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# TECHNOLOGY AND INNOVATIONS IN REGIONAL DEVELOPMENT FOR EUROPE 2020: JEAN MONNET CENTRE OF EXCELLENCE TIR 2020 FOR SMART, INCLUSIVE AND SUSTAINABLE GROWTH

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**Abstract:** *The European Union is steering its development by a series of successive strategic documents, its grand strategies. While having important role, these strategies do not have a perfect implementation score and a score of initiatives and research is dedicated to better understand these processes. The article presents one such initiative, Jean Monnet Centre of Excellence Technologies and Innovations in Regional Development for Europe 2020, a focal point of competence on the topic. Utilising novel Social Fields approach to innovation, the centre combines original empirical research, public debates and formal and informal learning to collect and disseminate knowledge on the topic.*

**Key words:** Jean Monnet Centre of Excellence; Europe 2020; technologies; innovations; regional development

## 1. Introduction

The European Union is steering its development by a series of successive strategic documents, its grand strategies. The first, *the Lisbon Strategy*, valid from 2000 to 2010, set as its aim to make the European Union "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion". It was succeeded by the grand strategy Europe 2020, which aims to achieve smart, sustainable and inclusive growth. The main vision thus remained relatively similar, although implementation tools have been upgraded significantly, especially through Smart Specialisation Strategy (Foray 2015). This upgrade was necessitated by the questionable implementation of the Lisbon Strategy (Makarovič et al. 2014). It seems that the next grand strategy until 2030 will follow the same general strategic emphases.

Generally speaking, the implementation success of the EU grand strategies has been a subject to intense scrutiny (see Silander 2019; Stec and Grzebyk 2018; Pandiloska Jurak, 2019; Rončević, 2019) and various efforts are dedicated to improving it. Jean Monnet Centre of Excellence *Technologies and Innovations in Regional Development for Europe 2020 (TIR 2020)* is one such effort. While the project itself does not aim to have the implementation capacities, since it does not have the required resources and, additionally, it has not been designed with this purpose, it nevertheless has the capacity to make a strong indirect impact. This is done in at least two ways. The first is its focus on contribution of technologies and innovations to implementation of Europe 2020. Their role has been recognised not only be the EU, for example by its emphasis and focus on Smart Specialisation Strategy as a delivery tool for Europe 2020, but also by extensive research on ability of technological innovations to deliver smart, sustainable and inclusive development. Furthermore, this research has provided evidence that these processes do not only depend on technological capabilities but are a result of complex interrelationship between various social forces: institutions, social networks and cognitive frames (Cepoi 2016; Cepoi 2019; Modic and Rončević 2011; Modic and Rončević 2018), as is the case with developmental processes in general (Adam et al. 2005).

These conclusions are also presented in this special journal issue of *Research in Social Change*. In his article, Cepoi utilises meta-analysis to demonstrate the relevance of Social Fields theory – the theoretical background of TIR 2020 – in analysing the processes of innovation, ergo the "smart" aspect of the much-desired European growth. In his article, he also presents the data collection tool that we have used to collect the data in 20 European regions, as a part TIR 2020. Pandiloska Jurak narrowed her focus on the importance of high-tech companies for EU economy, from the particular perspective of the EU grand strategies. Hafner and Modic further narrowed focus down to deal with the specific case of the technological innovations in the automotive industry, the backbone of the EU industry as a whole, but in many cases also the crucial line of regional innovation systems. Džajić Uršič, on the other hand, shifted her attention to the "sustainable" growth, by outlining methodology to deal with increasingly large body of work on Circular Economy. This special journal issue is concluded by Erman's methodological review of prospects for innovation performance on European level.

Hence comes the second impact of TIR 2020 on implementation of Europe 2020. Centre of Excellence was designed as a multi-activity focal point for competence and knowledge on implementation of Europe 2020 vision of smart, sustainable and inclusive growth, which includes not only research, but also formal and informal learning, social networking, and infrastructure for sharing of relevant knowledge and ideas.

## 2. The ambition of TIR 2020

To achieve this, Jean Monnet Centre of Excellence titled Technology and Innovations in Regional Development for Europe 2020 (TIR2020) was designed to be the focal point for competence and knowledge on implementation of Europe 2020 vision of smart, sustainable and inclusive growth via technological innovations on the regional level, with a particular focus on its institutional, social and cognitive foundations and mechanisms. Furthermore, TIR2020 was designed to complement and upgrade the activities of its predecessor project, Jean Monnet Chair CPE 2020, focusing on implementation deficit of the EU grand strategies.

To achieve ambitious goals, TIR2020 is based on i.) Open Innovation 2.0, an emerging paradigm where academia, policymakers, industry and civil society co-create the future and drive structural changes, ii.) Open Source model, drawing from and contributing to knowledge freely available to the public, and iii.) Social Fields conceptual framework, where regional systems of technological innovations are continuously (re)shaped by institutions, social networks and cognitive frames. TIR2020 will engage a variety of target groups, i.e. academia, students, professionals, policymakers, businesses and civil society.

In TIR2020 we set up infrastructure, methodologies, protocols, and tools to systematically collect, evaluate and make publicly available both already existing documentary resources and new primary empirical data. All are available on TIR2020 platform www.tir2020.net. This is the foundation for multi-level policy debate with relevant audiences (conference special sessions, joint field trips and round table discussions) and enables us to develop content and tools on EU subjects, to complement and upgrade current courses and curricula (course modules, summer schools, workshops).

