of the influence EU of the investment on the innovation performance of the member states. The left side of the scheme reflects the empirical steps which are used to achieve the sought results.

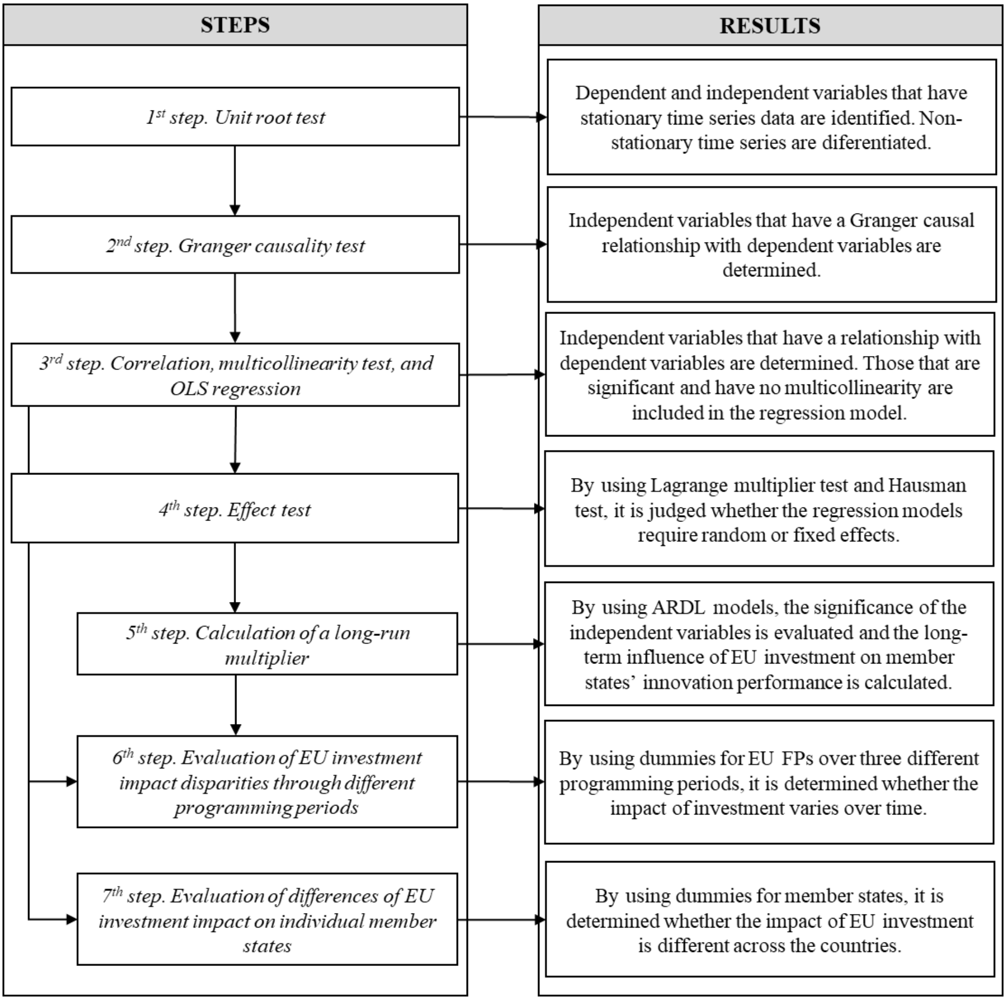

Figure 5. Empirical research scheme for the evaluation of the influence of EU investment on the innovation performance of member states.

1st step. To begin with, in order to include the variables into the regression model for a long-run analysis, the variables must be stationary. Otherwise, the test results in spurious regression and misleading results. 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:

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

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

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

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

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). This logic is applied in the empirical analysis (see Section 3). If time series have unit roots, a series of successive differences, d, can transform the time series into one with stationarity.

2nd step. Furthermore, 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 one of the hypotheses of this dissertation seeks to check whether a country's innovative capacity causes its national innovation performance, the following regression 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):

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

3rd step. As long as it has been determined which of the independent variables might possibly cause the dependent variables, correlation analysis was applied to select the variables for the regression models. Pearson's correlation coefficient (r) formula was employed for this purpose:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \qquad (4)$$

The formula returns a value between -1 and 1, where:

- r close to 1 indicates a strong positive linear relationship.
- r close to -1 indicates a strong negative linear relationship.
- r close to zero indicates no linear relationship.

The relationship between the two variables is considered strong when their r value is bigger than 0.7. Therefore, in order to avoid multicollinearity, all independent variables having a correlation coefficient higher than 0.7 were carefully examined, and the ones with a weaker r towards the dependent variable were omitted from the following stages of the analysis.

In order to demonstrate how independent variables cause the dependent variable, regression analysis was applied. As its first step, Ordinary Least Squares regression (OLS) is performed (here and further, cf. Min, 2019):

$$Y = \beta_0 + \sum_{j=1}^{p} \beta j Xj + \varepsilon \qquad (5)$$

where p is the number of explanatory variables, Y is the dependent variable, β_0 is the intercept of the model, βj are parameters, Xj corresponds to the j_{th} explanatory variable of the model (j= 1 to p), and ε is the random error with expectation 0 and variance σ^2. Independent variables having significant correlation with dependent variables are included into the model.

***4^th^ and* 5^th^ steps.** OLS regression is suitable if there are not significant differences among individuals (countries in this research). Since the panel data is analysed, cross-sectional and time effects should be tested as well. As the focus lies on capturing the unmeasured individual effects so that to correct for the omitted variables problem, a Lagrange multiplier is applied to check whether the model should include any of these effects. The most widely known random effects test is the Breusch-Pagan LM test. The LM test for the random effects view implements Lagrange multiplier tests of individual or/and time effects based on the results of the pooling model:

$$LM = \left(\frac{\partial l}{\partial \theta}\right)' \left(-E\left[\frac{\partial^2 l}{\partial \theta\, \partial \theta}\right]\right)^{-1} \left(\frac{\partial l}{\partial \theta}\right) \qquad (6)$$

where $l(x, \theta)$ is the objective function. This test is analogical for the following three-step procedure:

1) The least squares method is used to construct a regression model and calculate residuals;
2) Auxiliary regression is calculated:

$$e_i^2 = \gamma_1 + \gamma_2 z_{2i} + \cdots + \gamma_p z_{pi} + \eta_i \qquad (7)$$

3) The result of the test statistics is calculated from the coefficient of determination of the auxiliary regression equation calculated in the second step and the sample size n:

$$LM = nR^2 \text{ (with k degrees of freedom)} \qquad (8)$$

where n is the sample size, R^2 is the coefficient of determination of the regression of squared residuals from the original regression, and k is the number of independent variables. The test statistics approximately follow the chi-square distribution:

- the null hypothesis is that the error variances are all equal.
- the alternative hypothesis is that the error variances are not equal (as Y increases, the variances increase/decrease).

A small chi-square value along with the associated high p-value indicates that the null hypothesis is true (i.e., that the variances are all equal).

If the LM test is not significant, it implies no significant difference across units (i.e., no panel effect), thus simple OLS regression can be run. If the LM test is significant, the random effects model instead of the OLS model is used.

In order to evaluate the significance of the NIC elements and to test the long-term influence of EU investment on the innovation performance of the member states, an autoregressive distributed lag model (ARDL – regression models including lagged values of variables) was developed:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \cdots + \beta_p Y_{t-p} + \alpha_0 X_t + a_1 X_{t-1} + \cdots + a_q X_{t-q} + \varepsilon_t \quad (9)$$

where p represents lags of Y, and q represents lags of X. The optimal lag lengths p and q are chosen based on the minimum value of the Akaike information criterion (AIC). For an ARDL (p, q) model, the long-run multiplier is given by:

$$\frac{\sum_{i=0}^{p} \beta_1}{1 - \sum_{j=1}^{q} a_j} \quad (10)$$

It measures how much y will eventually change in response to a permanent change in x.

6th and 7th steps. The next step in the panel data analysis is the Hausman specification test which helps in choosing between the random effects model and the fixed effects model. Under the null hypothesis of no correlation between the random effects and the explanatory variables, the GLS estimator is consistent and efficient while the OLS estimator including dummy variables is consistent, but less efficient than the GLS estimator (the option of the random effects model). However, under the alternative hypothesis of correlation, the GLS estimator is inconsistent, but the dummy variable of the OLS estimator is still consistent (the option of the fixed effects model).

A fixed-effects model is used when the individual effects are fixed over time and are captured by shifts in the intercept term of the model. The regression model is expanded to account for the effects as follows:

$$Y_{it} = \beta_1 X_{1,it} + \cdots + \beta_k X_{k,it} + a_1 + b_t + \varepsilon_{it} \quad (11)$$

where a_i represents the unit-specific effects, and b_t denotes the time-specific effects, both being fixed parameters. If a_i and b_t are not correlated with the independent variables X, the OLS estimation can still produce consistent estimates even though a_i and b_t are ignored.

The random-effects model, on the other hand, is used when the individual effects are randomly distributed over cross-sectional units. Hence, unit-specific effects (v_i) and time-specific effects (e_t) are treated as random variables:

$$Y_{it} = \beta_0 + \beta_1 X_{1,it} + \cdots + \beta_k X_{k,it} + v_1 + e_t + \varepsilon_{it} \quad (12)$$

where $E(v_i)=0$, $Var(v_i)=\sigma_v^2$, $E(e_t)=0$ and $Var(e_t)= \sigma_e^2$, and the key assumption is that random effects v_i and e_t are uncorrelated with the explanatory variables.

There is great evidence that cross-sectional dependence frequently exists in panel regression settings. Pesaran (2004) CD test is used to check for cross-section dependence (since T is relatively small).

To sum up, the research path consists of 7 steps: (1) unit root tests to check the stationarity of time series; (2) Granger causality tests with five lag values for the evaluation of Granger causality between the variables; (3) correlation, multicollinearity test, and OLS regression; (4) Effect tests; (5) calculation of a long-run multiplier; (6) evaluation of EU investment influence disparities through different programming periods; and (7) evaluation of EU investment influence disparities across the member states. Since the national innovative capacity and the national innovation performance indicators are selected and justified and the methodology for the assessment of the influence of EU investment on the innovation performance of the member states is represented, the following section shall be devoted to the implementation of the model and testing the hypotheses.

3. ASSESSMENT OF EU INVESTMENT INFLUENCE ON THE INNOVATION PERFORMANCE OF MEMBER STATES

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*.

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*). Those sources which meet all the statistical requirements were used to construct evidence for the variables:

- The statistical office of the European Union (Eurostat, 2020);
- European Innovation Scoreboard databases from 2002 to 2019 (European Commission, 2019a);
- European Commission data from previous long-term budgets (European Commission, 2020e);
- International property rights index (Property Rights Alliance, 2019);
- Patent statistics from the European Patent Office (2020);
- World Bank Data bank, World development indicators (World Bank, 2019);
- Web of Science database Clarivate Analytics (Web of Science, 2019);
- World Intellectual Property Organisation (WIPO, 2020).

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 can be found in Table 16, while the full list of dependent variables, their definitions and sources can be found in Table 17. The descriptive statistics are presented in Annex 1 and Annex 2.

Table 16. 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
public_rd	Intramural R&D investment in the public sector (% of GDP).	Eurostat
edu_exp	Total public investment on education as % of GDP, for all levels of education combined.	Eurostat
rd_fte	Total R&D personnel and researchers by all sectors of performance, as % of total employment – numerator in full-time equivalent (FTE).	Eurostat
rd_fte_gov	R&D personnel and researchers in the government sector, as % of total employment – numerator in full-time equivalent (FTE).	Eurostat
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
doc_grad	New doctorate graduates per 1,000 population, aged 25–34.	Eurostat
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
quality_scientific	Quality of scientific research institutions, 1–7 (best).	World Bank
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
pub_top10	Scientific publications among the top 10% most cited publications worldwide (percentage of the total scientific publications of the country).	Web of Science
employees_edu	Employees with tertiary education, aged 15–74, % of total employees.	Eurostat
long_learning	Participation rate of adults aged 25–64 in education and training, also referred to as life-long learning.	Eurostat
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
private_rd	Intramural R&D investment in the business sector (% of GDP).	Eurostat
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
sector_hitech	Employment in high-technology sectors, as % of the total employment.	Eurostat
sector_kis	Employment in knowledge-intensive services, as % of the total employment.	Eurostat
sector_industry	Employment in the industry sector, as % of the total employment.	Eurostat
sector_services	Employment in the services sector, as % of the total employment.	Eurostat
pop_urban	Urban population (% of total population).	World Bank

higher_ed_rd	Intramural R&D investment in the higher education sector (% of GDP).	Eurostat
venture_cap	Venture capital (% of GDP).	Eurostat
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
inno_smes_collab	Innovative SMEs collaborating with others (% of SMEs).	EIS
new_business	New business density (new registrations per 1,000 people aged 15–64).	World Bank
exports	Total exports of goods and services, percentage of the gross domestic product (GDP).	Eurostat
imports	Imports of goods and services (% of GDP).	World Bank
fdi	Inward foreign direct investment (% of GDP).	World Bank
multiculture	Cultural diversity – foreign country or stateless population, % of the total population.	Eurostat
poverty	People at risk of poverty or social exclusion, % of the population.	Eurostat
gender_equality	Female share of employment in the senior and middle management (%).	World Bank
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
legal_political	Strength of the legal and political environment – judicial independence, rule of law, political stability. 1–7 (best).	World Bank
bureucracy	Time required to start a business (days).	World Bank
ipr	Protection of intellectual property rights, patent protection, copyright protection.	International Property Rights Index
gdp_capita	Gross domestic product, euro per capita.	Eurostat
pop	Population, millions of inhabitants as of January 1 of a specific year.	Eurostat
labour_force	Labor force – employment and activity, millions of persons aged from 15 to 64.	Eurostat
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
working life	The duration of working life.	Eurostat
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 (2020e)

Table 17. 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; European Patent Office
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
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
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
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
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
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 (CIS data)
inno_sales	Sales of new-to-market and new-to-firm innovations, as % of turnover.	Eurostat (CIS data)
exports_hitech	High-tech exports – exports of high technology products as % of the total product exports.	Eurostat
exports_kis	Knowledge-intensive services exports as % of the total services exports.	Eurostat

Before discussing the results of the assessment of the influence of EU investment on the innovation performance of the member states, it is crucial to describe the main research limitations which may potentially be resolved with future research: the challenge of a time-frame linked with the shortage of certain data availability, and any potential bias related with the selected evaluation methods. The issue of the time-frame dataset is mostly related with the dependent variables that (1) represent the sectoral distribution of patent applications: patent_business, patent_government, patent_higher_ed education (the time-frame for these variables includes years 2000–2012), and (2) the variables which were extracted from the Community Innovation Survey that is carried out every two years: smes_pp, smes_mo, and inno_sales (the considered time frame is 2004–2016, the missing values are replaced by using an interpolation method which counts the mean of values of the particular variable in between the years). It should also be considered that there is an obstacle related to the data availability of the longer-term indicators of Horizon2020 – as this EU FP is still ongoing, the evaluation is limited to the time frame of 2014–2018, which means that only a part of this R&I policy measure investment is taken into account. It is also important to emphasise that the direct interpretation and comparison of the results must be careful in those cases where the variables are expressed in different units (for instance, per million of inhabitants or as a percentage of the turnover or total exports). Finally, there are disparities between the magnitude of the influence of EU investment across the member states (as identified in Table 36 through Table 38). In the ideal situation, qualitative comparative case studies would bring more insights about the underlying factors between the NIC values of each particular country. Nevertheless, since it is beyond the scope of this dissertation, this beneficial contribution to the empirical research on the evaluation of the EU influence shall be left for future research.

As the research limitations have been overviewed, the results of the empirical section can now be presented.

1st step. Unit root tests.

An important part of panel data analysis includes unit root tests to check the stationarity of time series. As Table 18 demonstrates, 4 independent variables (employees_edu; multiculture; 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 18. Unit root test for the independent variables

Common innovation infrastructure	rd	I(0)	**Quality of linkages**	higher_ed_rd	I(0)
	public_rd	I(0)		venture_cap	I(0)
	edu_exp	I(0)		**d(public_private_collab)**	**I(1)**
	rd_fte	I(0)		inno_smes_collab	I(0)
	rd_fte_gov	I(0)		new_business	I(0)
	rd_fte_bus	I(0)	**International economic activities**	exports	I(0)
	doc_grad	I(0)		imports	I(0)
	knowledge_stock	I(0)		fdi	I(0)
	quality_scientific	I(0)	**Diversity and equality**	**d(multiculture)**	**I(1)**
	int_co_pub	I(0)		poverty	I(0)
	pub_top10	I(0)		gender_equality	I(0)
	d(employees_edu)	**I(1)**	**Legal and political strength**	corruption	I(0)
	long_learning	I(0)		legal_political	I(0)
	ict	I(0)		business_procedures	I(0)
Cluster-specific environment for innovation	**d(private_rd)**	**I(1)**		ipr	I(0)
	non_rd	I(0)	**General socio-economic conditions**	gdp_capita	I(0)
	sector_hitech	I(0)		pop	I(0)
	sector_kis	I(0)		labour_force	I(0)
	sector_industry	I(0)		healthy life	I(0)
	sector_services	I(0)		working_life	I(0)
	pop_urban	I(0)			
EU investment				eu_fp	I(0)

I(1) – integrated of order one, explained in Section 2.3.

As Table 19 demonstrates, 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 19. Unit root test for the dependent variables

Technological innovative outputs	
patent	I(0)
patent_bus	I(0)
patent_gov	I(0)
patent_higher_ed	I(0)
smes_pp	I(0)
Non-technological innovative outputs	
trademark	I(0)
design	I(0)
smes_mo	I(0)
Commercialisation of innovation	
inno_sales	I(0)
exports_hitech	I(0)
d(exports_kis)	**I(1)**

I(1) – integrated of order one, explained in Section 2.3.

2nd step. Granger causality tests

Evaluations of investment programmes should consider not only the magnitude of effects but also the Granger causality of other factors which may have influenced the outcomes. As the role of the national innovative capacity is discussed in Section 1.2., the hypothesis which is empirically tested at this stage is **H1**: There is Granger causal relationship between the national innovative capacity and the national innovation performance. Granger causality analysis was used to check whether the independent variables x cause the dependent variable y, to examine how much of the current dependent variable y can be explained by the past values of the dependent variable y and then to see whether adding lagged values of independent variables x can improve the explanation. Five time lags were taken into account.