These activities are carefully interwoven to incorporate principles of integrated collaboration, co-created shared value and rapid adoption of strategic vision of successful, smart and inclusive growth. As a result, TIR2020 will continue to advance interdisciplinary EU studies and deal with the phenomenon of EU implementation deficit, with a view to offer research and educational tools that could be utilised throughout Europe, to contribute to awareness of EU grand strategies and their implementation on regional level.

TIR2020 tackled an important policy issue and is at the same time providing academic value added. The European Union has been continuously rethinking its global position amidst emerging economic and geopolitical. Europe 2020 provides a number of good guidelines on how to meet the challenges, especially its focus on successful, smart and inclusive growth, in which technology and innovations on the regional level play one of key implementation mechanisms and significant resources are dedicated to this. However, long-standing policy implementation deficit of the European Union is also recognised for its grand strategies, including the initially ambitious Lisbon Strategy. Is Europe 2020 set to fail as well? Implementation deficit of the Lisbon Strategy was not due to the changed economic circumstances after 2008 which could hardly have been foreseen when the initial document was adopted, but due to failing to recognize the role of its institutional, social and cognitive underpinnings. This is also the main obstacle to success of Europe 2020. Excellent knowledge on this topic is one of the key necessary conditions to reduce implementation deficit.

TIR2020 is designed to achieve the maximum benefit per available resources. This also includes maximisation of the relevance of proposal for the specific objectives of Jean Monnet Centres of Excellence. We are blending activities of TIR2020 with already existing events at host institution to the greatest possible extent and by providing a 'clever' combination of research infrastructural development, including development of relevant methodologies, protocols and tools, educational activities at BA, MA and PhD levels of studies, as well as the winter camp workshops and summer schools, and outreach events, we aim to encourage synergistic effects and to achieve 'more with less'.

Firstly, Jean Monnet Centre of Excellence TIR2020 will gather the expertise and competencies of high-level experts in the field of EU studies. These experts were identified and communicated already during development of infrastructural framework for TIR2020 and then engaged during its various activities, among others through multi-level policy debates organized during the series of thematic events, workshops, and conference special sessions and during the thematic field trips. A number of high-level experts are expected to participate in its activities also in the future. Here we are not referring only to EU experts from academia, we also aim to attract high-level professionals from consultancy, public administrations and civil society.

Secondly, TIR2020 is designed to collect existing resources with the purpose to develop synergies between various disciplines and resources in European Union studies. In fact, one of the key activities of TIR2020 was to set up research infrastructure, including development of methodologies, protocols, and tools to systematically collect, evaluate and make publicly available both already existing documentary resources and new primary empirical data from a wide variety of disciplines (sociology, policy analysis, economic, economic geography, regional studies etc.). Centre of excellence provides not only one-stop-shop for a variety of resources. Instead, carefully designed and interwoven activities allow and enhance their cross-fertilization, exploitation and will continue to encourage debates across the boundaries of academic disciplines.

Thirdly, TIR2020 also encourages debates across boundaries of academia, businesses, public administration and the civil society, thereby allowing democratic participation in high-level debates on the issues of utmost importance to development of European societies. It will continue to do so by ensuring representation of these sectors in its outreach activities. However, this will not only contribute to openness to civil society, but also to increased relevance of TIR2020, recognizing the ubiquitous and multi-level nature of the policy process at stake, i.e. the implementation of Europe 2020 on the regional level by encouraging technologies and innovations in regional development.

In addition to these main specific objectives, Centre of Excellence TIR2020 implemented two additional activities each academic year. Firstly, its senior members specifically encouraged, advised and mentored the young generation of higher education teachers and researchers in European Union studies. TIR2020 included three young scholars at the beginning of their academic careers as part of the staff. They contributed to design of this Centre of Excellence and will continue to work on its implementation. Furthermore, various outreach activities of TIR2020 such as conference special sessions, workshops, special debates, summer schools and field trips will continue to actively encourage participation of junior colleagues.

Secondly, TIR2020 organized a large number of activities designed also to target policymakers at local, regional and national level as well as civil society. This is, in fact, necessary condition for successful implementation of this project, since this Centre of Excellence is dealing with multi-level policy process, in which a number of stakeholders play important role and in which we are focusing on the role of institutions, social networks and cognitive frames. These events were three winter camps with participation of students, young professionals and academics, three multi-day joint international field trips with participation of all target groups, three special thematic sessions at a conference that enabled scientific scrutiny of the results and nine round tables were be organized to enable more applied scrutiny of TIR2020 process by industry representatives and policy-makers. In this entire process, to achieve objectives and engage target groups TIR2020 systematically incorporated principles of integrated collaboration co-created shared value and rapid adoption.

## 3. Methodology

The methodology has been developed to meet the overall envisage objectives of Jean Monnet Centre of Excellence TIR2020, i.e. to develop and test innovative educational approach and related materials to advance the acceptance of the EU grand strategies, in this case the Europe 2020, and with a view to foster development and mainstreaming of interdisciplinary EU studies at the intersection of economic studies with comparative regionalism. At the same time, we are attentive to the need to offer educational tools that could be utilised in other environments with the goal to contribute to awareness of EU grand strategies and their implementation throughout Europe.

The working methodology is combining four interdisciplinary elements:

i. The developed educational approach will be based on student-centred learning, shifting the focus from professor to the student, aiming to develop autonomy and independence of the learner, which will substantially increase the quality of the teaching and assure better results.
ii. We incorporates the key elements of Open Innovation 2.0, a new paradigm where academia, policy-makers, industry and civil society work together to co-create structural changes far beyond the scope of individual actor. These elements guide the debating activities during the events.
iii. The methodology takes into account the social fields' theory, analytical approach in which regional innovation systems are conceptualised as social fields shaped by institutions, social networks and cognitive frames. This approach can also be instrumental in providing the relevant tools and provide inclusion of civil society members in the process.
iv. This approach provides the basis for research activities, which enables us to collect primary information in a number of European regions: crowdsourcing and online platform will in the future be further utilised to collect and exchange knowledge, information and data after the end of TIR2020.

TIR2020 thus incorporates principles of integrated collaboration, co-created shared value and rapid adoption. Consequently, teaching activities not only include (future) professionals undertaking degree awarding studies, but also industry representatives, policymakers and civil society.

TIR2020 is planned to achieve maximum impact with available resources by utilising the existing infrastructure. This is not only economically efficient but also allowed avoiding unnecessary new content loading in addition to already existing one. Instead, relevant fields of EU studies were integrated where appropriate in the existing curricula and events, thereby i.) providing increased visibility of highly relevant EU topics at an institution with EU studies at a nascent phase of development, ii.) improving the relevance of subjects which have not been specifically designed to deliver EU studies, and iii.) responding to an identified need to develop this field of study.

## 4. Conclusion: TIR2020 and its Impact

TIR 2020 particularly impacted three groups. Firstly, policymakers, public administration, industry representatives and civil society. Secondly, students and academic staff of the Jean Monnet Centre of Excellence host institution. Finally, and most importantly, the broader academic community and knowledge on European integration.

TIR2020 reached the first group by utilization of well-developed regional networks, where host institution often acts as a moderator in various initiatives. They were actively participating in TIR2020 in line with Open Innovation 2.0 paradigm to co-create structural changes with other actors. They were be encouraged to participate in education (online courses, winter schools) and research activities (collection of practices and exchange of information) and invited to outreach events (transnational round tables/special sessions, conference special sessions). The impact of this participation influenced their awareness of Europe 2020. The active participation of policymakers, businesses and civil society will strengthen intra-regional cooperation and increase mutual trust, which can spark further joint innovative efforts in these semi-peripheral regions.

The second group, the academic community at the host institution was approached directly and extremely actively participated at most TIR2020 events and not only contributed, but also benefited from them. This benefit is be both academic, i.e. discovering scientifically relevant EU topics, as well as pedagogic-didactical, i.e. contributing to development and testing new teaching method bringing greater teacher-student communication and achieving better learning outcomes. Students benefited from close communication with their professors, developing their autonomy and independent thinking, which will substantially increase the quality of the teaching and assure better results. The spillover effects of the discussions are innovative approaches to understanding and spreading other relevant topics as well.

Last but not least, the activities provided by TIR2020 also strengthened the academia – policy-makers communication, thereby providing them with new opportunities for future cooperation. The results of TIR2020 are available online and will continue to be. Availability of the material will enhance the knowledge about innovative approaches in teaching on EU studies. The events provided an open forum for international cross-disciplinary debates on the topic and enable cooperation with academic staff from other European academic institutions. Scientific knowledge will benefit from intensive debates with the stakeholders, providing unique insight and access to data on factors, bottlenecks and mechanisms of implementation deficits of the EU grand strategies. Last but not least, we collected and offered unique primary data, providing insight in the very core of regional technology transfer and innovation processes.

This does not imply that the story of TIR2020 is concluded. We have set up an important scientific infrastructure, that can in be in the future further upgraded either by upgrading the database with new developments, or by exploring specific limiting issues such as intellectual property (Modic et al. 2019) or reorientation towards sustainable and responsible development (Fric et al. 2019; Džajić Uršič 2020).

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# A META-ANALYSIS AND EXPLANATION OF INNOVATION PROCESSES THROUGH THE OUTLINE OF SOCIAL FIELDS THEORY

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**Abstract:** *Modern reports and studies on innovation processes offer a variety of possibilities for measuring and explaining innovation processes. These reports have a comparable model for operationalization of the concept of innovation, as they include both quantitative and qualitative indicators. The complexity of the modern societies and the interaction of actors, determines also to look for alternative models, which would embrace this complexity. We do not question these approaches and their reliability toward measuring the innovation performance, but rather to focus on alternative operationalization and explanation. Thus, through the embedment of the Social Fields Theory in the context of innovation processes it would offer various possibilities of applying a more coherent operationalization toward the explaining innovation. This article will display a critical assessment of a number of studies and projects, which used this approach in order to explain the innovation, but also using different methodologies that incorporate innovation processes and the theory of Social Fields.*

**Key words:** Innovation, Social Fields Theory, social forces, QCA, HPC

## 1. Introduction

Innovations have been the crucial element of developmental performances through all the human history. It is therefore not surprising that it is an important aspect of European grand strategies such as Europe 2020 and its predecessor Lisbon strategy (Rončević 2019; Makarovič at al. 2014). The role of a wheel or a paper or an electric bulb seems to be quite illustrative in that regard. However, according to the accelerated complexity of the social world, innovations have become not merely a breaking point in the development of human society, but a crucial component of social actions entailing successful adaptation to social contexts. The contemporary social order reflects the increasing complexity of social systems, and has thus given rise to the emergence of new social areas. Functional differentiation has raised the role of the autonomous social subsystems, and multiplied the social environments where social actions take place. New unpredictable and uncertain social areas have appeared that affected the character of social organisation (Beck, Giddens and Lash 1994). Due to the changing and more fluid structural settings, the relationship between actors and social environments indicates various techniques of adaptation and adjustments of the social context, which enable actors controlling new unpredictable social areas and risks of a contemporary era. Innovations can be seen as processes triggered from such actions.