Table 20 through Table 26 present the summarised conclusions, while the full results can be found in Annex 3 through Annex 13.

Table 20 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. All the types of investment, i.e., the total R&D investment in a country as well as R&D investment in the public sector and also the expenditures for education exhibit Granger causal relationship with at least one variable from each of the type of innovative output. The total amount of R&D personnel and researchers as well as the R&D personnel and researchers in the business enterprise sector seem to cause at least one variable from each of the types of innovative output. Furthermore, although slightly contrasting, but still a fairly logical result is that the doctoral graduates, together with the R&D personnel and researchers in the government sector, do not influence the processes of the commercialisation of innovation. 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, only causes patent applications by business representatives. While considering the role of scientific excellence, the variables of the quality of scientific research institutions, scientific publications among the top 10% most cited publications worldwide, and the number of international scientific publications showed Granger causal relationship with all three groups of NIP indicators. Life-long learning, as well as the usage of ICT demonstrated similar tendencies. At the same time, the variable which represents the share of employees with a higher education appeared to cause only the technological and non-technological innovative output but not the commercialisation of these aspects.

Table 20. Existence of Granger causal relationship: Common innovation infrastructure

Common innovation infrastructure (NIC)	**NIP**		
	Technological innovative output	**Non-technological innovative output**	**Commercialisation of innovation**
rd	patent; patent_bus; patent_higher_ed; smes_pp	smes_mo	d(exports_kis)
public_rd	patent_bus; patent_higher_ed; smes_pp	trademark; smes_mo	d(exports_kis)
edu_exp	patent_bus; patent_higher_ed	trademark; design	exports_hitech d(exports_kis)
rd_fte	patent_bus; patent_higher_ed; smes_pp	trademark; design; smes_mo	exports_hitech d(exports_kis)
rd_fte_gov	patent	trademark; design	-
rd_fte_bus	patent_bus; patent_higher_ed	smes_mo	d(exports_kis)
doc_grad	patent_bus; patent_gov; patent_higher_ed	smes_mo	-
knowledge_stock	patent_bus	-	-
quality_scientific	patent_gov; smes_pp	smes_mo	d(exports_kis); inno_sales
int_co_pub	patent; patent_bus; patent_gov; patent_higher_ed; smes_pp	design; smes_mo	d(exports_kis)
pub_top10	patent; patent_bus; smes_pp	trademark; design; smes_mo	exports_hitech; d(exports_kis); inno_sales
d(employees_edu)	patent; patent_bus; patent_higher_ed	trademark; design; smes_mo	-
long_learning	patent; patent_bus	design	exports_hitech
ict	patent_bus; patent_higher_ed	design; smes_mo	d(exports_kis)

The next NIC dimension to be discussed is 'Cluster-specific environment for innovation'. The results indicated in Table 21 suggest that R&D investment in the business sector causes both technological and non-technological innovative outputs, yet it has no influence on the commercialisation of innovation. Non-R&D investment, on the contrary, shows Granger causal relationship with the variable of SMEs introducing product or process innovations along with SMEs introducing marketing and organisational innovations. It also influences the sales of innovation and exports of high technology products.

It is worth noting that the employment in the knowledge-intensive sector features Granger causal relationship with all the three groups of NIP indicators. In contrast, the share of employment in the hi-tech sector does not induce non-technological innovative output. 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 trademarks and designs as well as the commercial exploitation of innovations. Still, they are not very effective in creating the technological innovative output; see Table 21.

Table 21. Existence of Granger causal relationship: Cluster-specific environment for innovation

Cluster-specific environment for innovation (NIC)	**NIP**		
	Technological innovative output	**Non-technological innovative output**	**Commercialisation of innovation**
d(private_rd)	patent; patent_bus; patent_gov; patent_higher_ed; smes_pp	trademark; design	-
non_rd	smes_pp	smes_mo	exports_hitech; inno_sales
sector_hitech	patent; patent_bus; patent_gov; patent_higher_ed	-	d(exports_kis)
sector_kis	patent_bus; patent_higher_ed; smes_pp	trademark; design; smes_mo	d(exports_kis)
sector_industry	patent_bus; smes_pp	trademark; design; smes_mo	exports_hitech
sector_services	patent_bus; smes_pp	trademark; design; smes_mo	exports_hitech; d(exports_kis)
pop_urban	patent; patent_gov; smes_pp	design; smes_mo	d(exports_kis)

As the next step of our research, Table 22 presents the Granger causal relationship between the NIC dimension 'Quality of linkages' and the NIP indicators. R&D investment in the higher education sector causes almost all the indicators from the technological innovative output group, except for government patent applications. It may also cause marketing and organisational innovations. In addition to this, by helping to share the R&D costs and risks, venture capital prompts businesses to apply for patents, introduce marketing and organisational innovations, and it also acts as an incentive for exports of high-technology products. These results also show that the collaboration between the public and private sectors causes both technological and non-technological innovative output, but it does not have a role in the commercialisation of innovation, differently from the case of collaboration between the innovative SMEs which also induce total patent applications in a country and the introduction of marketing and organisational innovations. Lastly, the countries which create favourable conditions for new businesses are more eminent in applying for trademarks, designs, and also in exporting hi-tech production.

Table 22. Existence of Granger causal relationship: Quality of linkages

Quality of linkages (NIC)	**(NIP)**		
	Technological innovative output	**Non-technological innovative output**	**Commercialisation of innovation**
higher_ed_rd	patent; patent_bus; patent_higher_ed; smes_pp	smes_mo	-
venture_cap	patent_bus	smes_mo	exports_hitech
d(public_private_collab)	patent; patent_bus; patent_gov; smes_pp	trademark; design	-
inno_smes_collab	patent	smes_mo	d(exports_kis)
new_business	-	trademark; design	exports_hitech

As the results outlined in Table 23 suggest, including the dimension of ‘International economic activities’ was worthwhile since the majority of its elements indicated below showed Granger causal relationship with the NIP indicators. Both exports and imports of goods and services showed the same tendencies of causing all the technological innovative output indicators, except for patent applications by the government sector. Also, all non-technological innovative output indicators, except for marketing and organisational innovations, and, finally, inducing exports of knowledge-intensive services and sales of new-to-market and new-to-firm innovations showed causality with this respect. Inward FDI does not play a role in affecting the amount of product and process innovations, but it causes marketing and organisational innovation, as well as commercialisation of innovation.

Table 23. Existence of Granger causal relationship: International economic activities

International economic activities (NIC)	(NIP)		
	Technological innovative output	**Non-technological innovative output**	**Commercialisation of innovation**
exports	patent; patent_bus; patent_higher_ed; smes_pp	trademark; design	d(exports_kis); inno_sales
imports	patent; patent_bus; patent_higher_ed; smes_pp	trademark; design	d(exports_kis); inno_sales
fdi	patent_bus; patent_gov	trademark; design; smes_mo	d(exports_kis); inno_sales

Continuing with the dimension 'Diversity and equality', the results presented in Table 24 demonstrate that the cultural diversity in a country has a Granger causal effect on trademark applications and hi-tech production exports. The poverty variable generally reflects the national income (in)equality which causes the introduction of new or significantly improved products and processes as well as exports of knowledge-intensive services and innovation sales. Finally, the variable which 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 of the NIP indicators.

Table 24. Existence of Granger causal relationship: Diversity and equality

Diversity and equality (NIC)	(NIP)		
	Technological innovative output	**Non-technological innovative output**	**Commercialisation of innovation**
d(multiculture)	-	trademark	exports_hitech
poverty	smes_pp	-	d(exports_kis); inno_sales
gender_equality	patent; patent_bus	trademark; design	inno_sales

Table 25 represents that corruption, the strength of legal and political environment, as well as the protection of intellectual property rights have Granger causal effects on all the three groups of NIP indicators. Bureaucracy, on the other hand, causes only the introduction of new or significantly improved products and processes in addition to sales of innovations.

Table 25. Existence of Granger causal relationship: Legal and political strength

Legal and political strength (NIC)	(NIP)		
	Technological innovative output	**Non-technological innovative output**	**Commercialisation of innovation**
corruption	patent; smes_pp	design; smes_mo	d(exports_kis)
legal_political	patent_bus; smes_pp	design; smes_mo	d(exports_kis)
bureaucracy	smes_pp	-	inno_sales
ipr	smes_pp	smes_mo	d(exports_kis); inno_sales

The last dimension of the redeveloped NIC model is 'General socio-economic conditions'. What concerns GDP per capita, labour force and the duration of working life, each of these elements can cause at least one element from each of the NIP indicators' groups. The results in Table 26 also indicate that the size of the country population has a Granger causal effect on business patent applications, trademark applications and the introduction of marketing and organisational innovations. In contrast, it does not affect the commercialisation of innovative outputs. Finally, although there exists a variable which reflects the living conditions in a country – i.e., healthy life (healthy life years in absolute value at birth) – it does not show Granger causal relationship with the technological innovative output, yet it may affect the non-technological innovative output and exports of the knowledge-intensive services.

Table 26. Existence of Granger causal relationship: General socio-economic conditions

General socio-economic conditions (NIC)	(NIP)		
	Technological innovative output	**Non-technological innovative output**	**Commercialisation of innovation**
gdp_capita	patent; patent_bus; patent_higher_ed; smes_pp	trademark; design; smes_mo	d(exports_kis)
pop	patent_bus	trademark; smes_mo	-
labour_force	patent_bus	trademark	d(exports_kis)
healthy_life	-	design; smes_mo	d(exports_kis)
working_life	patent_bus	design	d(exports_kis)

To sum up the previously described empirical results of Granger causality tests, it may be claimed that hypothesis **H1**: *There is Granger causal relationship between the national innovative capacity and the national innovation performance* is partially confirmed since the majority (27/41) of the national innovative capacity elements displayed Granger causal effects on all the three groups of the national innovation performance indicators.

3rd and 4th steps: Correlation, multicollinearity test, regression analysis, and effects test

In addition to the Granger causality tests, correlation analysis was applied before entering the variables into regression models. The correlation matrixes can be found in Annex 14 through Annex 24 *(note: only variables which are significantly correlated with the dependent variable were included in the tables; if any multicollinearity (coef. >0.7) between the input variables was captured, the independent variable with the weaker relationship with the dependent variable was omitted).* As the previous Granger causality and correlation tests helped in finding out which NIC elements may act as factors which influence the national innovation performance, from this point on, the variable of EU investment is included in all the stages of the analysis.

Continuing with the explanation of 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 (adj. R^2 in the tables). More explicit information about these methods and the interpretation of their results can be found in Section 2.3.

5th step: evaluation of the significance of independent variables and calculation of a long-run multiplier

At first, the general tendencies for the entire EU region are explored in order to reveal the influence of EU investment on all the member states' innovation performance by testing the following three hypotheses:

- **H2:** EU investment has positive long-term influence on the member states' national innovation performance expressed by the technological innovative output.
- **H3:** EU investment exerts positive long-term influence on the member states' national innovation performance expressed by the non-technological innovative output.
- **H4:** EU investment does not have long-term influence on the member states' national innovation performance expressed by commercialisation of innovation.

Table 27 through Table 29 depict the autoregressive distributed lag models which were used in the calculations of the long-term influence of EU investment. 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 that shows the effect on $E(Y_t)$ of a maintained unit increase in X_t for all the included periods. 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 so that to keep a sufficient degree of freedom.

To begin with the technological innovative output, Table 27 illustrates that, for the dependent variables patent, patent_bus, patent_higher_ed and smes_pp, EU investment has no immediate influence. Moreover, even when it is significant in the regression model of government patent applications, the variable of eu_fp turns out to be negative (-0.08**), while the quality of scientific institutions, as well as urban population has a positive influence (respectively, 0.13**; 0.79**). The share of the urban population also takes a significant part for the introduction of product and process innovations (1.13*).

For the total patent applications, intramural R&D investment in the higher education sector has a positive influence (0.19**), while corruption has a negative influence (-0.01**). For business patent applications, expenditures for education and the knowledge stock have a positive influence (respectively, 18.62*** and 14.64**), whereas, for patent applications by higher education institutions, only the variable of education expenditures was found to be positive and significant (0.02**).

Table 27. 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. variable (-1)	0.46***	1.28***	0.82***	1.11***	1.47***
dep. variable (-2)	-	-	-0.52***	-0.28***	-1.10***
dep. variable (-3)	-	-	-	-	0.61***
dep. variable (-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*

Furthermore, it can be seen that, for the non-technological innovative output of the member states, both NIC elements and EU investment are significant in most of the cases. On the other hand, in the case of trademark applications, a direct comparison of the strength of the influence of eu_fp and other variables cannot be made. The variable public_private_collab is integrated of order one, which means that, instead of the situation where the increase of x (d(public_private_collab)) determines the decrease of y (trademark), the interpretation is that the absolute increase of x (d(public_private_collab)) over the year determines the decrease of y (trademark). Nevertheless, it can still be claimed that EU investment has significant positive influence on trademarks even in a short period of time (1.67***).

In the case of the design variable, a bigger number of R&D specialists working in the business sector, as well as a longer duration of the working life, boost the amount of design applications (respectively, 18.00** and 0.21***), while the variable of EU investment is not significant. The total number of the R&D personnel exerts positive influence on the introduction of marketing and organisation innovations (1.25**), while the variable of EU investment is significant but negative in a short period of time.

Table 28. Regression models: Non-technological innovative output

	trademark	design	smes_mo
c	-46.81	83.11	7.22**
dep. variable (-1)	0.94***	0.83***	1.55***
dep. variable (-2)	-	-0.23***	-0.97***
dep. variable (-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**	-
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*

The last group of NIP indicators is related to the commercialisation of innovation. The results in Table 29 suggest that, for the sales of innovative products, international economic activities are essential (imports: 0.11**). A higher share of the services sector along with substantial venture capital show positive influence on the exports of high technology products (respectively, 6.59** and 3.44*). However, the variable of EU investment here is also significant and positive (0.10***). Lastly, the exports of knowledge-intensive services are positively influenced by the usage of ICT (internet and mobile) in a country (0.79**).

Table 29. Regression models: Commercialisation of innovation

	inno_sales	exports_hitech	exports_kis
c	8.25**	-2.24	-4.32
dep. variable (-1)	1.43***	1.15***	0.97***
dep. variable (-2)	-1.33***	-0.36***	-
dep. variable (-3)	1.03***	-	-
dep. variable (-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*

Considering the fact that the effects of the R&I policy as well as the pay off the investment can emerge in a longer period of time, it was decided to check whether EU investment has a long-term influence on the member states' national innovation performance expressed by technological, non-technological innovative output and the commercialisation of innovation. As it was mentioned above, the lagged values of the EU FP variable are used while counting a long-run multiplier. Having in mind the maximum available data for the analysed period of time, 10 lags were included in the analysis (see Table 27 through Table 29).

The results indicated in Table 30 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 (here and after the years, the interpretation is based on the results shown in Table 27 through Table 29).

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 (see Section 1.1.1. and Table 2).

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.

Table 30. 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	-	-

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 31 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 – the 6^{th} and the 7^{th} – will help identify the possible influence variations over time and across the countries.

Table 31. 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	-	-

As it was described in Sections 1.1.2 and 2.2., EU MSs endure the so-called European paradox of the successful promotion of R&D inputs but 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 32 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. Since Table 27 through Table 32 represent the tendencies for the entire region, the following steps of the empirical analysis will help in looking at a closer picture.

Table 32. 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	-

To sum up the results of the 4th and 5th steps of the empirical investigation, it can be stated that three hypotheses were partially confirmed:

- **H2**: EU investment has positive long-term influence on the member states' national innovation performance expressed by the technological innovative output – partially confirmed with one exception of influence on government patent applications (LRM -0.12).
- **H3**: EU investment exerts positive long-term influence on the member states' national innovation performance expressed by the non-technological innovative output – partially confirmed with one exception of influence on design applications (LRM -0.94).

- **H4**: EU investment does not have long-term influence on the member states' national innovation performance expressed by commercialisation of innovative output – partially confirmed by proving the absence of influence on the sales of innovations.

6th step. Evaluation of EU investment influence disparities during different programming periods

Since the previous stage of analysis raised several concerns about the results of the general long-term influence of EU investment, there was urgent necessity to analyse the dynamics and the variation of effects of individual FPs over time (**H5**: The influence of EU investment on the member states' innovation performance depends on the programming period). Therefore, by using OLS regression models and including dummies for separate framework programmes, a comparison was made (see the key statistics in Table 33 through Table 35; full models can be found in Annex 25 through Annex 33). 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, as Table 33 demonstrates, 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 instutions 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.

Table 33. Influence of individual EU Framework programmes on the innovation performance of member states (Technological innovative output)

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

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

Continuing with the non-technological innovative output, the results presented in Table 34 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.

Table 34. Influence of individual EU Framework programmes on the innovation performance of member states (Non-technological innovative output)

EU FP / Innovative output	FP6	FP7	H2020	F-stat.	Adjusted R^2
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

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

Lastly, as it can be seen in Table 35, for NIP 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.

Table 35. Influence of individual EU Framework programmes on the innovation performance of member states (Commercialisation of innovation)

EU FP / Innovative output	FP6	FP7	H2020	F-stat.	Adjusted R^2
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

To sum up the results of the 6th step of analysis, it can be concluded that the influence of individual EU FPs varied for the technological innovative output expressed by patent applications (total, business, and higher education institutions' patent applications) as well as for the non-technological innovative output expressed by marketing and organisational innovations. As there were no other differences between the influence of EU investment on other NIP indicators, hypothesis **H5**: *The influence of EU investment on the member states' innovation performance depends on the programming period* has been partially confirmed.

7th step. Evaluation of EU investment influence disparities across the member states

As it was indicated in the previous steps of the empirical analysis, the results of 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. Therefore, the dissertation includes testing hypothesis **H6**: The magnitude of the influence of EU investment is different across the member states. 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 36 through Table 38, full models can be found in Annex 34 through Annex 43).

Table 36 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 36 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 36. 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 37 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).

Table 37. 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*

Results in Table 38 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 29.