Scholars focusing on innovations research have contributed to extensive understanding of the factors that contribute to the development of the systems of innovation, as well as their mechanisms (Carlsson, Jacobsson, Holmen and Rickne 2002; Etzkowitz and Leydesdorff 2000; Isaksen 2001; Edquist 2001). Moreover, this process can take on a number of dimensions within the society, including economic, social or cultural. In this paper, the consideration of determinants of innovations is in the forefront. The focus is on factors that influence particular social environments to become a trigger for innovations to emerge and contribute to an existence of the innovative society. In order to deepen understanding of the determinants on innovation process, the integrated theory of strategic social fields (Fligstein and McAdam 2012) is taken into account, as it allows approaching the interplay between actors and social environments as social arenas or local orders.

With the constant technological progress, economic approaches are no longer able to explain all the changes that are happening. As a result, a broader view has to be taken into account for innovation processes, which are considered to be the promoters of economic development around the world. Most of the studies that deal with innovations are either case studies (community or regional level) or do not always consider all the aspects that trigger innovation.

When it comes to markets, these are both politically and socially constructed. In this regard, these social constructions reflect a country's culture and its history of class relations, but also the governments' interventions (Fligstein 2001). Nevertheless, the capitalist national system can be understood as a whole. Being more specific, it is about modes of capital allocations, labor relations, tax systems, and state involvement and ownership in key industries. Simultaneously, at regional levels, these also have to be at forefront. Therefore, not only the social constructions of the culture, capital allocations, labor relations, or tax systems on the national level influence the markets, but also the ones at regional levels.

Following this line of argument, one of the theories that consider the determinants of innovation processes on different levels, is the theory of strategic social fields (Fligstein and McAdam 2012). This framework allows us to approach the interaction between actors and social environments as social arenas or local orders. States present a complex system of fields, which share all the characteristics of the non-state field. Social fields are seen as the local orders, where "interactions between more and less powerful collective groups according to rules and shared meanings take place" (Fligstein 1997, 11). National environments frame a variety of strategic action fields, which are embedded in terms of Russian nesting dolls (Fligstein in McAdam 2012, 9). It has been argued that any given field is embedded "in a broader environment consisting of countless proximate or distant fields, as well as states, which are themselves organized as intricate system of strategic action fields" (Fligstein and McAdam 2012, 3).

The presence of rules and shared meanings define the interaction between more or less powerful collective groups (Fligstein 2001). The incorporation determines social rules of the local order, either individuals or collective agents as a unit of analysis. To center on specific regions, we focus on social fields because each region can be regarded as a specific order. In addition, focusing on social fields as an analytical outline, allows incorporating specific social forces. Each social field is formed with the help of the interplay between institutions, networks, and cognitive frames, which constitute the three social forces. New economic realities require new approaches toward development. As in any other social fields, also in national ones, three social forces influence the interplay between social setting and actions: institutional rules, cognitive frames, and network topography (Beckert 2010). In that regard, all such structures are seen as irreducible. Institutions influence structure of social networks and make certain cultural meanings socially relevant. At the same time, social networks establish power to shape institutions, and cognitive frames provide the legitimation of certain institutions. Cognitive frames also shape perceptions of network structure that reversely shape and diffuse cognitive frames (Beckert 2010, 612). All three social forces influence the stratification of fields within a national context and thus position actors who are accordingly embedded in different powerful positions. Conversely, actors draw on resources from their position, and through structural coupling they have the ability to influence institutions and networks.

The aim of this paper is to consider other studies that link innovation processes with the theoretical framework of Social Fields Theory and to have a more comprehensive understanding the way innovation and social forces can be conceptualized. Thus, it will lead to a better predictability and improvement of society's economic and social traits.

## 2. Conceptualization

The need for operationalization of the individual elements of innovation systems has been on the agenda for more than a decade (Balzat and Hanusch 2004). The variety of explanations of Innovation Systems on different levels is a necessary stage in embedding the topic in a framework, which would allow having a comparable model for operationalization of the concept of innovation. In present there are a number of reports (World Competitiveness Yearbook; Global Competitiveness Report, Innovation Union Scoreboard, Regional Innovation Scoreboard, etc.) that deal with innovation on different levels. These reports not only measure the level of innovation performance on different spatial scales, but also tend to different approaches toward the operationalization of innovation. A special emphasize has to be made in terms of the methodological approaches these reports use. For instance, WCY uses different types of data that measure qualitative and quantifiable issues. GCR uses statistical data from international agencies, but also some surveys to capture a qualitative assessment, especially for the statistical data that are not available. As we can see, these reports capture both quantitative and qualitative concepts that measure the competitiveness relying on a wide range of indicators. We do not question these approaches, and their reliability toward measuring the innovation performance. Through the embedment of the Social Field Theory in the context of Innovation Systems, it would offer various possibilities of applying a more coherent operationalization toward the explanation of innovation as an outcome. Additionally, it would solve the difficulty of focusing on larger number of indicators that sometimes are hard to access.