Table 38. 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*

Taking the results of the empirical analysis into consideration, hypothesis **H6**: *The magnitude of the influence of EU investment is different across the member states* has been partially confirmed. There were disparities of the influence of EU investment among the countries for nine dependent variables out of 11.

A conceptual model, along with the empirical research sceheme, 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.

The redefined interpretation of NIC and the redeveloped NIC model benefited in testing the following hypotheses:

- **H1:** There is Granger causal relationship between the national innovative capacity and the national innovation performance. The hypothesis has been confirmed.

The proposed methodology includes three types of innovative outputs: the 'traditional' industry innovation indicators (patent applications, product and process innovations), service sector based and non-technological forms of innovations (trademarks, designs, marketing and organisational innovations) and the commercialisation process of innovation (sales of innovation, exports of high-technology products, and knowledge-intensive services). These criteria helped to test the three following hypotheses:

- **H2:** EU investment has positive long-term influence on the member states' national innovation performance expressed by the technological innovative output. The hypothesis has been partially confirmed.
- **H3**: EU investment exerts positive long-term influence on the member states' national innovation performance expressed by the non-technological innovative output. The hypothesis has been partially confirmed.
- **H4:** EU investment does not have long-term influence on the member states' national innovation performance expressed by the commercialisation of innovation. The hypothesis has been partially confirmed.

Considering the effects of separate EU research and innovation Framework Programmes after the adoption of the Lisbon strategy was possible due to conducting precise examination of the influence of individual programmes on the member states' innovation performance and testing the following hypothesis:

- **H5**: The influence of EU investment on the member states' innovation performance depends on the programming period. The hypothesis has been partially confirmed.

Finally, since there is limited literature on the disparities of the influence of EU investment across the member states, the regression models considered the differences within the entire European Union (i.e., the 27 current member states plus 1 former member state – the United Kingdom) and benefited in testing the following hypothesis:

- **H6:** The magnitude of the influence of EU investment is different across the member states. The hypothesis has been partially confirmed.

It must be emphasised that since there are influence disparities, 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. Furthermore, as the results of our empirical investigation propose, there are differences in the extent of EU investment effects across the member states. Therefore, at the member states' level, a comparison of the distinguished components of the redeveloped NIC framework may help the national governments lead to the identification of areas for improvement.

CONCLUSIONS

1. The analysis of the EU research and innovation policy has shown that, in comparison to other initiatives, the Framework Programmes play a key role in ensuring the position of EU as a global innovation leader. Since 1984, along with the expanding concept of innovation, the period of each programme featured an evolved innovation policy with an increased funding. *Horizon Europe*, which starts in the beginning of 2021 with the budget of 80.9 billion euros, is the most extensive ever undertaken science and innovation programme in the world. Investments are focused on the directions of open science (internships of researchers, exchange projects, research), global challenges (cancer, global warming), and open innovation.

The results of the official assessment show various additionality effects of the Framework Programmes, starting from strengthening the expertise and skills of researchers, continuing with pooling industrial leadership in innovation, and finishing with acting as a pool of resources for finance and expertise from different countries, sectors and organisations.

Nevertheless, despite specific incentives and implemented instruments, membership in the EU does not automatically guarantee high innovation performance. The EU innovation gap with the world innovation leaders still persists, and the innovation performance strongly diverges across the member states with highly uneven and incoherent progress.

2. The current methods used in the ex-post evaluation of EU investment largely vary. Most of the options include individual use or a combination of the following methods: meta-evaluations, case studies, interviews, surveys, focus groups, statistical/bibliometric analysis, and econometric modelling.

However, most evaluations only consider the influence of individual projects on the beneficiary's innovation performance in the short period of time, typically, two to three years. Furthermore, the assessment indicators vary from report to report, national evaluations are fragmented, and inadequately little attention is given to the member state level context, which may mitigate the effect of EU investment. For these reasons, reliable comparison of the long-term macro level results is not ensured.

3. The concept of the national innovative capacity framework by Furman *et al.* (2002) was chosen as the basis for the analysis of other country-level factors which might influence the national innovation performance. The concept was redeveloped by including additional elements to the original dimensions of the common innovation infrastructure, cluster-specific environment for innovation and quality of linkages along with supplementing the model with the dimensions of international economic activities, diversity and equality, and legal and political strength.

The common innovation infrastructure consists of elements which reflect the overall science and innovation policy of a specific country. Cluster-specific environment for innovation defines sector-specific circumstances and investments, and the quality of linkages is described as the links between the different sectors so that to ensure the dissemination of knowledge.

As the national innovation performance is also influenced by a country's position in the global trade network and international cooperation, the model was supplemented with the dimension of international economic activity. It was also emphasised that the diversity in a community usually leads to a more generous amount of ideas and creativity, and that the culture and values of a society has a unique function in motivating and encouraging its members to innovate. Therefore, as the EU member states differ significantly in their social norms, morals, values, traditions and behaviours, the dimension of equality and diversity was included in the analysis. It was also found that corruption, bureaucracy, and the protection of IP rights might influence a country's potential to innovate, hence the aspect of the legal and political strength was also included in the model.

Finally, it must be emphasised that, in spite of the rise of services and intangibles, there still exists exceptionally prevalent focus in the scientific literature on the technological form of innovation and the 'traditional' measures, such as granted patents or patent applications, hence it is important to narrow down this gap by including other forms of innovations.

The current methods used in the evaluation of the national innovative capacity concentrate and are mostly based on correlation and OLS regression. Further alternatives include fixed and random effects models, Granger causality tests, the general method of moments, network autocorrelation models, cluster analysis, exploratory qualitative comparative analysis, negative binomial estimation, and vector error correction models.

Since these methods have been proven to be well-applicable for the analysis of the national innovative capacity context, they are later used as an empirical 'know-how' to evaluate the influence of EU investment on the member states' innovation performance.

4. The suggested methodology for the assessment of the influence of EU investment on the member states' innovation performance considers 41 variables which reflect the national innovative capacity, one variable which reflects EU investment, and 11 variables that are proxied for national innovation performance. Three types of innovative outputs comprise: 1) the 'traditional' industry innovation indicators (patent applications, product and process innovations); 2) service sector-based and non-technological forms of innovations (trademarks, designs, marketing and organisational innovations); and 3) the commercialisation process of innovation (sales of innovation, exports of high-technology products and knowledge-intensive services). The full research path consists of 7 steps: (1) unit root tests to check the stationarity of time series; (2) Granger causality tests with five lag values for the evaluation of Granger causality between the variables; (3) correlation, multicollinearity test, and OLS regression; (4) effect tests; (5) calculation of a long-run multiplier; (6) evaluation of EU investment influence disparities through different programming periods; and (7) evaluation of the disparities of the influence of EU investment across the member states.

5. In order to evaluate the influence of EU investment on the member states' innovation performance and to test the six proposed hypotheses, a panel dataset for

28 former and current EU member states was compiled of the most recent available data from 2000 to 2018.

5.1. The results of the Granger causality test proved that there is Granger causal relationship between the national innovative capacity and the national innovation performance (hypothesis H1).

5.2. The findings of an empirical analysis 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 (hypothesis H2). On the other hand, small but negative influence of EU investment was found in the case of patent applications by the government sector. It is assumed that the explanation of this result might be related to the degree of capabilities of governments so that to ensure the effective practical distribution of EU financial flows.

5.3. Considering the effects on the non-technological innovative outputs, they were found to be positive in most of the cases, i.e., trademarks and marketing, and organisational innovations (hypothesis H3). These results might reflect the benefits of the growing and more substantial focus on business enterprises as well as social sciences and humanities in the EU research and innovation policy. Nevertheless, it was discovered that EU investment has small but negative long-term influence on the exports of hi-tech products and knowledge-intensive services. Several of the assumptions which might explain these outcomes may be that either the member states encounter the crowding-out effect, or the investment simply targets other points of innovation performance.

5.4. As it was initially expected, no significant influence of EU investment on the sales of innovation was found (hypothesis H4) since FPs 'suffer' from the European paradox of the successful promotion of R&D inputs but the inability to transform these results into commercial benefits.

5.5. Since the analysis raised several concerns about the results of the general long-term influence of EU investment, the dynamics and variation of the effects of individual FPs over time and across the member states were investigated. The results showed that, in most cases, the influence of EU investment on the member states' innovation performance depends on the programming period (hypothesis H5). Therefore, EU policy makers may employ the research findings of the intended and unintended effects of the individual 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 society and economy.

5.6. The final step of the analysis revealed that the magnitude of the influence of EU investment is different across the member states (hypothesis H6). These results apply for all the analysed technological innovative outputs, as well as trademark applications, marketing and organisational innovations and exports of high technology products. In the ideal situation, qualitative comparative case studies would bring more insights into the underlying factors regarding each country's NIC. Nevertheless, since it is beyond the scope of this dissertation, this beneficial contribution to the empirical research on EU influence evaluation shall be left for future research.

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ANNEXES

Annex 1. Descriptive statistics of dependent variables

	patent	patent_bus	patent_gov	patent_higher_ed	smes_pp
Mean	83.85	67.22	2.00	2.32	31.96
Median	28.88	17.09	0.83	1.02	32.73
Maximum	350.41	292.84	17.82	17.62	56.03
Minimum	0.27	0.11	0.00	0.00	4.63
Std. Dev.	95.97	83.31	3.07	3.25	11.30

	trademark	design	smes_mo	exports_hitech	exports_kis	inno_sales
Mean	181.85	113.07	35.73	14.23	48.93	12.40
Median	102.15	78.64	36.67	11.33	45.29	12.25
Maximum	2304.56	1251.78	68.18	71.74	94.04	28.64
Minimum	0.14	0.01	7.35	1.67	8.88	3.14
Std. Dev.	323.02	154.22	12.07	10.29	20.97	4.35

Annex 2. Descriptive statistics of independent variables

	rd	public_ rd	edu_ exp	rd_ fte	rd_ fte_gov	rd_ fte_bus	doc_ grad	knowledge_ stock	quality_ scientific
Mean	1.44	0.30	5.24	1.08	0.16	0.55	1.36	0.00	4.75
Median	1.24	0.24	5.17	0.97	0.15	0.47	1.20	-0.39	4.80
Maximum	3.91	0.88	8.81	2.49	0.53	1.94	13.76	7.37	6.35
Minimum	0.22	0.01	2.80	0.23	0.01	0.03	0.01	-0.49	3.23
Std. Dev.	0.87	0.19	1.10	0.54	0.09	0.44	1.01	1.00	0.82
	int_ co_pub	pub_ top10	employees_edu	long_ learning	ict	private _rd	non_rd_ exp	sector_ hitech	sector_ kis
Mean	710.02	10.83	31.22	9.59	5.33	0.74	0.79	4.09	34.80
Median	535.08	10.88	31.55	7.20	5.42	0.58	0.72	4.00	34.50
Maximum	2929.33	18.27	51.20	32.60	6.99	2.80	3.36	8.50	58.30
Minimum	38.21	3.97	12.80	0.90	3.22	0.04	0.12	1.70	11.10
Std. Dev.	575.97	3.35	8.87	7.34	0.99	0.61	0.47	1.41	8.87
	sector_ industry	sector_ services	pop_ urban	higher_ ed_rd	venture_ cap	public_ private_collab	inno_ smes_collab	new_ business	exports
Mean	0.27	0.67	72.14	1.45	0.09	0.08	11.47	6.02	58.47
Median	0.27	0.67	70.34	1.25	0.07	0.06	11.47	4.15	48.85
Maximum	0.41	0.82	98.00	3.90	0.62	3.52	30.56	39.27	224.80
Minimum	0.15	0.35	50.75	0.23	0.00	-3.07	1.20	0.47	18.50
Std. Dev.	0.06	0.09	12.44	0.87	0.09	0.53	6.05	5.44	35.16
	imports	fdi	multiculture	poverty	female_ manage	corruption	legal_ political	bureaucracy	ipr
Mean	57.34	10.44	0.08	24.29	30.14	263.00	6.71	19.77	6.87
Median	49.09	3.53	0.06	22.85	30.58	264.00	6.80	15.75	6.70
	191.55	451.72	0.48	61.30	50.03	525.00	8.90	138.00	9.10

Maximum									
Minimum	22.91	0.10	0.01	12.20	9.35	1.00	2.90	3.50	3.40
Std. Dev.	29.99	35.68	0.09fdi	7.91	7.67	151.68	1.37	17.80	1.28

	gdp_ capita	pop	labour_ force	healthy_ life	working_ life	eu_fp
Mean	23700.89	17.87	7.59	61.46	34.17	12.50
Median	20246.10	8.84	3.85	61.50	33.90	8.10
Maximum	97788.56	82.79	40.636	73.90	41.90	113.64
Minimum	1746.55	0.389	0.143	50.35	27.50	0.03
Std. Dev.	16374.51	22.62	9.71	4.71	3.04	15.26

Annex 3. Granger causality test: NIC → NIP (patent), 5 lags

Dependent variable: patent	l=1		l=2		l=3		l=4		l=5	
	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.
rd	16.33	0.00	11.71	0.00	5.91	0.00	4.68	0.00	3.21	0.01
public_rd	1.97	0.16	2.09	0.13	0.86	0.46	1.08	0.37	1.02	0.41
edu_exp	2.90	0.09	1.51	0.22	1.59	0.19	1.79	0.13	1.21	0.30
rd_fte	0.00	0.97	0.33	0.72	0.43	0.73	1.08	0.37	0.98	0.43
rd_fte_gov	4.51	0.03	2.75	0.07	1.36	0.25	1.64	0.16	3.80	0.00
rd_fte_bus	0.43	0.51	1.51	0.22	0.92	0.43	1.76	0.14	1.04	0.40
doc_grad	0.01	0.94	0.16	0.85	1.06	0.37	0.73	0.57	0.60	0.70
knowledge_stock	1.43	0.23	1.72	0.18	1.52	0.21	1.49	0.20	1.01	0.41
quality_scientific	0.60	0.44	1.60	0.20	1.01	0.39	1.54	0.19	1.15	0.34
int_co_pub	0.60	0.44	1.90	0.15	2.06	0.11	0.99	0.41	3.08	0.01
pub_top10	0.09	0.77	0.93	0.40	0.86	0.46	2.08	0.08	2.90	0.01
d(employees_edu)	4.13	0.04	1.36	0.26	0.27	0.85	0.62	0.65	0.36	0.87
long_learning	0.83	0.36	1.35	0.26	2.44	0.06	3.07	0.02	2.58	0.03
ict	0.48	0.49	0.30	0.74	1.64	0.18	1.97	0.11	0.43	0.82
d(private_rd)	3.65	0.06	2.28	0.10	3.43	0.02	2.74	0.03	2.32	0.04
non_rd	0.11	0.74	0.12	0.89	0.18	0.91	0.19	0.94	0.50	0.77
sector_hitech	0.75	0.39	0.46	0.63	3.43	0.02	3.48	0.01	3.23	0.01
sector_kis	0.44	0.51	0.77	0.46	0.72	0.54	1.20	0.31	1.09	0.37
sector_industry	0.13	0.72	0.50	0.61	0.48	0.70	0.35	0.85	0.91	0.47
sector_services	0.02	0.89	0.33	0.72	0.39	0.76	0.30	0.88	0.50	0.77
pop_urban	0.24	0.62	0.58	0.56	1.50	0.21	5.88	0.00	9.44	0.00
higher_ed_rd	16.50	0.00	11.83	0.00	6.13	0.00	4.76	0.00	3.24	0.01
venture_cap	0.43	0.51	1.00	0.37	1.12	0.34	0.51	0.73	0.62	0.68
d(public_private_collab)	11.76	0.00	4.55	0.01	16.39	0.00	6.45	0.00	6.71	0.00
inno_smes_collab	0.81	0.37	5.08	0.01	3.62	0.01	1.96	0.10	3.15	0.01
new_business	0.21	0.65	0.22	0.81	0.30	0.83	0.56	0.69	0.71	0.62
exports	3.18	0.08	3.06	0.05	2.11	0.10	2.27	0.06	2.57	0.03
imports	3.42	0.07	2.19	0.11	1.26	0.29	1.76	0.14	2.49	0.03
fdi	3.61	0.06	2.77	0.06	2.38	0.07	1.54	0.19	1.35	0.24

d(multiculture)	0.73	0.39	0.82	0.44	0.85	0.47	0.55	0.70	0.73	0.60
poverty	0.40	0.53	0.05	0.96	0.20	0.89	0.16	0.96	0.28	0.92
gender_equality	0.38	0.54	4.41	0.01	4.91	0.00	5.33	0.00	4.38	0.00
corruption	3.62	0.04	1.71	0.18	2.02	0.11	0.88	0.48	0.35	0.88
legal_political	1.19	0.28	2.01	0.14	1.17	0.32	1.71	0.15	1.88	0.10
bureaucracy	1.12	0.29	0.66	0.52	0.22	0.88	0.28	0.89	0.23	0.95
ipr	0.59	0.44	0.22	0.80	0.15	0.93	0.12	0.97	0.23	0.95
gdp_capita	1.21	0.27	1.27	0.28	0.90	0.44	2.55	0.04	1.00	0.00
pop	0.09	0.76	0.15	0.86	0.28	0.84	0.30	0.88	0.11	0.99
labour_force	0.14	0.70	0.50	0.61	0.45	0.72	0.39	0.82	0.19	0.97
healthy_life	0.21	0.65	1.19	0.30	1.43	0.24	1.72	0.15	1.29	0.27
working_life	0.59	0.44	0.40	0.67	0.13	0.94	1.17	0.32	1.31	0.26

Annex 4. Granger causality test: NIC → NIP (patent_bus), 5 lags

Dependent variable: patent_bus	l=1		l=2		l=3		l=4		l=5	
	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.
rd	4.00	0.05	1.00	0.37	4.40	0.00	9.03	0.00	8.53	0.00
public_rd	41.74	0.00	19.18	0.00	30.00	0.00	19.14	0.00	22.75	0.00
edu_exp	1.36	0.24	1.79	0.17	1.24	0.29	4.42	0.00	3.84	0.00
rd_fte	8.53	0.00	3.18	0.04	1.56	0.20	1.51	0.20	2.61	0.03
rd_fte_gov	0.31	0.58	0.80	0.45	0.44	0.72	0.39	0.81	0.55	0.74
rd_fte_bus	5.79	0.02	4.02	0.02	3.00	0.03	2.95	0.02	5.63	0.00
doc_grad	16.45	0.00	5.51	0.00	3.29	0.02	7.26	0.00	5.66	0.00
knowledge_stock	11.27	0.00	3.73	0.03	2.66	0.05	1.29	0.28	1.62	0.16
quality_scientific	1.07	0.30	0.10	0.91	0.76	0.52	0.29	0.88	0.34	0.88
int_co_pub	60.43	0.00	42.72	0.00	33.24	0.00	22.99	0.00	39.14	0.00
pub_top10	8.55	0.00	2.73	0.07	2.97	0.03	2.07	0.09	1.37	0.24
d(employees_edu)	0.79	0.38	11.23	0.00	8.17	0.00	7.18	0.00	3.97	0.00
long_learning	5.30	0.02	2.27	0.10	2.15	0.09	1.05	0.38	1.02	0.40
ict	12.25	0.00	1.89	0.18	-	-	-	-	-	-
d(private_rd)	1.57	0.21	0.14	0.87	2.99	0.03	4.93	0.00	3.33	0.01
non_rd	2.84	0.09	0.90	0.41	0.91	0.44	0.18	0.95	0.22	0.95
sector_hitech	0.74	0.39	1.18	0.31	3.77	0.01	4.49	0.00	4.64	0.00
sector_kis	15.88	0.00	4.72	0.01	4.47	0.00	3.79	0.01	3.58	0.00
sector_industry	4.25	0.04	4.77	0.01	2.68	0.05	2.70	0.03	1.64	0.15
sector_services	3.07	0.08	2.59	0.08	2.03	0.11	2.69	0.03	1.69	0.14
pop_urban	1.42	0.23	0.68	0.51	1.29	0.28	1.23	0.30	1.52	0.19
higher_ed_rd	3.65	0.06	1.03	0.36	4.71	0.00	9.16	0.00	8.01	0.00
venture_cap	0.23	0.63	0.13	0.88	0.55	0.65	0.98	0.42	3.02	0.01
d(public_private_collab)	2.08	0.15	3.90	0.02	3.22	0.02	2.75	0.03	0.75	0.59
inno_smes_collab	0.70	0.40	0.12	0.89	0.49	0.69	0.55	0.70	0.34	0.89
new_business	0.03	0.85	0.59	0.56	0.81	0.49	1.08	0.38	1.71	0.16
exports	1.42	0.23	9.21	0.00	7.28	0.00	6.94	0.00	5.56	0.00
imports	1.74	0.19	7.39	0.00	5.44	0.00	4.44	0.00	3.83	0.00

fdi	0.67	0.41	2.44	0.09	3.44	0.02	4.08	0.00	3.16	0.01
d(multiculture)	0.01	0.90	0.02	0.98	0.47	0.70	0.78	0.54	0.46	0.81
poverty	0.02	0.88	0.04	0.96	0.03	0.99	0.13	0.97	0.27	0.93
gender_equality	1.47	0.23	1.03	0.36	1.23	0.30	2.39	0.05	3.45	0.01
corruption	0.06	0.81	0.14	0.87	0.56	0.64	0.49	0.74	0.35	0.88
legal_political	4.21	0.04	2.82	0.07	2.01	0.12	0.81	0.53	0.36	0.86
bureaucracy	3.53	0.06	0.49	0.62	0.24	0.87	0.15	0.96	0.01	1.00
ipr	0.74	0.39	0.91	0.41	0.65	0.58	0.38	0.82	1.03	0.45
gdp_capita	6.19	0.01	5.96	0.00	5.07	0.00	13.92	0.00	14.27	0.00
pop	0.00	0.97	1.76	0.17	2.66	0.05	1.99	0.10	1.48	0.20
labour_force	0.02	0.89	0.02	0.98	3.13	0.03	2.01	0.09	2.71	0.02
healthy_life	0.13	0.72	1.51	0.22	0.61	0.61	0.63	0.65	1.54	0.19
working_life	4.01	0.05	1.51	0.22	2.08	0.10	1.51	0.20	0.94	0.45

Annex 5. Granger causality test: NIC → NIP (patent_gov), 5 lags

Dependent variable:	l=1		l=2		l=3		l=4		l=5	
patent_gov	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.
rd	0.01	0.93	0.33	0.72	0.64	0.59	1.93	0.11	1.55	0.18
public_rd	26.23	0.00	14.92	0.00	11.17	0.00	7.18	0.00	5.26	0.00
edu_exp	1.63	0.20	0.40	0.67	0.52	0.67	1.05	0.38	1.09	0.37
rd_fte	0.00	0.95	0.29	0.75	0.28	0.84	0.18	0.95	0.93	0.47
rd_fte_gov	0.76	0.38	0.28	0.76	0.54	0.65	0.28	0.89	0.20	0.96
rd_fte_bus	0.04	0.84	1.57	0.21	0.96	0.41	0.45	0.77	0.60	0.70
doc_grad	5.12	0.02	2.76	0.07	1.68	0.17	1.03	0.39	0.92	0.47
knowledge_stock	3.46	0.06	1.45	0.24	0.88	0.45	0.42	0.79	0.70	0.62
quality_scientific	0.14	0.71	0.12	0.88	2.80	0.05	0.96	0.44	1.25	0.38
int_co_pub	2.74	0.10	1.99	0.14	3.42	0.02	2.19	0.07	4.35	0.00
pub_top10	0.03	0.86	0.47	0.62	0.78	0.51	1.10	0.36	0.71	0.61
d(employees_edu)	0.27	0.60	0.06	0.95	0.28	0.84	0.30	0.88	1.51	0.20
long_learning	0.01	0.92	0.11	0.89	0.31	0.82	0.43	0.79	0.89	0.49
ict	0.71	0.41	0.63	0.55	-	-	-	-	-	-
d(private_rd)	0.13	0.72	3.27	0.04	2.61	0.05	1.94	0.11	2.65	0.03
non_rd	0.09	0.76	0.86	0.43	0.66	0.58	0.18	0.95	0.48	0.79
sector_hitech	0.83	0.36	2.12	0.12	1.84	0.14	2.04	0.09	2.57	0.03
sector_kis	0.71	0.40	0.33	0.72	0.33	0.81	1.30	0.27	1.40	0.23
sector_industry	0.26	0.61	0.14	0.87	0.61	0.61	1.18	0.32	1.03	0.40
sector_services	0.11	0.74	0.06	0.94	1.41	0.24	1.38	0.24	1.49	0.20
pop_urban	0.00	1.00	2.02	0.14	2.03	0.11	3.14	0.02	2.06	0.07
higher_ed_rd	0.01	0.92	0.35	0.71	0.63	0.60	1.76	0.14	1.49	0.20
venture_cap	0.01	0.94	1.08	0.34	1.05	0.37	0.83	0.51	0.31	0.91
d(public_private_collab)	7.46	0.01	4.31	0.01	3.82	0.01	2.60	0.04	1.98	0.09
inno_smes_collab	0.16	0.69	1.11	0.33	0.75	0.52	1.30	0.28	1.49	0.21
new_business	0.50	0.48	0.96	0.39	0.83	0.48	0.89	0.48	0.26	0.93
exports	0.05	0.82	1.11	0.33	0.47	0.71	1.25	0.29	2.00	0.08
imports	0.00	0.99	0.72	0.49	0.36	0.78	0.95	0.43	1.50	0.19
fdi	11.13	0.00	5.78	0.00	5.70	0.00	4.46	0.00	3.62	0.00

d(multiculture)	0.00	0.95	0.17	0.84	0.05	0.98	0.37	0.83	0.23	0.95
poverty	0.00	0.98	0.09	0.91	0.14	0.94	0.11	0.98	0.48	0.79
gender_equality	0.40	0.53	0.95	0.39	1.15	0.33	1.18	0.32	1.45	0.21
corruption	0.32	0.57	0.47	0.62	0.61	0.61	0.52	0.72	0.69	0.63
legal_political	0.92	0.34	0.42	0.66	0.16	0.93	0.70	0.60	1.16	0.46
bureaucracy	0.53	0.47	0.16	0.85	0.12	0.95	0.33	0.86	0.55	0.74
ipr	0.05	0.82	0.08	0.92	0.43	0.73	0.52	0.72	0.77	0.61
gdp_capita	0.00	0.97	0.08	0.92	0.27	0.85	0.94	0.44	0.95	0.45
pop	0.06	0.80	1.66	0.19	1.06	0.37	0.72	0.58	0.47	0.80
labour_force	0.03	0.86	0.51	0.60	0.68	0.56	0.61	0.65	0.83	0.53
healthy_life	0.00	1.00	0.32	0.72	1.09	0.36	0.28	0.89	0.41	0.84
working_life	0.48	0.49	1.36	0.26	0.77	0.51	0.60	0.66	0.57	0.73

Annex 6. Granger causality test: NIC → NIP (patent_higher_ed), 5 lags

Dependent variable: patent_higher_ed	l=1		l=2		l=3		l=4		l=5	
	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.
rd	0.35	0.55	2.81	0.06	2.60	0.05	3.77	0.01	2.76	0.02
public_rd	13.66	0.00	6.01	0.00	4.45	0.00	3.27	0.01	6.08	0.00
edu_exp	0.45	0.51	1.23	0.29	1.02	0.38	2.51	0.04	1.72	0.13
rd_fte	1.12	0.29	4.65	0.01	2.38	0.07	1.43	0.23	1.47	0.21
rd_fte_gov	0.43	0.51	0.06	0.94	0.12	0.95	2.11	0.08	1.70	0.14
rd_fte_bus	0.28	0.59	5.61	0.00	3.54	0.02	3.17	0.02	2.86	0.02
doc_grad	6.52	0.01	3.25	0.04	1.97	0.12	1.24	0.30	0.62	0.69
knowledge_stock	1.77	0.18	0.90	0.41	0.66	0.58	0.40	0.81	0.35	0.88
quality_scientific	0.06	0.81	0.17	0.84	0.48	0.70	0.59	0.67	0.64	0.67
int_co_pub	7.88	0.01	11.30	0.00	9.09	0.00	8.85	0.00	8.38	0.00
pub_top10	0.46	0.50	0.67	0.52	0.79	0.50	0.59	0.67	0.57	0.72
d(employees_edu)	0.02	0.88	0.54	0.58	5.65	0.00	4.88	0.00	3.47	0.01
long_learning	0.05	0.82	1.64	0.20	1.90	0.13	1.37	0.25	0.97	0.44
ict	6.19	0.02	3.28	0.06	-	-	-	-	-	-
d(private_rd)	9.30	0.00	8.24	0.00	3.80	0.01	3.39	0.01	2.89	0.02
non_rd	1.52	0.22	1.17	0.31	1.89	0.14	0.62	0.65	0.09	0.99
sector_hitech	1.03	0.31	1.12	0.33	1.07	0.36	2.09	0.08	1.95	0.09
sector_kis	2.38	0.12	1.18	0.31	1.10	0.35	2.11	0.08	4.45	0.00
sector_industry	2.08	0.15	0.65	0.52	0.63	0.59	1.54	0.19	1.34	0.25
sector_services	0.38	0.54	0.07	0.93	0.46	0.71	1.81	0.13	1.94	0.09
pop_urban	0.08	0.78	0.15	0.86	0.16	0.92	0.62	0.65	1.55	0.18
higher_ed_rd	0.23	0.63	2.82	0.06	2.62	0.05	3.79	0.01	2.75	0.02
venture_cap	0.00	0.99	0.13	0.87	0.94	0.42	0.80	0.53	0.42	0.83
d(public_private_collab)	3.25	0.07	1.74	0.18	0.77	0.51	0.38	0.82	1.26	0.29
inno_smes_collab	0.01	0.91	0.16	0.85	0.46	0.71	1.24	0.30	2.38	0.06
new_business	0.00	0.99	0.03	0.97	0.55	0.65	0.34	0.85	0.28	0.92
exports	0.20	0.65	3.89	0.02	3.83	0.01	3.77	0.01	3.33	0.01
imports	0.34	0.56	1.90	0.15	1.54	0.20	1.67	0.16	3.30	0.01
fdi	0.01	0.91	0.94	0.39	1.63	0.18	0.82	0.51	0.64	0.67

d(multiculture)	0.61	0.44	0.50	0.61	0.31	0.82	0.34	0.85	0.39	0.86
poverty	0.15	0.70	0.14	0.87	0.24	0.87	0.44	0.78	0.67	0.65
gender_equality	0.07	0.79	1.19	0.31	0.73	0.53	0.78	0.54	1.36	0.24
corruption	0.79	0.38	1.06	0.35	0.58	0.63	1.08	0.37	0.82	0.54
legal_political	1.63	0.20	0.54	0.58	1.16	0.34	0.75	0.57	3.94	0.06
bureaucracy	0.74	0.39	0.28	0.75	0.71	0.55	0.93	0.45	1.37	0.24
ipr	0.30	0.58	0.54	0.59	0.79	0.51	0.70	0.60	1.97	0.19
gdp_capita	0.16	0.69	3.49	0.03	2.40	0.07	9.23	0.00	6.00	0.00
pop	0.08	0.78	0.59	0.55	0.68	0.56	0.60	0.66	0.61	0.70
labour_force	0.06	0.81	0.43	0.65	1.09	0.35	0.78	0.54	0.91	0.48
healthy_life	0.00	0.98	0.08	0.92	0.22	0.88	0.16	0.96	1.51	0.20
working_life	0.33	0.56	2.60	0.08	2.03	0.11	1.57	0.18	1.41	0.23

Annex 7. Granger causality test: NIC → NIP (smes_pp), 5 lags

Dependent variable: smes_pp	l=1		l=2		l=3		l=4		l=5	
	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.
rd	4.17	0.04	2.75	0.07	0.93	0.42	6.67	0.00	7.22	0.00
public_rd	0.13	0.72	0.10	0.91	0.21	0.89	0.40	0.81	3.30	0.01
edu_exp	0.72	0.40	1.10	0.34	0.85	0.47	1.44	0.22	1.17	0.32
rd_fte	6.61	0.01	3.68	0.03	1.77	0.15	1.42	0.23	1.36	0.24
rd_fte_gov	0.00	0.95	0.46	0.63	0.78	0.50	0.79	0.53	0.68	0.64
rd_fte_bus	2.36	0.13	1.44	0.24	1.26	0.29	1.05	0.38	0.84	0.53
doc_grad	2.71	0.10	2.58	0.08	1.34	0.26	1.12	0.35	0.93	0.46
knowledge_stock	0.80	0.37	0.56	0.57	0.71	0.54	0.61	0.66	0.86	0.51
quality_scientific	9.68	0.00	5.63	0.00	4.33	0.01	3.60	0.01	3.75	0.00
int_co_pub	6.23	0.01	18.71	0.00	10.53	0.00	7.03	0.00	5.35	0.00
pub_top10	14.20	0.00	8.29	0.00	3.86	0.01	3.13	0.02	2.24	0.05
d(employees_edu)	0.05	0.82	0.08	0.92	0.84	0.47	1.36	0.25	1.43	0.21
long_learning	2.19	0.14	1.95	0.14	1.33	0.26	1.12	0.35	0.88	0.50
ict	5.26	0.02	5.41	0.01	0.14	0.94	0.04	1.00	0.73	0.60
d(private_rd)	0.33	0.56	0.35	0.70	8.33	0.00	9.62	0.00	9.20	0.00
non_rd	1.98	0.16	1.63	0.20	0.52	0.67	0.52	0.72	2.86	0.02
sector_hitech	0.13	0.72	0.35	0.70	0.34	0.80	0.26	0.90	0.62	0.69
sector_kis	4.82	0.03	2.77	0.06	1.81	0.15	1.59	0.18	5.54	0.00
sector_industry	3.16	0.08	4.10	0.02	2.46	0.06	4.44	0.00	3.69	0.00
sector_services	5.54	0.02	5.21	0.01	3.35	0.02	4.01	0.00	3.54	0.00
pop_urban	2.56	0.11	4.23	0.02	3.26	0.02	2.57	0.04	2.33	0.04
higher_ed_rd	3.89	0.05	2.63	0.07	0.88	0.45	6.06	0.00	6.43	0.00
venture_cap	0.01	0.92	1.02	0.36	0.16	0.92	0.22	0.93	0.41	0.84
d(public_private_collab)	5.32	0.02	3.12	0.05	3.61	0.01	2.99	0.02	2.16	0.06
inno_smes_collab	1.07	0.30	0.57	0.57	2.24	0.08	1.52	0.20	0.94	0.46
new_business	0.02	0.90	0.43	0.65	0.51	0.68	0.77	0.55	1.02	0.41
exports	0.16	0.69	5.74	0.00	4.97	0.00	4.26	0.00	3.66	0.00
imports	0.21	0.65	1.10	0.33	2.15	0.09	3.06	0.02	-	-
fdi	0.06	0.80	0.04	0.97	0.21	0.89	0.21	0.93	0.31	0.91

d(multiculture)	0.73	0.39	0.35	0.70	0.73	0.53	0.48	0.75	0.60	0.70
poverty	3.95	0.05	1.74	0.18	1.79	0.15	1.09	0.36	1.35	0.24
gender_equality	0.15	0.70	1.23	0.29	1.32	0.27	1.17	0.32	1.38	0.23
corruption	4.82	0.03	2.69	0.07	1.60	0.19	1.74	0.14	1.69	0.14
legal_political	3.86	0.05	3.60	0.03	2.51	0.06	2.22	0.07	1.53	0.19
bureaucracy	2.58	0.11	2.46	0.09	2.75	0.04	2.09	0.08	1.09	0.37
ipr	4.32	0.04	5.67	0.00	3.72	0.01	3.25	0.01	1.96	0.09
gdp_capita	1.69	0.19	3.99	0.02	1.63	0.18	1.76	0.14	1.58	0.17
pop	0.00	0.97	0.67	0.51	1.08	0.36	0.82	0.51	0.98	0.43
labour_force	0.00	0.97	0.15	0.86	0.73	0.54	0.69	0.60	0.88	0.50
healthy_life	0.28	0.60	0.59	0.56	0.59	0.62	0.98	0.42	1.20	0.31
working_life	3.65	0.06	2.79	0.06	2.38	0.07	1.96	0.10	1.18	0.32