Following this line argument, in the following paragraphs we would like to display a number of studies, which used this approach in order to explain the innovation from different levels of analysis, but also using different methodologies that incorporate the theory of Social Field Theory, and Innovation System. Among the pioneers in explaining RIS as Social Fields, were Rončević and Dolores (2012). In their paper, the authors focused on seven regions in order to show the necessary and sufficient conditions for innovation. The authors used data from various reports (OECD, World Values Survey, EPO/WIPO, Regional Innovation Scoreboard, Academic Ranking of World Universities database, and other) in order to measure the regional innovation innovativeness. Their approach toward the analysis of the data was with the help of QCA. The popularity of the Qualitative Comparative Analysis is gaining the popularity among scholars from different domains. This method was developed by Charles Ragin (1987; 2000; 2008), which allows to test the necessary, and sufficient of the present or absent conditions for any particular outcome. The authors were able to combine the theoretical framework, and verify it empirically the influence of the social forces on RIS, by showing that these conditions are necessary, and sufficient for innovation (Rončević and Modic 2011, 326). Additionally, as the authors point, when these social forces are considered separately, these do not have enough explanatory power to explain innovation.

The authors focused on several indicators in order to measure Innovation and the three Social Forces:

- Innovations – number of patents; high-tech items in export; general innovation performance.
- Institutions – supportive government regulation for new firms or/ and IPR/ spin-offs; support services; density of technology parks, and technology transfer entities; regional entity (-ies) for innovation support; and top universities.
- Networks – trust/social capital; university-industry cooperation; intraregional collaboration of firms; cooperation with customers.
- Cognitive frames – firm based innovation system; presence of science-based industry; skilled work force; knowledge absorption capacity.

In their paper Cepoi and Rončević (2015), focused not on explaining innovation processes, but also on explaining development performance with the help of the three social forces. The authors collected the data for 29 countries from various databases as Global Competitiveness Report, World Competitiveness Yearbook and Innovation Union Scoreboard.

- Innovation – Country capacity of innovation, nature of competitive advantage, production process sophistication and the total % of SMEs introducing product innovations.
- Institutions – Intellectual property protection, quality of math and science education, country to retain talent, country to attract talent, quality of scientific research institutions, availability of scientists and engineers and R&D expenditure in the business sector as % of GDP.
- Social Networks – University-industry collaboration in R&D, innovative SMEs collaborating with others as % of SMEs, international scientific co-publications per million population and state of cluster development.

- Cognitive Frames – Firm-level technology absorption, the openness of national culture to foreign culture, flexibility and adaptability toward new challenges, and country's value system in supporting competitiveness.

This data was used for the analysis with the help of Structural Equation Modelling and Fuzzy-Set Analysis to test the relationship between the proposed indicators (Cepoi and Rončević 2015, 44). The results show that for the outcome (innovation), all three social forces (institutions, networks and cognitive frames) are considered as necessary conditions, meanwhile institutions having the strongest effect. Additionally, in their subset/superset analysis, the authors also highlighted that all three social forces are also sufficient conditions for innovation to take place. Even more, what it is important to stress, is that this analysis showed various combinations of these social forces. For example, the strongest effect on innovation is from the presence of institutions and social networks or cognitive frames and social networks. Meanwhile, even if the analysis of the data with the help of Structural Equation Modelling has mostly backed the results, there was an exception. The results pointed that there is an absence of an effect from cognitive frames, meanwhile institutions and social networks are at forefront (Cepoi and Rončević 2015, 43).

Another article that focused on the explaining Innovations relying on Social Forces and QCA is from Rončević and Cepoi (2016). The study relies on a sample of 29 European countries. The paper proposes a model that explains the outcomes of innovation processes. Additionally, it tests the robustness of the theoretical model with the application of multivariate statistical analysis, structural equation modelling and especially fuzzy-set analysis. Thus, the authors rely on:

- Innovations – PCT Patents, applications/million pop., country capacity of innovation, nature of competitive advantage, production process sophistication, total % of SMEs introducing product innovations.
- Institutions – Intellectual property protection, quality of math and science education, country capacity to retain talent, country capacity to attract talent, quality of scientific research institutions, availability of scientists and engineers, R&D expenditure in the business sector as % of GDP.
- Social Networks – University-industry collaboration in R&D, innovative SMEs collaborating with others as % of SMEs, international scientific co-publications per million population, State of cluster development.

- Cognitive Frames – Firm-level technology absorption, the openness of national culture to foreign culture, flexibility and adaptability toward new challenges, country's value system in supporting competitiveness.

In their analysis, the authors highlighted the differences between Western and Eastern European countries. Thus, in the West, the social forces are shaping the social fields of innovations. Meanwhile, in the East, it is the absence of social forces that is relevant; the social fields of innovations cannot even develop. Nevertheless, their conclusion was that the proposed model is explaining endogenous innovation; innovation can still occur through FDI; typical for semi-peripheral and peripheral development. It also might offer possible inputs for innovation policies in the two regions.