Annex 8. Granger causality test: NIC → NIP (trademark), 5 lags

Dependent variable: trademark	l=1		l=2		l=3		l=4		l=5	
	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.
rd	0.47	0.49	0.18	0.83	0.01	1.00	0.10	0.98	0.22	0.95
public_rd	7.04	0.01	3.74	0.02	2.21	0.09	1.64	0.16	1.28	0.27
edu_exp	0.56	0.45	0.13	0.87	1.99	0.11	3.84	0.00	3.62	0.00
rd_fte	0.05	0.83	0.54	0.58	0.86	0.46	2.07	0.08	3.02	0.01
rd_fte_gov	4.03	0.05	3.41	0.03	2.88	0.04	2.93	0.02	2.29	0.05
rd_fte_bus	1.46	0.23	3.99	0.02	2.87	0.04	2.64	0.03	2.44	0.03
doc_grad	1.92	0.17	2.44	0.09	1.66	0.18	0.88	0.48	0.64	0.67
knowledge_stock	0.01	0.94	0.06	0.94	0.08	0.97	0.10	0.98	0.50	0.78
quality_scientific	2.60	0.11	2.45	0.09	1.60	0.19	1.33	0.26	0.73	0.60
int_co_pub	2.46	0.12	2.11	0.12	2.61	0.05	1.94	0.10	1.37	0.23
pub_top10	0.80	0.37	5.15	0.01	4.47	0.00	4.52	0.00	3.53	0.00
d(employees_edu)	5.88	0.02	18.58	0.00	10.12	0.00	7.06	0.00	5.12	0.00
long_learning	0.18	0.67	0.46	0.63	0.26	0.86	0.41	0.80	0.55	0.74
ict	0.51	0.48	0.24	0.79	0.10	0.96	1.14	0.34	1.46	0.21
d(private_rd)	10.59	0.00	9.32	0.00	1.68	0.17	0.49	0.75	0.79	0.56
non_rd	3.66	0.06	2.16	0.12	0.82	0.49	1.78	0.13	1.07	0.38
sector_hitech	0.02	0.88	0.57	0.57	0.44	0.72	0.37	0.83	1.80	0.11
sector_kis	0.85	0.36	2.88	0.06	5.95	0.00	4.33	0.00	2.60	0.03
sector_industry	8.70	0.00	4.49	0.01	4.99	0.00	4.04	0.00	0.89	0.49
sector_services	16.92	0.00	8.35	0.00	9.09	0.00	6.36	0.00	0.88	0.50
pop_urban	2.19	0.14	1.98	0.14	1.25	0.29	1.02	0.40	0.77	0.58
higher_ed_rd	2.09	0.15	0.66	0.52	0.55	0.65	0.52	0.72	0.48	0.79
venture_cap	5.51	0.02	2.34	0.10	1.18	0.32	0.45	0.77	0.79	0.56
d(public_private_collab)	7.39	0.01	6.93	0.00	10.42	0.00	8.31	0.00	7.98	0.00
inno_smes_collab	0.34	0.56	0.18	0.84	0.19	0.90	0.57	0.68	1.09	0.37
new_business	5.26	0.02	10.15	0.00	15.58	0.00	16.96	0.00	13.46	0.00
exports	13.86	0.00	9.13	0.00	5.43	0.00	3.77	0.01	4.20	0.00
imports	13.51	0.00	7.74	0.00	4.27	0.01	2.78	0.03	2.69	0.02
fdi	11.75	0.00	6.87	0.00	2.95	0.03	3.35	0.01	3.78	0.00

d(multiculture)	1.26	0.26	0.71	0.49	1.11	0.34	1.09	0.36	2.53	0.03
poverty	0.91	0.34	0.50	0.61	0.91	0.43	0.80	0.53	1.10	0.36
gender_equality	2.54	0.11	9.12	0.00	5.30	0.00	3.53	0.01	3.06	0.01
corruption	0.06	0.80	0.32	0.73	1.07	0.36	0.61	0.66	0.94	0.46
legal_political	0.64	0.42	0.43	0.65	0.61	0.61	0.59	0.67	0.78	0.56
bureaucracy	0.07	0.80	0.02	0.98	0.01	1.00	0.36	0.84	0.82	0.54
ipr	1.20	0.28	0.73	0.48	0.47	0.70	0.08	0.99	0.24	0.94
gdp_capita	0.59	0.44	1.31	0.27	1.51	0.21	2.97	0.02	2.34	0.04
pop	4.51	0.03	2.24	0.11	1.15	0.33	0.84	0.50	0.47	0.80
labour_force	4.56	0.03	2.24	0.11	1.11	0.35	0.83	0.51	0.47	0.80
healthy_life	3.37	0.07	2.31	0.10	2.35	0.07	1.97	0.10	1.29	0.27
working_life	0.26	0.61	2.91	0.06	2.40	0.07	2.26	0.06	2.00	0.08

Annex 9. Granger causality test: NIC → NIP (design), 5 lags

Dependent variable: design	l=1		l=2		l=3		l=4		l=5	
	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.
rd	1.89	0.17	0.51	0.60	0.50	0.68	0.44	0.78	0.42	0.83
public_rd	1.58	0.21	0.85	0.43	0.23	0.88	0.40	0.81	0.93	0.47
edu_exp	0.78	0.38	2.67	0.07	4.17	0.01	2.55	0.04	1.33	0.25
rd_fte	9.68	0.00	5.76	0.00	3.76	0.01	4.25	0.00	1.53	0.18
rd_fte_gov	3.17	0.08	3.26	0.04	4.28	0.01	4.25	0.00	2.59	0.03
rd_fte_bus	15.10	0.00	14.49	0.00	9.68	0.00	9.70	0.00	3.50	0.00
doc_grad	0.38	0.54	0.12	0.89	0.60	0.61	0.27	0.90	0.14	0.98
knowledge_stock	0.01	0.94	0.06	0.94	0.08	0.97	0.10	0.98	0.50	0.78
quality_scientific	0.11	0.75	1.06	0.35	0.73	0.53	0.75	0.56	1.41	0.22
int_co_pub	0.96	0.33	13.02	0.00	11.38	0.00	8.35	0.00	6.87	0.00
pub_top10	3.55	0.06	3.50	0.03	2.26	0.08	2.16	0.07	1.87	0.10
d(employees_edu)	6.14	0.01	8.40	0.00	6.22	0.00	5.14	0.00	7.49	0.00
long_learning	1.61	0.21	0.86	0.42	0.67	0.57	2.66	0.03	1.10	0.36
ict	0.38	0.54	3.48	0.03	1.98	0.12	2.86	0.03	0.61	0.69
d(private_rd)	7.31	0.01	4.39	0.01	4.02	0.01	0.10	0.98	0.62	0.68
non_rd	0.10	0.76	0.11	0.90	0.17	0.92	0.32	0.87	1.00	0.42
sector_hitech	1.66	0.20	0.83	0.44	0.64	0.59	1.16	0.33	2.04	0.07
sector_kis	7.71	0.01	4.15	0.02	5.46	0.00	4.09	0.00	3.31	0.01
sector_industry	1.81	0.18	0.10	0.91	0.22	0.88	0.60	0.67	2.45	0.03
sector_services	3.90	0.05	0.08	0.92	0.38	0.76	1.07	0.37	2.31	0.05
pop_urban	4.93	0.03	2.22	0.11	1.15	0.33	1.15	0.33	0.61	0.69
higher_ed_rd	2.09	0.15	0.66	0.52	0.55	0.65	0.52	0.72	0.48	0.79
venture_cap	5.35	0.02	9.36	0.00	3.47	0.02	2.59	0.04	3.06	0.01
d(public_private_collab)	4.51	0.03	13.43	0.00	17.32	0.00	12.36	0.00	3.63	0.00
inno_smes_collab	0.31	0.58	0.51	0.60	0.44	0.73	0.25	0.91	0.14	0.98
new_business	1.09	0.30	2.56	0.08	1.68	0.17	4.22	0.00	9.96	0.00
exports	11.85	0.00	7.64	0.00	5.05	0.00	4.89	0.00	11.45	0.00
imports	7.27	0.01	4.52	0.01	2.76	0.04	2.86	0.02	10.20	0.00

fdi	8.62	0.00	4.30	0.01	3.10	0.03	2.95	0.02	2.19	0.06
d(multiculture)	0.95	0.33	1.40	0.25	0.61	0.61	0.66	0.62	0.22	0.95
poverty	3.46	0.06	1.34	0.26	1.50	0.22	1.19	0.32	0.65	0.66
gender_equality	2.78	0.10	7.69	0.00	4.78	0.00	4.43	0.00	1.21	0.31
corruption	7.49	0.01	2.88	0.06	1.78	0.15	1.44	0.22	0.47	0.80
legal_political	2.05	0.15	3.07	0.05	0.95	0.42	0.37	0.83	0.07	1.00
bureaucracy	0.51	0.47	0.11	0.89	0.10	0.96	0.13	0.97	0.54	0.75
ipr	0.71	0.40	2.49	0.08	0.86	0.46	0.24	0.92	1.79	0.12
gdp_capita	25.38	0.00	14.92	0.00	8.82	0.00	8.32	0.00	0.92	0.47
pop	0.06	0.80	0.11	0.90	0.05	0.99	0.13	0.97	0.35	0.88
labour_force	0.04	0.84	0.22	0.81	0.11	0.95	0.17	0.96	0.42	0.83
healthy_life	2.36	0.13	1.27	0.28	1.14	0.33	1.38	0.24	2.35	0.04
working_life	0.03	0.86	1.33	0.27	1.93	0.12	2.46	0.05	3.80	0.00

Annex 10. Granger causality test: NIC→NIP (smes_mo), 5 lags

Dependent variable: smes_mo	l=1		l=2		l=3		l=4		l=5	
	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.
rd	3.86	0.05	2.30	0.10	1.28	0.28	4.10	0.00	3.44	0.01
public_rd	0.69	0.41	0.55	0.58	2.28	0.08	2.57	0.04	1.44	0.21
edu_exp	1.05	0.31	1.47	0.23	1.05	0.37	1.13	0.34	1.31	0.26
rd_fte	7.73	0.01	4.70	0.01	4.06	0.01	3.76	0.01	1.68	0.14
rd_fte_gov	0.00	0.97	0.30	0.74	0.16	0.92	0.87	0.48	0.61	0.69
rd_fte_bus	5.46	0.02	3.22	0.04	2.73	0.04	2.11	0.08	0.90	0.48
doc_grad	0.89	0.35	3.39	0.04	1.57	0.20	1.35	0.25	1.21	0.30
knowledge_stock	1.09	0.30	0.69	0.50	1.41	0.24	1.46	0.22	1.74	0.13
quality_scientific	9.02	0.00	3.04	0.05	1.92	0.13	1.19	0.32	1.57	0.17
int_co_pub	1.63	0.20	5.37	0.01	3.51	0.02	3.81	0.01	1.98	0.08
pub_top10	4.15	0.04	2.56	0.08	2.83	0.04	4.27	0.00	2.38	0.04
d(employees_edu)	2.22	0.14	4.54	0.01	3.34	0.02	1.22	0.31	1.07	0.38
long_learning	0.81	0.37	0.51	0.60	0.96	0.41	1.26	0.29	1.25	0.29
ict	6.29	0.01	6.00	0.00	4.78	0.00	3.95	0.01	1.10	0.37
d(private_rd)	0.17	0.68	0.25	0.78	2.24	0.09	2.30	0.06	1.82	0.11
non_rd	0.37	0.54	1.20	0.30	2.47	0.06	2.27	0.06	4.14	0.00
sector_hitech	0.97	0.33	0.79	0.46	1.60	0.19	3.01	0.02	3.27	0.01
sector_kis	6.52	0.01	5.47	0.00	6.71	0.00	6.82	0.00	4.50	0.00
sector_industry	4.58	0.03	3.42	0.03	3.00	0.03	3.03	0.02	2.45	0.04
sector_services	7.77	0.01	4.79	0.01	6.85	0.00	5.93	0.00	4.37	0.00
pop_urban	3.37	0.07	2.67	0.07	2.67	0.05	2.66	0.03	1.96	0.09
higher_ed_rd	3.87	0.05	2.33	0.10	1.28	0.28	3.67	0.01	2.92	0.01
venture_cap	0.56	0.45	3.06	0.05	1.37	0.25	1.97	0.10	1.89	0.10
d(public_private_collab)	2.01	0.16	1.50	0.23	1.39	0.25	0.89	0.47	0.50	0.77
inno_smes_collab	1.17	0.28	0.60	0.55	4.13	0.01	2.86	0.02	2.87	0.02
new_business	1.95	0.16	1.87	0.16	2.06	0.11	1.88	0.12	0.77	0.58
exports	0.19	0.66	1.25	0.29	1.01	0.39	0.83	0.51	0.79	0.56
imports	0.48	0.49	0.92	0.40	1.01	0.39	0.94	0.44	0.75	0.59
fdi	0.02	0.89	0.05	0.95	0.13	0.94	0.43	0.79	2.36	0.04

d(multiculture)	1.02	0.31	0.92	0.40	0.99	0.40	1.26	0.29	1.79	0.12
poverty	3.30	0.07	1.91	0.15	1.99	0.12	1.02	0.40	0.88	0.49
gender_equality	0.22	0.64	1.56	0.21	1.12	0.34	1.01	0.40	0.53	0.75
corruption	3.16	0.08	1.67	0.19	5.08	0.00	4.05	0.00	4.28	0.00
legal_political	8.61	0.00	3.86	0.02	2.21	0.09	3.11	0.02	2.59	0.03
bureaucracy	0.08	0.78	0.27	0.77	1.26	0.29	2.03	0.09	0.45	0.81
ipr	12.27	0.00	3.59	0.03	3.00	0.03	3.21	0.01	3.03	0.01
gdp_capita	4.85	0.03	10.43	0.00	7.18	0.00	6.21	0.00	3.38	0.01
pop	1.13	0.29	3.83	0.02	4.53	0.00	3.32	0.01	3.05	0.01
labour_force	1.02	0.31	0.55	0.58	0.88	0.45	0.90	0.47	1.48	0.20
healthy_life	0.35	0.55	0.42	0.65	2.07	0.10	2.82	0.03	1.76	0.12
working_life	0.37	0.54	0.28	0.76	1.11	0.35	0.87	0.48	0.32	0.90

Annex 11. Granger causality test: NIC → NIP (inno_sales), 5 lags

dependent variable:	l=1		l=2		l=3		l=4		l=5	
inno_sales	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.
rd	0.09	0.76	0.59	0.55	0.28	0.84	0.29	0.89	0.56	0.73
public_rd	3.30	0.07	2.12	0.12	1.13	0.34	0.96	0.43	0.44	0.82
edu_exp	0.06	0.80	0.55	0.58	0.17	0.92	0.93	0.44	1.68	0.14
rd_fte	0.06	0.81	0.12	0.88	1.01	0.39	1.89	0.11	1.84	0.11
rd_fte_gov	0.84	0.36	0.25	0.78	0.10	0.96	0.20	0.94	0.92	0.47
rd_fte_bus	0.19	0.67	0.15	0.86	1.07	0.36	1.43	0.22	1.45	0.21
doc_grad	0.32	0.57	0.39	0.68	1.02	0.39	1.19	0.32	1.01	0.41
knowledge_stock	0.49	0.48	0.58	0.56	1.24	0.29	1.22	0.30	0.99	0.42
quality_scientific	0.65	0.42	2.47	0.09	3.92	0.01	3.06	0.02	2.79	0.02
int_co_pub	0.56	0.45	0.25	0.78	1.35	0.26	1.46	0.22	1.44	0.21
pub_top10	0.00	0.95	1.50	0.22	3.21	0.02	2.38	0.05	2.05	0.07
d(employees_edu)	5.47	0.02	1.63	0.20	0.95	0.42	1.14	0.34	0.60	0.70
long_learning	1.70	0.19	0.90	0.41	0.30	0.82	0.19	0.95	0.26	0.94
ict	1.21	0.27	0.72	0.49	1.17	0.33	1.59	0.19	1.18	0.33
d(private_rd)	1.01	0.32	0.81	0.45	0.55	0.65	0.42	0.79	0.66	0.66
non_rd	6.47	0.01	3.19	0.04	0.63	0.59	0.47	0.76	0.78	0.56
sector_hitech	0.01	0.92	0.61	0.55	0.67	0.57	1.00	0.41	0.96	0.44
sector_kis	2.76	0.10	1.49	0.23	0.27	0.85	0.95	0.44	0.55	0.74
sector_industry	0.39	0.53	1.05	0.35	1.60	0.19	1.49	0.21	1.62	0.16
sector_services	0.14	0.71	0.21	0.81	1.93	0.13	1.96	0.10	1.98	0.08
pop_urban	0.16	0.69	0.16	0.85	0.14	0.94	0.15	0.96	0.09	0.99
higher_ed_rd	0.09	0.76	0.43	0.65	0.17	0.92	0.18	0.95	0.53	0.75
venture_cap	1.90	0.17	1.04	0.35	0.45	0.72	0.25	0.91	0.97	0.44
d(public_private_collab)	0.46	0.50	0.29	0.75	0.38	0.77	0.06	0.99	0.19	0.97
inno_smes_collab	2.93	0.09	2.01	0.14	1.90	0.13	2.14	0.08	1.65	0.15
new_business	0.33	0.56	0.38	0.68	0.78	0.51	0.78	0.54	0.82	0.54
exports	3.11	0.08	2.73	0.07	1.89	0.13	4.20	0.00	3.61	0.00
imports	2.53	0.11	1.35	0.26	0.86	0.46	2.21	0.07	2.63	0.02
fdi	0.31	0.58	0.81	0.45	3.08	0.03	2.28	0.06	1.63	0.15

d(multiculture)	0.32	0.57	0.21	0.81	0.03	0.99	0.20	0.94	0.38	0.86
poverty	2.92	0.09	3.98	0.02	3.04	0.03	2.42	0.05	1.96	0.09
gender_equality	0.37	0.54	2.23	0.11	3.22	0.02	2.05	0.09	1.57	0.17
corruption	0.02	0.90	1.28	0.28	1.56	0.20	1.02	0.40	1.03	0.40
legal_political	0.10	0.76	0.39	0.68	1.38	0.25	0.78	0.54	2.01	0.08
bureaucracy	2.51	0.11	3.59	0.03	1.33	0.27	1.67	0.16	1.83	0.11
ipr	0.81	0.37	0.97	0.38	0.81	0.49	1.26	0.29	4.15	0.00
gdp_capita	0.25	0.62	0.98	0.38	0.59	0.62	0.59	0.67	0.47	0.80
pop	0.42	0.52	0.23	0.79	1.01	0.39	1.08	0.37	0.94	0.46
labour_force	0.45	0.50	1.27	0.28	1.20	0.31	1.21	0.31	0.97	0.44
healthy_life	0.20	0.66	0.17	0.85	0.32	0.81	0.24	0.92	0.36	0.87
working_life	0.02	0.89	1.04	0.35	1.30	0.28	1.35	0.25	1.08	0.37

Annex 12. Granger causality test: NIC → NIP (exports_hitech), 5 lags

Dependent variable:	l=1		l=2		l=3		l=4		l=5	
exports_hitech	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.
rd	0.74	0.39	2.07	0.13	1.81	0.14	1.17	0.32	0.73	0.60
public_rd	0.75	0.39	1.09	0.34	0.02	0.99	0.21	0.93	0.28	0.92
edu_exp	0.92	0.34	3.48	0.03	2.41	0.07	1.92	0.11	1.21	0.30
rd_fte	1.55	0.21	2.85	0.06	2.84	0.04	2.34	0.05	1.42	0.22
rd_fte_gov	0.77	0.38	0.65	0.52	0.60	0.62	0.68	0.61	0.59	0.71
rd_fte_bus	1.43	0.23	2.23	0.11	1.95	0.12	1.59	0.18	1.04	0.39
doc_grad	0.30	0.59	0.21	0.81	1.34	0.26	0.97	0.42	0.80	0.55
knowledge_stock	0.93	0.34	0.26	0.77	0.72	0.54	1.37	0.24	1.00	0.42
quality_scientific	1.00	0.32	0.78	0.46	0.71	0.55	1.31	0.27	1.34	0.25
int_co_pub	0.56	0.45	0.43	0.65	0.55	0.65	0.34	0.85	0.66	0.65
pub_top10	0.02	0.88	1.06	0.35	6.32	0.00	5.00	0.00	4.16	0.00
d(employees_edu)	0.31	0.58	0.69	0.50	0.75	0.52	0.47	0.76	0.59	0.71
long_learning	0.07	0.79	0.24	0.79	1.72	0.16	1.55	0.19	2.73	0.02
ict	3.38	0.07	2.13	0.12	0.14	0.94	0.45	0.77	0.39	0.85
d(private_rd)	0.37	0.54	0.45	0.64	0.29	0.83	0.54	0.71	0.33	0.89
non_rd	2.17	0.14	0.21	0.81	0.40	0.75	1.63	0.17	2.49	0.03
sector_hitech	0.09	0.76	2.51	0.08	1.30	0.27	1.65	0.16	1.31	0.26
sector_kis	0.04	0.85	0.43	0.65	0.49	0.69	0.52	0.72	0.43	0.83
sector_industry	3.09	0.08	3.02	0.05	4.19	0.01	4.39	0.00	3.67	0.00
sector_services	0.66	0.42	1.48	0.23	2.65	0.05	2.89	0.02	2.23	0.05
pop_urban	0.03	0.86	0.37	0.69	0.20	0.90	0.26	0.90	0.27	0.93
higher_ed_rd	0.72	0.40	1.96	0.14	2.39	0.07	1.42	0.23	0.97	0.44
venture_cap	0.12	0.73	0.62	0.54	3.21	0.02	3.10	0.02	2.81	0.02
d(public_private_collab)	0.13	0.72	0.13	0.88	0.47	0.70	0.44	0.78	0.46	0.81
inno_smes_collab	1.25	0.26	2.85	0.06	2.25	0.08	1.29	0.28	1.81	0.11
new_business	0.90	0.34	6.46	0.00	7.50	0.00	10.64	0.00	9.92	0.00
exports	0.31	0.58	0.23	0.80	0.84	0.47	0.59	0.67	0.65	0.67
imports	0.32	0.57	0.89	0.41	0.45	0.72	0.50	0.74	0.35	0.88
fdi	2.04	0.15	1.34	0.26	1.49	0.22	1.60	0.17	1.59	0.16

d(multiculture)	10.49	0.00	5.31	0.01	3.08	0.03	3.95	0.00	3.61	0.00
poverty	0.36	0.55	0.20	0.82	0.72	0.54	1.09	0.36	0.90	0.48
gender_equality	0.28	0.60	0.31	0.73	0.64	0.59	0.92	0.45	0.85	0.52
corruption	0.10	0.75	0.04	0.96	0.41	0.74	1.10	0.36	1.13	0.34
legal_political	0.03	0.85	1.15	0.32	0.24	0.87	0.46	0.76	0.52	0.76
bureaucracy	0.86	0.35	1.55	0.21	1.89	0.13	1.79	0.13	0.15	0.98
ipr	0.05	0.83	0.26	0.77	0.11	0.95	1.63	0.17	1.87	0.10
gdp_capita	0.62	0.43	0.87	0.42	2.21	0.09	1.63	0.17	1.51	0.19
pop	0.79	0.38	0.23	0.80	0.23	0.87	0.35	0.85	0.33	0.89
labour_force	0.99	0.32	0.25	0.78	0.29	0.84	0.36	0.83	0.30	0.91
healthy_life	0.05	0.82	0.63	0.53	0.04	0.99	0.29	0.89	0.67	0.65
working_life	0.04	0.85	0.01	0.99	0.38	0.77	0.51	0.73	0.62	0.68

Annex 13. Granger causality test: NIC → NIP d(exports_kis), 5 lags

Dependent variable: d(exports_kis)	l=1		l=2		l=3		l=4		l=5	
	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.
rd	1.22	0.27	2.32	0.10	1.83	0.14	1.72	0.15	2.75	0.02
public_rd	17.92	0.00	6.83	0.00	3.07	0.03	2.89	0.02	5.70	0.00
edu_exp	0.41	0.52	3.11	0.05	3.24	0.02	2.94	0.02	2.36	0.04
rd_fte	1.88	0.17	3.27	0.04	2.20	0.09	1.45	0.22	1.68	0.14
rd_fte_gov	0.31	0.58	0.24	0.79	0.16	0.92	0.08	0.99	0.16	0.98
rd_fte_bus	4.29	0.04	4.41	0.01	3.45	0.02	2.76	0.03	3.46	0.00
doc_grad	1.00	0.32	1.18	0.31	2.46	0.06	1.61	0.17	1.58	0.17
knowledge_stock	0.75	0.39	0.99	0.37	1.04	0.37	1.42	0.23	1.85	0.10
quality_scientific	9.75	0.00	1.82	0.16	2.56	0.06	2.35	0.06	1.23	0.30
int_co_pub	4.13	0.04	0.76	0.47	0.46	0.71	0.28	0.89	0.83	0.53
pub_top10	12.69	0.00	5.37	0.01	6.45	0.00	5.69	0.00	4.60	0.00
d(employees_edu)	1.04	0.31	2.07	0.13	2.33	0.08	0.74	0.56	0.61	0.70
long_learning	2.10	0.15	0.69	0.50	0.83	0.48	1.15	0.33	0.99	0.42
ict	7.61	0.01	3.39	0.04	1.74	0.16	1.04	0.39	0.71	0.62
d(private_rd)	2.24	0.14	1.01	0.37	1.21	0.31	1.04	0.39	1.16	0.33
non_rd	2.11	0.15	0.74	0.48	1.18	0.32	1.28	0.28	1.14	0.34
sector_hitech	10.58	0.00	2.96	0.05	2.86	0.04	2.19	0.07	0.54	0.75
sector_kis	3.55	0.06	0.69	0.50	1.14	0.33	2.70	0.03	4.90	0.00
sector_industry	0.60	0.44	1.39	0.25	1.22	0.30	1.85	0.12	1.89	0.10
sector_services	4.74	0.03	3.27	0.04	3.01	0.03	2.67	0.03	1.96	0.09
pop_urban	5.50	0.02	3.13	0.04	3.62	0.01	3.31	0.01	2.32	0.04
higher_ed_rd	0.38	0.54	1.61	0.20	0.96	0.41	1.08	0.37	1.61	0.16
venture_cap	2.72	0.10	1.35	0.26	2.37	0.07	1.68	0.16	1.83	0.11
d(public_private_collab)	0.62	0.43	2.00	0.14	1.51	0.21	1.43	0.22	0.24	0.94
inno_smes_collab	6.85	0.01	2.13	0.12	2.67	0.05	1.91	0.11	0.53	0.76
new_business	3.41	0.07	2.21	0.11	1.01	0.39	0.43	0.78	0.97	0.44
exports	2.80	0.10	1.53	0.22	3.39	0.02	2.58	0.04	0.58	0.72
imports	2.52	0.11	1.86	0.16	3.52	0.02	1.98	0.10	0.39	0.85

fdi	0.37	0.54	2.00	0.14	3.41	0.02	9.49	0.00	7.33	0.00
d(multiculture)	3.18	0.08	1.13	0.33	0.76	0.52	1.00	0.41	0.68	0.64
poverty	5.31	0.02	3.15	0.04	3.85	0.01	2.02	0.09	1.19	0.31
gender_equality	1.33	0.25	1.85	0.16	1.80	0.15	1.16	0.33	0.50	0.77
corruption	10.42	0.00	4.24	0.02	5.91	0.00	4.80	0.00	4.00	0.00
legal_political	10.56	0.00	5.32	0.01	3.22	0.02	1.73	0.15	1.45	0.21
bureaucracy	0.76	0.39	1.56	0.21	1.86	0.14	2.12	0.08	1.68	0.14
ipr	17.63	0.00	2.15	0.12	1.31	0.27	2.57	0.04	0.34	0.89
gdp_capita	16.76	0.00	7.03	0.00	6.17	0.00	4.63	0.00	4.69	0.00
pop	0.07	0.79	0.22	0.80	0.06	0.98	0.04	1.00	0.07	1.00
labour_force	0.01	0.92	7.58	0.00	4.29	0.01	2.96	0.02	2.57	0.03
healthy_life	1.90	0.17	0.88	0.42	1.56	0.20	2.95	0.02	0.93	0.47
working_life	2.04	0.15	4.97	0.01	3.87	0.01	3.07	0.02	3.14	0.01

Annex 14. Correlation matrix: independent variables and patent

	patent	sector_hitech	higher_ed_rd	inno_smes_collab	imports	gender_equality	corruption	pop_urban	eu_fp
patent	1.000								
	-----								
sector_hitech	0.413	1.000							
	0.000	-----							
higher_ed_rd	0.882	0.478	1.000						
	0.000	0.000	-----						
inno_smes_collab	0.453	0.248	0.529	1.000					
	0.000	0.000	0.000	-----					
imports	-0.195	0.371	-0.208	-0.101	1.000				
	0.001	0.000	0.001	0.094	-----				
gender_equality	-0.220	0.044	-0.082	-0.138	-0.035	1.000			
	0.000	0.473	0.175	0.022	0.569	-----			
corruption	-0.767	-0.519	-0.662	-0.623	0.015	0.158	1.000		
	0.000	0.000	0.000	0.000	0.802	0.009	-----		
pop_urban	0.374	0.343	0.281	0.266	0.257	-0.270	-0.408	1.000	
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-----	
eu_fp	0.528	0.319	0.468	0.511	0.183	-0.266	-0.590	0.551	1.000
	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	-----

Annex 15. Correlation matrix: independent variables and patent_bus

	patent_bus	rd_ exp	edu_ exp	doc_ grad	knowledge_ stock	d(employees_ edu)	sector_ hitech	sector_ services	imports	working_life	eu_fp
patent_bus	1.000										
	-----										
rd	0.821	1.000									
	0.000	-----									
edu_exp	0.482	0.520	1.000								
	0.000	0.000	-----								
doc_grad	0.583	0.650	0.101	1.000							
	0.000	0.000	0.439	-----							
knowledge_stock	0.477	0.349	-0.108	0.410	1.000						
	0.000	0.006	0.409	0.001	-----						
d(employees_edu)	-0.303	-0.229	0.031	-0.134	-0.172	1.000					
	0.018	0.076	0.810	0.303	0.184	-----					
sector_hitech	0.415	0.573	0.338	0.379	0.070	-0.039	1.000				
	0.001	0.000	0.008	0.003	0.591	0.767	-----				
sector_services	0.420	0.470	0.642	0.205	0.266	0.043	0.475	1.000			
	0.001	0.000	0.000	0.112	0.038	0.744	0.000	-----			
imports	-0.253	-0.156	0.027	-0.193	-0.430	-0.029	0.355	-0.043	1.000		
	0.049	0.228	0.839	0.135	0.001	0.826	0.005	0.740	-----		
working_life	0.524	0.584	0.585	0.503	0.310	0.053	0.224	0.587	-0.300	1.000	
	0.000	0.000	0.000	0.000	0.015	0.683	0.082	0.000	0.019	-----	
eu_fp	0.452	0.573	0.538	0.263	0.123	-0.168	0.430	0.640	0.101	0.305	1.000
	0.000	0.000	0.000	0.041	0.346	0.196	0.001	0.000	0.440	0.017	-----

Annex 16. Correlation matrix: independent variables and patent_gov

	patent_gov	doc_grad	quality_scientific	int_co_pub	sector_hitech	pop_urban	eu_fp
patent_gov	1.000						
	-----						
doc_grad	0.209	1.000					
	0.020	-----					
quality_scientific	0.514	0.504	1.000				
	0.000	0.000	-----				
int_co_pub	0.446	0.578	0.733	1.000			
	0.000	0.000	0.000	-----			
sector_hitech	0.372	0.338	0.669	0.604	1.000		
	0.000	0.000	0.000	0.000	-----		
pop_urban	0.419	0.072	0.513	0.418	0.395	1.000	
	0.000	0.427	0.000	0.000	0.000	-----	
eu_fp	0.537	0.419	0.659	0.882	0.531	0.576	1.000
	0.000	0.000	0.000	0.000	0.000	0.000	-----

Annex 17. Correlation matrix: independent variables and patent_higher_ed

	patent_higher_ed	edu_exp	sector_hitech	higher_ed_rd	venture_cap	exports	eu_fp
patent_higher_ed	1.000						
	-----						
edu_exp	0.489	1.000					
	0.000	-----					
sector_hitech	0.448	0.353	1.000				
	0.000	0.005	-----				
higher_ed_rd	0.402	0.504	0.579	1.000			
	0.001	0.000	0.000	-----			
venture_cap	0.385	0.298	0.655	0.375	1.000		
	0.002	0.019	0.000	0.003	-----		
exports	0.330	0.141	0.485	0.035	0.121	1.000	
	0.009	0.275	0.000	0.786	0.347	-----	
eu_fp	0.697	0.520	0.443	0.543	0.400	0.167	1.000
	0.000	0.000	0.000	0.000	0.001	0.195	-----

Annex 18. Correlation matrix: independent variables and smes_pp

	smes_pp	rd_fte	ict	sector_services	poverty	bureaucracy	pop_urban	eu_fp
smes_pp	1.000							
	-----							
rd_fte	0.701	1.000						
	0.000	-----						
ict	0.559	0.684	1.000					
	0.000	0.000	-----					
sector_services	0.619	0.502	0.590	1.000				
	0.000	0.000	0.000	-----				
poverty	-0.589	-0.639	-0.420	-0.326	1.000			
	0.000	0.000	0.000	0.000	-----			
bureaucracy	-0.356	-0.176	-0.301	-0.361	-0.049	1.000		
	0.000	0.034	0.000	0.000	0.554	-----		
pop_urban	0.406	0.478	0.537	0.654	-0.224	-0.230	1.000	
	0.000	0.000	0.000	0.000	0.007	0.005	-----	
eu_fp	0.618	0.556	0.520	0.661	-0.413	-0.384	0.602	1.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-----

Annex 19. Correlation matrix: independent variables and trademark

	trademark	public_ rd	edu_ exp	rd_fte_ gov	rd_fte_ bus	sector_ services	d(public_ private_collab)	new_ business	fdi	female_ manage	eu_fp
trademark	1.000										
	-----										
public_rd	-0.173	1.000									
	0.021	-----									
edu_exp	0.374	-0.179	1.000								
	0.000	0.017	-----								
rd_fte_gov	-0.352	0.552	-0.302	1.000							
	0.000	0.000	0.000	-----							
rd_fte_bus	0.308	0.263	0.296	0.097	1.000						
	0.000	0.000	0.000	0.198	-----						
sector_services	0.603	-0.240	0.461	-0.398	0.397	1.000					
	0.000	0.001	0.000	0.000	0.000	-----					
d(public_ private_collab)	-0.193	0.030	-0.129	0.132	-0.024	-0.096	1.000				
	0.010	0.692	0.087	0.080	0.756	0.202	-----				
new_business	0.330	-0.355	0.338	-0.284	-0.367	0.319	-0.079	1.000			
	0.000	0.000	0.000	0.000	0.000	0.000	0.299	-----			
fdi	0.263	-0.105	0.094	-0.198	-0.049	0.204	0.009	0.259	1.000		
	0.000	0.165	0.213	0.008	0.515	0.006	0.901	0.001	-----		
female_ manage	-0.526	0.009	-0.055	0.219	-0.162	-0.256	0.250	-0.122	-0.124	1.000	
	0.000	0.902	0.468	0.004	0.031	0.001	0.001	0.107	0.099	-----	
eu_fp	0.497	-0.118	0.416	-0.244	0.556	0.642	-0.090	-0.002	0.215	-0.218	1.000
	0.000	0.118	0.000	0.001	0.000	0.000	0.235	0.978	0.004	0.004	-----