Another study (Cepoi and Golob 2017) embedded the framework of strategic action fields in explaining innovations systems on the level of the EU 28. The authors used statistical data from Global Competitiveness Report, Innovation Union Scoreboard, and World Competitiveness Yearbook. By clustering the countries in various ways, the results emphasized that in the case of countries that have less developed innovation level, the three social forces not constitute sufficient conditions. Additionally, the social forces are necessary conditions, regardless of the innovation level. Nevertheless, identical tendency is seen when the countries were grouped not geographically, but statistically. Therefore, the authors came to the conclusion that there are no differences in the way the countries are grouped (Cepoi and Golob 2017, 574). Relying on the theoretical background, in all case studies the authors selected the indicators from various reports that (in)directly influence innovation systems on the national, and regional levels. As the comparison of the two operationalization approaches point, we can observe that all approaches relied on the operationalization of innovations, and the three social forces.

- Innovation – country capacity for innovation; nature of competitive advantage; production process sophistication; the total % of small-medium enterprises introducing product innovations; number of applications filed under the patent cooperation treaty per million population.
- Institutions – intellectual property protection; country capacity to retain talent; country capacity to attract talent; availability of scientists and engineers; R&D expenditure in the business sector as % of GDP; quality of math and science education; quality of scientific research institutions.
- Networks – university-industry collaboration in R&D; international

scientific co-publications per million population; innovative SMEs collaborating with others as % of SMEs; state of cluster development.

- Cognitive frames – the openness of national culture to foreign culture; the country's value system in supporting competitiveness; the firm-level technology absorption; flexibility and adaptability toward new challenges.

The results at the national level show that innovation processes should not be understood only as a one-dimensional process from an economic perspective, but rather also to consider the social aspect. As the authors point, social forces can facilitate or hinder the development processes, including innovations.

Modic and Rončević (2018) focus on the analysis of the individual social forces influences on regional innovation performance. The authors selected fifteen diverse regions from four continents, thus showing that for a region to be successful, the outcome is determined by the combined influence of institutions, social networks and cognitive frames. As a result, for each of the indicator, the authors looked at:

- Innovation – Number of patents, high-tech items in export, general innovation performance.
- Institutions – Supportive government regulation for new firms or/and IPR/ spin-offs, support services, density of Technology parks and technology transfer entities, regional entity (-ies) for innovation support, top universities.
- Networks – Trust, universities-industry cooperation, intraregional collaboration of firms, interregional collaboration of firms, cooperation with customers.
- Cognitive frames – Firm based innovation system, presence of science-based industry, skilled work force, knowledge absorption capacity, business R&D expenditures.

The results of the study show that institutions, social networks and cognitive frames have a nuanced impact on shaping the regional innovation systems. Nevertheless, as the authors point, even the social forces impact the level of regional innovation level there is no universal model of adaption.

The common ground for these articles is the quantitative approach toward measuring innovation and social forces. As a result, these approaches implied the collection of available secondary data from different databases. At the same time, the differences arise within the indicators that measure innovation and the social forces.

Cepoi (2019) focused on the three social forces (networks, institutions, and cognitive frames) as an alternative explanation for innovation processes. Thus, it encompasses the aspects of different social fields on the regional level.

The approach was similar to Cepoi (2018) (will be discussed in details in the following chapters), but with QCA as the main method of analysis. The focus was on both individual and combined influence of the social forces. The author considered seven regions in the analysis. The results show that social forces are absent in three regions: Kragujevac (Serbia), Balti (Moldova) and Trieste (Italy). Meanwhile, in Carlisle (UK) and Cluj (Romania) there are present only networks, in Novo mesto (Slovenia) there are cognitive frames and networks and in Waterford (Ireland) we have the presence of all social forces.

## 3. Innovation and Social Fields. A qualitative approach

As it was highlighted in the previous chapters, until now we observed a pattern of quantitative approach studies toward explanation of innovation processes through the framework of Social Fields theory, based on the original conceptual exploratory work of Rončević and Modic (Rončević and Modic 2011; Rončević and Modic 2012; Modic and Rončević, 2018). In the PhD dissertation (Cepoi 2018), there is an attempt to incorporate also the qualitative approach. Thus, the study researches innovation processes through the framework of Social Fields, namely the three social forces (networks, institutions, and cognitive frames) at the regional level with the help of both qualitative and quantitative methods. On the one hand, the developed framework constituted based on a semi-structures interview guide, which allows not only see the strengths and weaknesses, but also to collect scores for each of the indicator. In comparison to the previous studies, this qualitative approach, allows stakeholders to acknowledge which aspects of the innovation process have to be considered (Cepoi 2018, 39). On the other hand, these scores are used for the Qualitative Comparative Analysis. The data was collected in seven regions with different levels of innovation performance. Thus, the author operationalized each of the variables in a set of four questions:

Innovations

- Please assess the level of innovation within your region?
- What are the strengths and weaknesses concerning collecting, processing and disseminating innovation information (such as funding opportunities, potential partners, available know how, technologies, etc.) in the region?
- What are the regional strengths and weaknesses concerning enterprises and R&D?
- Is the final product oriented toward regional level?

Institutions

- What are the strengths and weaknesses concerning the role of the public authorities and/or intermediary organizations representing these authorities?
- Does your region have the capacity to attract talented people?
- Does your region have the capacity to retain talented people?
- What are the strengths and weaknesses regional innovation-policy?

Networks

- How networks are organized (e.g. multi-sectoral, enterprises only or sector only) and to which extent do the networks contribute effectively to innovation performance?
- What are the strengths and weaknesses concerning cooperation between stakeholders within the region?
- What are the strengths and weaknesses concerning cooperation between regional stakeholders and parties outside the region?
- Do stakeholders trust each other?

Cognitive frames

- What are the strengths and weaknesses of the culture and attitude of the population concerning creativity, and entrepreneurship?
- To what extent do the regional attitudes / culture enable the learning processes in the region?
- Is competition seen as a positive or negative value for innovation processes?
- What is the role of Globalization for the innovation processes?

Nevertheless, the author focused on two types of analysis. Firstly, at forefront was the in-depth qualitative analysis of data gathered through the help of focus groups (Cepoi 2018, 38). Secondly, the collected data allowed also to perform a Fuzzy-Set Analysis. The results of the combination of both methods offered explanation for regional stakeholders, which go beyond simple economics (Cepoi 2018, 134). Even more, the interview guide allowed to explore in more depth the level of the innovation and social forces. Consequently, the results show that networks and cognitive frames are both necessary conditions for innovation, additionally, networks can be considered also sufficient to have innovation in a given region. Nevertheless, when institutions and networks are both considered, these are necessary conditions. These conclusions were backed also by the qualitative analysis of the focus groups.

The application of Social Fields Theory in the framework of innovation development, goes beyond the studies mentioned earlier. The model of embedding the framework of the Social Fields into explaining different processes also applies to the context of project implementation. Therefore, as it was mentioned earlier, at this stage we will present some cases where within the research scholars use the qualitative methodology for collecting the data. For instance, one of such approach is the "High-Performance Computing for Effective Innovation in the Danube Region"[1]. The aim is to create transnational HPC laboratory for co-designing knowledge-intensive innovative products with high value-added in transnational value-chains for companies from the electronic, and automotive industries. Within the framework of the project, before providing the guidelines for the Digital Transformation of Industry in the countries of the Danube region, the project relies on the data collection of the regional needs, and competencies. The template for the structured interviews, and focus group was formulated around the framework of the three social forces, and the level of HPC development. Each of the four profiles (High Performance Computing and Innovation, Institutions, Networks, and Cognitive Frames) is measured through four question that represent different indicators. An additional aspect of the tool, is that on one had it also emphasizes the strengths, and weaknesses of each indicator. On the other hand, it allows to collect data and perform Qualitative Comparative Analysis, therefore focus on the necessary and sufficient conditions of the HPC and Innovation profile. The data was collected within the countries of the Danube, thus constituting an important asset for the region.

HPC and Innovation

- Please assess the level of application of HPC in industrial R&D in your country?
- What are the strengths and weaknesses concerning collecting, processing and disseminating High Performance Computing information (such as applicability, funding opportunities, potential partners, available know-how, technologies, etc.) in the country?
- What are the strengths and weaknesses concerning applications of advanced ICT tools for R&D in enterprises from automotive and electronics industries?
- Is the existing HPC application oriented towards industrial R&D?

Institutions

[1] High-Performance Computing for Effective Innovation in the Danube Region is a project in the framework of the Interreg Danube Transnational Programme, the Faculty of Information Studies (Slovenia) is the leading partner, http://www.interreg-danube.eu/approved-projects/innohpc.

- What are the strengths and weaknesses concerning the role of the public authorities and/or intermediary organizations (e.g. technology transfer offices) for HPC?
- Does your country have the capacity to attract talented people, including – but not exclusively – those with HPC competencies?
- Does your country have the capacity to retain talented people, including those – but not exclusively – with HPC competencies?
- What are the strengths and weaknesses regional/national innovation-policy? (Also, take into account conduciveness for HPC applications.)

Networks

- How are networks organized (e.g. multi-sectoral, enterprises only or sector only, regional, cross-border etc.) and to which extent could these networks contribute effectively to the implementation of HPC in industrial R&D?
- What are the strengths and weaknesses concerning cooperation between stakeholders active in innovation and technological policy?
- What are the strengths and weaknesses concerning cooperation between stakeholders active in innovation and technological policy and actors outside your country?
- Do stakeholders/entrepreneurs active in innovation and technological policy trust each other?

Cognitive Frames

- What are the strengths and weaknesses of the culture and attitude of the population concerning creativity, entrepreneurship and new technologies? (Take into account its conduciveness for implementation of HPC in industrial R&D.)
- To what extent do the attitudes and culture enable the learning processes in the country?
- Is competition seen as a positive value in your country?
- What is the role of globalization with respect to adoption of new technologies in your country?

The in-depth analysis showed, as in the case of the previous researches, the presence of an interconnected influence of the social forces on HPC and innovation in the three pilot regions from Ireland, Slovenia and Romania. The obtained knowledge can be used as context-specific policy guidelines for the improvement of the HPC and innovation landscape.

Additionally, we can speak about Social Fields in the framework of the Technology and Innovations in Regional Development for Europe 2020[2], which has the aim to focus on successful, smart and inclusive growth, in which technology and innovations on the regional level are at the forefront. Following this line of argument, one of the aim was to have more than 20 focus groups at regional level with stakeholders from academia, business, and state institutions.

Innovation

- Please assess the level of innovation within your region?
- Please assess the situation regarding collecting, processing and disseminating of information (such as funding opportunities, potential partners, available know-how, technologies, innovations etc.) in the region?
- Please assess the involvement of enterprises in R&D?
- Does the region rely on Open Innovation Practices, which is emphasising use of freely and openly available ideas and knowledge in their own R&D?