Annex 20. Correlation matrix: independent variables and design

	design	edu_ exp	rd_fte_ bus	ict	sector_ services	new_ business	imports	female_ manage	pop_ urban	working_ life	eu_fp
design	1.000										
	-----										
edu_exp	0.212	1.000									
	0.012	-----									
rd_fte_bus	0.739	0.338	1.000								
	0.000	0.000	-----								
ict	0.578	0.175	0.662	1.000							
	0.000	0.039	0.000	-----							
sector_services	0.381	0.512	0.446	0.599	1.000						
	0.000	0.000	0.000	0.000	-----						
new_business	-0.321	0.290	-0.354	-0.048	0.323	1.000					
	0.000	0.001	0.000	0.573	0.000	-----					
imports	-0.389	0.053	-0.114	-0.280	-0.082	0.058	1.000				
	0.000	0.537	0.181	0.001	0.335	0.498	-----				
gender_equality	-0.363	-0.088	-0.200	-0.150	-0.266	-0.101	0.240	1.000			
	0.000	0.302	0.018	0.078	0.002	0.235	0.004	-----			
pop_urban	0.318	0.332	0.416	0.549	0.649	0.115	-0.159	-0.158	1.000		
	0.000	0.000	0.000	0.000	0.000	0.176	0.062	0.063	-----		
working_life	0.473	0.452	0.518	0.647	0.630	0.219	-0.198	-0.270	0.409	1.000	
	0.000	0.000	0.000	0.000	0.000	0.010	0.020	0.001	0.000	-----	
eu_fp	0.421	0.419	0.591	0.519	0.658	0.024	0.071	-0.285	0.601	0.428	1.000
	0.000	0.000	0.000	0.000	0.000	0.777	0.407	0.001	0.000	0.000	-----

Annex 21. Correlation matrix: independent variables and smes_mo

	smes_mo	rd_ fte	doc_ grad	sector_ hitech	sector_ industry	venture_ cap	inno_smes_ collab	pop	pop_ urban	healthy_ life	eu_ fp
smes_mo	1.000										
	-----										
rd	0.582										
	0.000										
rd_fte	0.650	1.000									
	0.000	-----									
doc_grad	0.292	0.503	1.000								
	0.000	0.000	-----								
sector_hitech	0.389	0.626	0.374	1.000							
	0.000	0.000	0.000	-----							
sector_industry	-0.437	-0.347	-0.009	-0.158	1.000						
	0.000	0.000	0.906	0.046	-----						
venture_cap	0.353	0.373	0.093	0.455	-0.456	1.000					
	0.000	0.000	0.242	0.000	0.000	-----					
inno_smes_collab	0.650	0.571	0.255	0.321	-0.478	0.353	1.000				
	0.000	0.000	0.001	0.000	0.000	0.000	-----				
pop	0.179	0.067	0.077	-0.078	-0.034	0.182	0.009	1.000			
	0.023	0.400	0.332	0.325	0.673	0.022	0.905	-----			
pop_urban	0.313	0.541	0.073	0.226	-0.549	0.489	0.500	0.192	1.000		
	0.000	0.000	0.361	0.004	0.000	0.000	0.000	0.015	-----		
healthy_life	0.223	0.152	-0.040	0.205	-0.454	0.350	0.192	0.175	0.411	1.000	
	0.005	0.055	0.619	0.009	0.000	0.000	0.015	0.027	0.000	-----	
eu_fp	0.485	0.568	0.222	0.375	-0.543	0.375	0.656	-0.071	0.658	0.300	1.000
	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.373	0.000	0.000	-----

Annex 22. Correlation matrix: independent variables and inno_sales

	inno_sales	quality_scientific	exports	imports	gender_equality	eu_fp
inno_sales	1.000					
	-----					
quality_scientific	-0.132	1.000				
	0.035	-----				
exports	-0.265	0.028	1.000			
	0.000	0.653	-----			
imports	-0.243	-0.056	0.985	1.000		
	0.000	0.377	0.000	-----		
gender_equality	-0.240	0.017	-0.201	-0.154	1.000	
	0.000	0.785	0.001	0.014	-----	
eu_fp	-0.110	0.510	0.432	0.372	-0.353	1.000
	0.081	0.000	0.000	0.000	0.000	-----

Annex 23. Correlation matrix: independent variables and exports_hitech

	exports_hitech	edu_exp	long_learning	sector_services	venture_cap	new_business	d(multiculture)	eu_fp
exports_hitech	1.000							
	-----							
edu_exp	0.192	1.000						
	0.006	-----						
long_learning	0.205	0.637	1.000					
	0.003	0.000	-----					
sector_services	0.440	0.524	0.601	1.000				
	0.000	0.000	0.000	-----				
venture_cap	0.347	0.243	0.401	0.505	1.000			
	0.000	0.001	0.000	0.000	-----			
new_business	0.378	0.313	0.074	0.300	0.081	1.000		
	0.000	0.000	0.294	0.000	0.250	-----		
d(multiculture)	0.240	0.107	0.157	0.005	0.063	0.061	1.000	
	0.001	0.127	0.025	0.944	0.374	0.386	-----	
eu_fp	0.182	0.425	0.371	0.633	0.286	0.000	0.154	1.000
	0.009	0.000	0.000	0.000	0.000	0.996	0.029	-----

Annex 24. Correlation matrix: independent variables and d(exports_kis)

	d(exports_ kis)	public_ rd	edu_ exp	ict	sector_ hitech	sector_ services	inno_ smes_ collab	fdi	corruption	pop_ urban	labour_ force	healthy _life	eu_ fp
d(exports_ kis)	1.000												
	-----												
public_ rd	-0.253	1.000											
	0.001	-----											
edu_ exp	0.349	-0.241	1.000										
	0.000	0.002	-----										
ict	0.563	-0.025	0.290	1.000									
	0.000	0.757	0.000	-----									
sector_ hitech	0.565	-0.034	0.217	0.399	1.000								
	0.000	0.671	0.006	0.000	-----								
sector_ services	0.685	-0.295	0.544	0.658	0.397	1.000							
	0.000	0.000	0.000	0.000	0.000	-----							
inno_ smes_collab	0.496	-0.062	0.511	0.547	0.324	0.636	1.000						
	0.000	0.439	0.000	0.000	0.000	0.000	-----						
fdi	0.228	-0.193	0.050	0.035	0.125	0.180	0.061	1.000					
	0.004	0.015	0.528	0.662	0.116	0.023	0.442	-----					
corruption	-0.667	0.069	-0.643	-0.725	-0.515	-0.707	-0.634	-0.089	1.000				
	0.000	0.373	0.000	0.000	0.000	0.000	0.000	0.250	-----				
pop_ urban	0.523	0.059	0.426	0.611	0.231	0.690	0.500	0.014	-0.559	1.000			
	0.000	0.462	0.000	0.000	0.003	0.000	0.000	0.858	0.000	-----			
labour_	0.265	0.376	-	0.287	-0.054	0.124	0.055	-	-0.189	0.208	1.000		

force			0.268					0.112					
	0.001	0.000	0.001	0.000	0.500	0.120	0.491	0.159	0.014	0.009	-----		
healthy_ life	0.404	-0.241	0.093	0.335	0.219	0.452	0.191	0.146	-0.212	0.410	0.160	1.000	
	0.000	0.002	0.243	0.000	0.006	0.000	0.016	0.066	0.006	0.000	0.044	-----	
eu_ fp	0.555	-0.119	0.449	0.549	0.376	0.644	0.656	0.141	-0.615	0.658	-0.055	0.303	1.000
	0.000	0.134	0.000	0.000	0.000	0.000	0.000	0.075	0.000	0.000	0.491	0.000	-----

Annex 25. Influence of individual EU Framework programmes on member states' innovation performance: patent applications as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
c	4.817102	7.039535	0.684293	0.4942
patent(-1)	0.750091	0.050655	14.80783	0.0000
patent(-2)	0.182569	0.049643	3.677636	0.0003
sector_hitech	-0.109134	0.606273	-0.180008	0.8573
higher_ed_rd	7.106654	1.781049	3.990150	0.0001
inno_smes_collab	-0.132808	0.130488	-1.017783	0.3095
imports	-0.007793	0.026084	-0.298760	0.7653
gender_equality	-0.109644	0.087454	-1.253734	0.2108
corruption	-0.010590	0.008245	-1.284400	0.1999
pop_urban	0.026011	0.062090	0.418918	0.6755
eu_fp	0.243583	0.127546	1.909766	0.0570
dum2	-0.950863	1.929860	-0.492711	0.6225
dum3	-3.766023	2.304824	-1.633974	0.1032
dum2*eu_fp	-0.395262	0.125738	-3.143540	0.0018
dum3*eu_fp	-0.335705	0.131957	-2.544043	0.0114
Root MSE	10.55897	R-squared		0.988371
Mean dependent var	86.46651	Adjusted R-squared		0.987899
S.D. dependent var	98.05271	S.E. of regression		10.78607
Akaike info criterion	7.635161	Sum squared resid		40137.03
Schwarz criterion	7.797082	Log likelihood		-1359.329
Hannan-Quinn criterion	7.699544	F-statistic		2094.496
Prob(F-statistic)	0.000000			

Annex 26. Influence of individual EU Framework programmes on member states' innovation performance: business patent applications as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
c	23.69731	23.12901	1.024571	0.3072
patent_bus(-1)	1.651677	0.141071	11.70812	0.0000
patent_bus(-2)	-0.682340	0.142068	-4.802909	0.0000
rd	-4.555265	4.666150	-0.976236	0.3305
edu_exp	2.885613	2.151088	1.341467	0.1817
doc_grad	-0.447937	2.937824	-0.152472	0.8790
knowledge_stock	-8.329665	6.421376	-1.297178	0.1965
d(employees_edu)	-2.214344	1.541552	-1.436438	0.1529
sector_hitech	1.908879	1.695283	1.125994	0.2619
sector_services	-6.409350	35.95748	-0.178248	0.8588
imports	-0.208242	0.117851	-1.766993	0.0792
working_life	-0.823139	0.775605	-1.061287	0.2902
eu_fp	0.271197	0.284138	0.954455	0.3413
dum2	4.099069	4.410553	0.929378	0.3541
eu_fp*dum2	-0.553953	0.298804	-1.853901	0.0657
Root MSE	16.91940	R-squared		0.956607
Mean dependent var	60.84111	Adjusted R-squared		0.952662
S.D. dependent var	81.46344	S.E. of regression		17.72425
Akaike info criterion	8.672313	Sum squared resid		48378.94
Schwarz criterion	8.950115	Log likelihood		-717.8105
Hannan-Quinn criter.	8.785050	F-statistic		242.4960
Prob(F-statistic)	0.000000			

Annex 27. Influence of individual EU Framework programmes on member states' innovation performance: higher education institutions' patent applications as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
c	-0.040172	0.653607	-0.061461	0.9511
patent_higher_ed(-1)	1.167131	0.094294	12.37761	0.0000
patent_higher_ed(-2)	-0.338401	0.133107	-2.542319	0.0120
patent_higher_ed(-3)	0.440445	0.135608	3.247929	0.0014
patent_higher_ed(-4)	-0.448714	0.106330	-4.220007	0.0000
higher_ed_rd	-0.175113	0.198308	-0.883039	0.3786
edu_exp	0.076520	0.128035	0.597647	0.0410
sector_hitech	-0.018048	0.127072	-0.142027	0.8872
venture_cap	0.502296	1.408265	0.356677	0.7218
exports	-0.003500	0.007043	-0.497014	0.6199
eu_fp	0.048524	0.022153	2.190421	0.0300
dum2	-0.082241	0.339055	-0.242560	0.8087
dum2*eu_fp	-0.051755	0.021141	-2.448124	0.0155
Root MSE	1.229757	R-squared		0.886585
Mean dependent var	3.178202	Adjusted R-squared		0.876756
S.D. dependent var	3.662797	S.E. of regression		1.285866
Akaike info criterion	3.422243	Sum squared resid		248.0178
Schwarz criterion	3.686866	Log likelihood		-266.6239
Hannan-Quinn criterion	3.529670	F-statistic		90.19843
Prob(F-statistic)	0.000000			

Annex 28. Influence of individual EU Framework programmes on member states' innovation performance: trademark applications as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
trademark(-1)	1.220534	0.022286	54.76791	0.0000
public_rd	27.73781	14.85055	1.867797	0.0632
edu_exp	1.058824	2.117658	0.499997	0.6176
rd_fte_gov	48.32017	24.45550	1.975840	0.0495
rd_fte_bus	-17.39229	6.531749	-2.662732	0.0083
sector_services	-76.29148	23.01243	-3.315230	0.0011
d(public_private_collab)	-21.62264	4.783689	-4.520077	0.0000
new_business	0.894134	0.454989	1.965178	0.0507
fdi	-0.100385	0.062616	-1.603187	0.1104
gender_equality	0.393308	0.297658	1.321342	0.1878
eu_fp	0.334572	0.240538	1.390931	0.1657
dum3	6.651421	5.415137	1.228302	0.2207
dum3*eu_fp	-0.222613	0.252208	-0.882657	0.3784
Root MSE	23.90376	R-squared		0.974969
Mean dependent var	158.9907	Adjusted R-squared		0.973331
S.D. dependent var	151.4172	S.E. of regression		24.72732
Akaike info criterion	9.316953	Sum squared resid		130848.2
Schwarz criterion	9.541869	Log likelihood		-1051.791
Hannan-Quinn criterion	9.407689			

Annex 29. Influence of individual EU Framework programmes on member states' innovation performance: design applications as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
c	6.588063	16.92669	0.389212	0.6977
design(-1)	1.141029	0.068997	16.53745	0.0000
design(-2)	-0.153546	0.071479	-2.148129	0.0334
edu_exp	1.819623	1.219399	1.492229	0.1378
rd_fte_bus	-0.003481	5.228012	-0.000666	0.9995
ict	2.797032	2.228955	1.254862	0.2116
sector_services	-20.62219	20.13423	-1.024235	0.3074
new_business	0.176647	0.312227	0.565765	0.5724
imports_gs	0.028635	0.061864	0.462871	0.6442
gender_equality	-0.301739	0.179746	-1.678699	0.0954
pop_urban	0.125076	0.125036	1.000328	0.3188
working_life	-0.315666	0.556476	-0.567258	0.5714
eu_fp	-0.240228	0.154066	-1.559258	0.1211
dum3	-2.709629	3.101914	-0.873534	0.3838
dum3*eu_fp	0.078342	0.136898	0.572267	0.5680
Root MSE	10.79523	R-squared		0.980176
Mean dependent var	101.5315	Adjusted R-squared		0.978111
S.D. dependent var	76.91251	S.E. of regression		11.37917
Akaike info criterion	7.796086	Sum squared resid		18645.92
Schwarz criterion	8.103603	Log likelihood		-607.6869
Hannan-Quinn criterion	7.920958	F-statistic		474.6598
		Prob(F-statistic)		0.000000

Annex 30. Influence of individual EU Framework programmes on member states' innovation performance: marketing and organisational innovations as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
c	2.156946	3.513701	0.613867	0.5403
smes_mo(-1)	0.779353	0.043229	18.02830	0.0000
smes_mo(2)	0.297038	0.032847	9.043169	0.0000
smes_mo(-3)	-0.098560	0.033117	-2.976108	0.0034
rd_fte	-0.327216	0.645274	-0.507097	0.6129
doc_grad	0.088614	0.278426	0.318269	0.7508
sector_hitech	0.305489	0.188556	1.620148	0.1075
sector_industry	-2.908739	3.598621	-0.808293	0.4203
venture_cap	-2.652130	3.155008	-0.840610	0.4020
inno_smes_collab	0.024334	0.037900	0.642057	0.5219
pop	6.18E-09	7.59E-09	0.814009	0.4170
pop_urban	0.013601	0.022011	0.617902	0.5377
healthy_life	-0.039979	0.052242	-0.765277	0.4454
eu_fp	-0.020075	0.021798	-0.920922	0.3587
dum3	-1.935070	0.570418	-3.392373	0.0009
eu_fp*dum3	0.080037	0.033624	2.380348	0.0187
Root MSE	1.685995	R-squared		0.978441
Mean dependent var	34.54859	Adjusted R-squared		0.975941
S.D. dependent var	11.51974	S.E. of regression		1.786827
Akaike info criterion	4.101944	Sum squared resid		440.5998
Schwarz criterion	4.435739	Log likelihood		-300.9006
Hannan-Quinn criterion	4.237524	F-statistic		391.4313
Prob(F-statistic)	0.000000			

Annex 31. Influence of individual EU Framework programmes on member states' innovation performance: innovative sales as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
c	1.160002	0.927229	1.251041	0.2122
inno_sales(-1)	1.632366	0.063467	25.71981	0.0000
inno_sales(-2)	-1.261302	0.114097	-11.05468	0.0000
inno_sales(-3)	0.897499	0.128902	6.962643	0.0000
inno_sales(-4)	-0.382846	0.072765	-5.261413	0.0000
quality_scientific	0.092173	0.140785	0.654708	0.5133
exports	-0.024117	0.016990	-1.419428	0.1571
imports	0.023990	0.019542	1.227611	0.2208
gender_equality	-0.012797	0.015174	-0.843371	0.3999
eu_fp	0.005153	0.009838	0.523741	0.6010
dum3	0.310060	0.270858	1.144734	0.2535
dum3*eu_fp	-0.005283	0.011552	-0.457350	0.6478
Root MSE	1.288645	R-squared		0.910624
Mean dependent var	12.06524	Adjusted R-squared		0.906405
S.D. dependent var	4.319285	S.E. of regression		1.321412
Akaike info criterion	3.443019	Sum squared resid		406.8484
Schwarz criterion	3.614509	Log likelihood		-409.7698
Hannan-Quinn criterion	3.512078	F-statistic		215.8159
Prob(F-statistic)	0.000000			

Annex 32. Influence of individual EU Framework programmes on member states' innovation performance: exports of high technology products as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
c	-0.027855	2.244502	-0.012410	0.9901
exports_hitech(-1)	1.122332	0.066947	16.76456	0.0000
exports_hitech(-2)	-0.356603	0.097097	-3.672645	0.0003
exports_hitech(-3)	0.119233	0.062283	1.914357	0.0570
edu_exp	-0.177738	0.203091	-0.875163	0.3825
long_learning	-0.033052	0.026550	-1.244922	0.2146
sector_services	4.527958	3.454233	1.310843	0.1914
venture_cap	3.410539	2.311610	1.475396	0.1417
new_business	-0.018552	0.037967	-0.488639	0.6256
d(multiculture)	82.77119	32.22005	2.568934	0.0109
eu_fp	-0.015821	0.044731	-0.353679	0.7239
dum2	-0.933235	0.865237	-1.078589	0.2821
dum3	-0.462615	0.911110	-0.507749	0.6122
dum2*eu_fp	0.026599	0.047205	0.563484	0.5737
dum3*eu_fp	0.020411	0.046908	0.435139	0.6639
Root MSE	1.972472	R-squared		0.919501
Mean dependent var	13.57021	Adjusted R-squared		0.913552
S.D. dependent var	6.968004	S.E. of regression		2.048730
Akaike info criterion	4.342571	Sum squared resid		852.0511
Schwarz criterion	4.590174	Log likelihood		-459.5115
Hannan-Quinn criterion	4.442570	F-statistic		154.5839
Prob(F-statistic)	0.000000			

Annex 33. Influence of individual EU Framework programmes on member states' innovation performance: exports of knowledge-intensive services as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
c	-4.999421	4.957901	-1.008374	0.3149
exports_kis(-1)	0.975319	0.020345	47.93900	0.0000
public_rd	-1.284918	3.299361	-0.389445	0.6975
edu_exp	0.032977	0.335888	0.098177	0.9219
ict	1.251696	0.430743	2.905903	0.0042
sector_hitech	0.192405	0.233330	0.824603	0.4109
sector_services	-4.021471	4.935488	-0.814807	0.4165
inno_smes_collab	0.000808	0.049024	0.016486	0.9869
fdi	-0.005088	0.011510	-0.442022	0.6591
corruption	0.002724	0.003558	0.765707	0.4451
pop_urban	-0.000715	0.031231	-0.022893	0.9818
labour_force	-3.00E-05	3.46E-05	-0.868987	0.3862
healthy_life	0.026005	0.064612	0.402475	0.6879
eu_fp	-0.020299	0.035998	-0.563882	0.5737
dum3	-0.070932	0.671540	-0.105626	0.9160
dum3*eu_fp	-0.002087	0.030684	-0.068027	0.9459
Root MSE	2.480335	R-squared		0.983963
Mean dependent var	53.40522	Adjusted R-squared		0.982252
S.D. dependent var	19.64503	S.E. of regression		2.617116
Akaike info criterion	4.858258	Sum squared resid		1027.395
Schwarz criterion	5.175658	Log likelihood		-388.6645
Hannan-Quinn criterion	4.987083	F-statistic		575.2096
Prob(F-statistic)	0.000000			

Annex 34. EU investment influence disparities across the member states: patent applications as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
patent(-1)	0.816986	0.028063	29.11267	0.0000
higher_ed_rd	3.291459	0.836722	3.933756	0.0001
dum_it	9.865884	3.140589	3.141412	0.0018
dum_ie	9.806554	3.058298	3.206540	0.0014
dum_fi*eu_fp	-0.690660	0.386194	-1.788378	0.0744
dum_fi	48.24632	10.00798	4.820783	0.0000
dum_se	44.13796	7.686196	5.742497	0.0000
dum_nl*eu_fp	-0.083938	0.211157	-0.397517	0.6912
dum_at	32.78954	5.535742	5.923241	0.0000
dum_lu*eu_fp	0.328814	0.082527	3.984346	0.0001
dum_uk	10.02286	3.368704	2.975288	0.0031
dum_dk	35.30569	6.067140	5.819165	0.0000
dum_es	2.448937	2.694355	0.908914	0.3639
dum_fr	18.55144	4.140522	4.480459	0.0000
dum_be	19.24465	4.219444	4.560944	0.0000
dum_si	5.270008	2.953705	1.784202	0.0751
dum_de	61.84005	11.68433	5.292564	0.0000
dum_de*eu_fp	-2.193570	0.836652	-2.621843	0.0090
dum_nl	34.03202	8.195220	4.152667	0.0000
R-squared	0.988742	Mean dependent var		84.19062
Adjusted R-squared	0.988292	S.D. dependent var		96.17018
S.E. of regression	10.40577	Akaike info criterion		7.562184
Sum squared resid	48834.33	Schwarz criterion		7.730061
Log likelihood	-1758.113	Hannan-Quinn criterion		7.628231

Annex 35. EU investment influence disparities across the member states: business patent applications as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
patent_bus(-1)	1.280084	0.046465	27.54937	0.0000
dum_ee	3.550063	6.680625	0.531397	0.5956
working_life	-0.076965	0.360342	-0.213590	0.8310
dum_se*eu_fp	-4.476257	0.616742	-7.257905	0.0000
dum_lu	13.53796	10.76547	1.257536	0.2096
dum_dk*eu_fp	-3.415291	0.475894	-7.176580	0.0000
dum_de	-71.58036	11.92811	-6.000982	0.0000
dum_cz	3.125506	5.392549	0.579597	0.5627
dum_nl	-42.52335	8.231096	-5.166183	0.0000
eu_fp	-0.907340	0.152422	-5.952820	0.0000
dum_fr*eu_fp	-2.944138	2.320167	-1.268934	0.2056
dum_at*eu_fp	-2.466770	0.515829	-4.782145	0.0000
dum_pt	1.464174	5.501963	0.266118	0.7904
dum_es	8.783028	5.442522	1.613779	0.1077
dum_fi	-67.46477	9.949820	-6.780501	0.0000
dum_lt	0.137479	5.356167	0.025667	0.9795
dum_lv	-0.841186	5.401576	-0.155730	0.8764
dum_fr	4.215540	23.35317	0.180513	0.8569
edu_exp	6.212508	1.667628	3.725355	0.0002
sector_services	-48.91957	20.45567	-2.391492	0.0175
dum_pl	-2.639451	5.387121	-0.489956	0.6246
dum_uk	-10.57172	5.656933	-1.868808	0.0627
dum_el	18.17529	7.499040	2.423682	0.0160
dum_hu	-0.639018	5.520597	-0.115752	0.9079
dum_sk	5.507103	5.396511	1.020493	0.3084
R-squared	0.963786	Mean dependent var		68.40819
Adjusted R-squared	0.960578	S.D. dependent var		83.45151

S.E. of regression	16.56919	Akaike info criterion	8.533646
Sum squared resid	74399.84	Schwarz criterion	8.845331
Log likelihood	-1237.980	Hannan-Quinn criterion	8.658438

Annex 36. EU investment influence disparities across the member states: government patent applications as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
dum_nl	26.22648	2.550814	10.28161	0.0000
dum_fr	21.55218	3.064258	7.033409	0.0000
quality_scientific	0.209587	0.052764	3.972150	0.0001
dum_de	5.192166	0.540440	9.607290	0.0000
dum_fi	10.15702	2.592939	3.917186	0.0001
dum_nl*eu_fp	-0.663870	0.110795	-5.991846	0.0000
dum_fr*eu_fp	-1.016974	0.274741	-3.701572	0.0003
eu_fp	0.040473	0.009751	4.150499	0.0001
dum_si	1.484735	0.535696	2.771599	0.0064
int_co_pub	-0.001003	0.000369	-2.720276	0.0074
dum_fi*eu_fp	-0.285537	0.134841	-2.117576	0.0361
R-squared	0.883123	Mean dependent var		2.191762
Adjusted R-squared	0.874269	S.D. dependent var		3.565720
S.E. of regression	1.264353	Akaike info criterion		3.380801
Sum squared resid	211.0136	Schwarz criterion		3.608712
Log likelihood	-230.7273	Hannan-Quinn criterion		3.473413

Annex 37. EU investment influence disparities across the member states: higher education institutions' patent applications as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
patent_higher_ed(-1)	1.097598	0.089580	12.25267	0.0000
patent_higher_ed(-2)	-0.238903	0.090748	-2.632601	0.0092
dum_be	16.02593	3.880088	4.130300	0.0001
dum_be*eu_fp	-0.320337	0.082478	-3.883902	0.0001
inno_smes_collab	0.020340	0.010557	1.926760	0.0555
R-squared	0.869796	Mean dependent var		2.930158
Adjusted R-squared	0.867010	S.D. dependent var		3.663065
S.E. of regression	1.335837	Akaike info criterion		3.442690
Sum squared resid	333.6940	Schwarz criterion		3.527520
Log likelihood	-325.4982	Hannan-Quinn criterion		3.477047

Annex 38. EU investment influence disparities across the member states: product and process innovations as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
smes_pp(-1)	1.535525	0.062635	24.51550	0.0000
smes_pp(-2)	-1.127368	0.114104	-9.880180	0.0000
smes_pp(-3)	0.663340	0.130633	5.077901	0.0000
smes_pp(-4)	-0.173181	0.076616	-2.260357	0.0248
dum_lt*eu_fp	2.344067	0.920714	2.545923	0.0116
dum_pt*eu_fp	0.722598	0.241563	2.991344	0.0031
dum_pl	-1.716608	0.730297	-2.350561	0.0197
dum_el*eu_fp	0.717890	0.241132	2.977162	0.0033
dum_el	-9.301634	3.359861	-2.768458	0.0061
dum_dk	-0.888733	0.710304	-1.251201	0.2123
dum_bg*eu_fp	-1.577116	2.002403	-0.787612	0.4318
dum_es	-2.283558	0.752879	-3.033102	0.0027
dum_si	0.231241	0.738177	0.313259	0.7544
dum_cy	-0.709782	0.711488	-0.997603	0.3196
dum_ie	0.861555	0.775253	1.111321	0.2677
dum_it	0.853616	0.695450	1.227429	0.2210
dum_sk	-0.621011	0.673160	-0.922531	0.3573
dum_lt	-4.833116	2.221082	-2.176019	0.0307
dum_mt	0.290246	1.911865	0.151813	0.8795
dum_ee	-7.528933	1.801759	-4.178658	0.0000
dum_fi	-5.650995	3.276654	-1.724623	0.0861
dum_fi*eu_fp	0.318512	0.148482	2.145120	0.0331
dum_ee*eu_fp	0.783773	0.172943	4.531986	0.0000
dum_hr	0.030685	0.711355	0.043137	0.9656
dum_pt	-2.611943	1.819540	-1.435497	0.1526
dum_cz	-0.421600	0.687923	-0.612859	0.5406
pop_urban	0.048386	0.011530	4.196357	0.0000

dum_mt*eu_fp	-0.270991	0.182212	-1.487235	0.1385
dum_hu	-1.723264	0.779919	-2.209541	0.0282
dum_be	0.183399	0.725195	0.252896	0.8006
dum_bg	0.141414	3.036684	0.046569	0.9629
dum_ro	-2.577374	0.739831	-3.483734	0.0006
dum_at	1.565275	0.788861	1.984223	0.0485
dum_lu	-0.279358	0.723094	-0.386337	0.6996
R-squared	0.975727	Mean dependent var		31.50485
Adjusted R-squared	0.971894	S.D. dependent var		11.46750
S.E. of regression	1.922501	Akaike info criterion		4.274239
Sum squared resid	772.4659	Schwarz criterion		4.762980
Log likelihood	-485.3200	Hannan-Quinn criterion		4.471099

Annex 39. EU investment influence disparities across the member states: trademark applications as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
trademark(-1)	0.893968	0.017042	52.45583	0.0000
dum_lu	185.3869	25.15811	7.368874	0.0000
dum_cy*eu_fp	4.206143	0.618508	6.800463	0.0000
public_rd	20.05903	5.943300	3.375066	0.0008
dum_lv*eu_fp	2.311171	3.402552	0.679246	0.4973
eu_fp	1.316085	0.222177	5.923599	0.0000
dum_be	-47.61384	13.28932	-3.582866	0.0004
fdi	-0.143532	0.048240	-2.975370	0.0031
dum_mt*eu_fp	15.92070	1.609228	9.893379	0.0000
dum_el*eu_fp	-0.968344	0.774552	-1.250198	0.2119
R-squared	0.987890	Mean dependent var		185.8409
Adjusted R-squared	0.987639	S.D. dependent var		330.1962
S.E. of regression	36.71092	Akaike info criterion		10.06624
Sum squared resid	586245.7	Schwarz criterion		10.15833
Log likelihood	-2229.739	Hannan-Quinn criterion		10.10255

Annex 40. EU investment influence disparities across the member states: design applications as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
design(-1)	1.452097	0.044831	32.39066	0.0000
dum_bg	12.77979	11.97221	1.067454	0.2871
dum_dk*eu_fp	-1.062173	2.009035	-0.528698	0.5976
dum_nl*eu_fp	-0.390576	1.002766	-0.389498	0.6973
design(-2)	-0.890851	0.046786	-19.04077	0.0000
dum_mt	68.89654	13.41541	5.135627	0.0000
dum_uk	5.803164	11.46097	0.506341	0.6132
eu_fp	0.066413	0.218591	0.303823	0.7616
dum_el	-7.561764	47.83872	-0.158068	0.8746
ict	1.522141	2.904961	0.523980	0.6009
dum_pl	21.90510	11.52733	1.900275	0.0589
dum_lv	-0.978509	11.91761	-0.082106	0.9346
dum_at	68.61287	13.94144	4.921505	0.0000
dum_de	64.89958	12.74995	5.090184	0.0000
dum_cy	9.523646	12.40256	0.767878	0.4435
rd_fte_bus	31.05952	10.53263	2.948886	0.0036
dum_nl	37.18025	35.74735	1.040084	0.2996
dum_lu	312.0528	23.06545	13.52901	0.0000
dum_se	25.60864	12.70992	2.014854	0.0453
dum_pt	17.69393	11.35317	1.558502	0.1208
dum_dk	93.56169	56.60492	1.652890	0.1000
pop_urban	0.025527	0.210002	0.121554	0.9034
dum_el*eu_fp	-0.230169	3.049927	-0.075467	0.9399
dum_fr	-2.755197	18.25569	-0.150923	0.8802
dum_it	45.51939	11.66297	3.902900	0.0001
R-squared	0.975983	Mean dependent var		133.4413
Adjusted R-squared	0.972996	S.D. dependent var		184.1689

S.E. of regression	30.26414	Akaike info criterion	9.765357
Sum squared resid	176772.3	Schwarz criterion	10.15349
Log likelihood	-1039.424	Hannan-Quinn criterion	9.922129

Annex 41. EU investment influence disparities across the member states: marketing and organisational innovations as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
smes_mo(-1)	0.819138	0.042805	19.13667	0.0000
smes_mo(2)	0.314798	0.036300	8.672124	0.0000
smes_mo(-3)	-0.129454	0.036930	-3.505434	0.0006
dum_fr*eu_fp	0.090738	0.474395	0.191270	0.8485
dum_fr	-1.621984	5.640433	-0.287564	0.7740
dum_el	-0.557241	0.884244	-0.630189	0.5294
dum_cy	3.425362	2.590972	1.322037	0.1879
dum_cy*eu_fp	-0.240057	0.187647	-1.279299	0.2025
dum_lv	-0.176823	0.993096	-0.178052	0.8589
dum_fi	-0.740220	1.065330	-0.694827	0.4881
dum_lt	-0.993453	0.807374	-1.230475	0.2202
dum_pl	-0.391229	0.784605	-0.498631	0.6187
dum_cz*eu_fp	-1.515903	0.886455	-1.710074	0.0891
dum_cz	4.898416	2.822316	1.735602	0.0844
dum_pt	-1.260345	0.870929	-1.447127	0.1497
dum_hr	-0.776561	1.018285	-0.762617	0.4467
dum_hu	-0.627975	0.782055	-0.802981	0.4231
dum_it*eu_fp	-0.042817	0.097960	-0.437087	0.6626
dum_sk	-0.020515	0.904540	-0.022680	0.9819
dum_be	-0.035205	0.979648	-0.035937	0.9714
dum_ie	0.158946	0.935332	0.169935	0.8653
dum_mt*eu_fp	0.009239	0.286410	0.032259	0.9743
dum_nl	-0.233515	0.846700	-0.275795	0.7830
dum_lu	-1.586081	6.404672	-0.247644	0.8047
dum_at	-0.960282	0.884343	-1.085870	0.2791
dum_ee	-0.897197	0.844247	-1.062719	0.2894
dum_lu*eu_fp	0.023717	0.114881	0.206447	0.8367

dum_es	-0.130861	0.907899	-0.144136	0.8856
dum_uk	0.014668	0.910761	0.016105	0.9872
dum_se	-0.158941	1.024346	-0.155163	0.8769
dum_mt	-0.698362	2.051308	-0.340447	0.7339
R-squared	0.971172	Mean dependent var		35.43851
Adjusted R-squared	0.966085	S.D. dependent var		11.59445
S.E. of regression	2.135243	Akaike info criterion		4.495989
Sum squared resid	775.0743	Schwarz criterion		5.005454
Log likelihood	-420.8469	Hannan-Quinn criterion		4.702140

Annex 42. EU investment influence disparities across the member states: exports of high technology products as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
exports_hitech(-1)	1.068888	0.053866	19.84356	0.0000
sector_services	1.131231	0.327983	3.449053	0.0006
exports_hitech(-2)	-0.145087	0.050538	-2.870860	0.0043
dum_ie*eu_fp	0.014397	0.027175	0.529804	0.5966
dum_fr*eu_fp	0.089569	0.056638	1.581431	0.1147
d(multiculture)	28.50534	24.99725	1.140339	0.2549
dum_uk*eu_fp	0.320144	0.153338	2.087831	0.0375
dum_uk	-3.824542	2.150874	-1.778133	0.0763
R-squared	0.943338	Mean dependent var		14.29079
Adjusted R-squared	0.942195	S.D. dependent var		9.266278
S.E. of regression	2.227860	Akaike info criterion		4.462238
Sum squared resid	1722.286	Schwarz criterion		4.549497
Log likelihood	-784.0472	Hannan-Quinn criterion		4.496952

Annex 43. EU investment influence disparities across the member states: exports of knowledge intensive services as a proxy for NIP

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
exports_kis(-1)	0.979714	0.011495	85.23314	0.0000
ict	0.955679	0.254108	3.760912	0.0002
sector_services	-5.704770	2.053109	-2.778601	0.0060
dum_cy	1.485078	0.970033	1.530957	0.1274
dum_dk*eu_fp	-0.029717	0.032760	-0.907102	0.3655
R-squared	0.984498	Mean dependent var		53.62721
Adjusted R-squared	0.984175	S.D. dependent var		19.39378
S.E. of regression	2.439655	Akaike info criterion		4.646643
Sum squared resid	1142.768	Schwarz criterion		4.729974
Log likelihood	-452.6944	Hannan-Quinn criterion		4.680376

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