Institutions

- Please assess the level of impact of the public authorities and/or publicly founded intermediary organizations (such as regional development agencies, innovation agencies, incubators, technology parks) in supporting R&D and innovations in the region? (R&D or Innovations?)
- Does your region have the capacity to attract talented people?
- Does your region have the capacity to retain talented people?
- Please assess the innovation-policy?

Networks

- How do the networks between businesses, institutions of knowledge, public bodies, professional associations, trade unions, NGOs etc. contribute to innovation performance in the region?
- Please assess the level of cooperation between stakeholders within the region?
- Please assess the level of cooperation between regional stakeholders and actors outside the region?
- Do stakeholders trust each other?

Cognitive Frames

[2] Technology and Innovations in Regional Development for Europe 2020 (TIR2020) is a project in the framework of the Jean Monnet Centre of Excellence at the Faculty of Information Studies, Slovenia, https://www.tir2020.net/.

- Please assess the level of the culture and attitude of the population concerning creativity and entrepreneurship?
- To what extent do the regional attitudes/culture enable learning processes in the region?
- Is competition seen positively or negatively by most people?
- How is globalization perceived in the context of the innovation processes?

TCV embeddedness

- How embedded are Transnational Value Chain relationships (TVC) or other forms of transnational relationships (TR) in the region?
- Assess the role of Transnational Value Chain (TVC) relationships or other forms of Transnational Relationships (TR) for the R&D and innovative processes in the region?
- To which extent does the regional economic performance depend on Transnational Value Chain (TVC) relationships or other forms of Transnational Relationships (TR)?
- What is the role of the regional actors (enterprises, industrial sectors and clusters) in the Transnational Value Chains?

The interview guide was constructed on the Social Fields framework, having the same principle of the InnoHPC project, allowing to underline the strengths, and weaknesses of the indicators, and to collect the information that will be used for the Fuzzy-Set Analysis. Nevertheless, if in the case of the InnoHPC project the focus was in determining conditions, which contribute to the development HPC and Innovation, while within this project the aim was to focus exclusively on innovation and technology transfer.

## 4. Conclusion

As shown in these examples, even if the approach is rather novel there were made several attempts from different authors who opted toward an approach that embeds the theory of Social Fields around the concept of the Innovation Systems. It not only triggers economic changes, but also rather this approach allows stakeholders to search and to assess for theoretical and policy solutions for boosting the competitivity and development. Even more, from a scientific approach, the cases emphasized that rather similar operationalization can be adapted for both regional and national levels. The results presented at the regional level (Rončević and Modic 2012; Modic and Rončević 2018; Cepoi 2018; Cepoi 2019) are in accordance with the results obtained in other studies at the national level (Cepoi and Rončević 2015; Rončević and Cepoi 2016; Cepoi and Golob 2017). At least, these results show the importance of incorporation of different social aspects that determine the evolution and development of innovation processes within a particular milieu. Therefore, it is important to see that the same logic is applied in the context of national innovation systems as in the case of regional innovation systems. The obtained results do not contradict each other, but rather emphasize the robustness of the model. It is important to point those even current tendencies to focus on decentralization; regions are regarded as independent social-political frameworks, though the role of national innovation system remains important. Nonetheless, the model considers the particularities of the specific social fields (either national or regional) and supports the sufficient and necessary factors in the complex context specifics. Overall, we consider that the results present valuable assets for policy-makers, both at regional and national levels, who consider in planning innovation systems.

Even more, it is important to highlight the flexibility of using the Social Fields Theory in data collection and different types of analysis. Therefore, the proposed approach points toward the flexibility of the data collection, which is either of statistical or qualitative nature. It allows cross-fertilizing not only the social factors with and economic phenomenon, but from a methodological stand point – the qualitative and quantitative empirical evidence. Although the model has proved to be robust from the perspective of the obtained results, there is still a need of improvements from the theoretical and explanatory assessments.

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Technology and Innovations in Regional Development for Europe 2020 (TIR2020), Jean Monnet Centre of Excellence at the Faculty of Information Studies, Slovenia, https://www.tir2020.net/.

# THE IMPORTANCE OF HIGH – TECH COMPANIES FOR EU ECONOMY – OVERVIEW AND THE EU GRAND STRATEGIES PERSPECTIVE

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**Abstract:** *In the context of economic globalization, technology is a key factor in boosting growth and competitiveness in the business world. Technologically intensive companies have more innovation, gain new markets, use available resources more productively, and generally offer more to the people they employ. Europe spends less on R&D, compared to the US and Japan, mainly due to lower levels of private investment. The lower share of HTC in the EU is the reason for half of the EU's lag behind the US. The aim of this paper is therefore to present the importance of high – tech companies for EU economy and to evaluate the steering of Europe 2020 grand strategies towards active support of HTCs and estimate, how Europe 2030 strategies will continue the effort of boosting EU economy.*

**Key words:** high – tech companies, EU Grand strategies, policy, innovation, research and development, business ecosystem prerequisites

## 1. Introduction

Technology is a key driver in the global economy (Morrison 2002, 279). In the context of economic globalization, technology is a key factor in boosting growth and competitiveness in the business world. This is also one of the key aspects of European grand strategies, aiming to achieve smart, sustainable and includive growth (Rončević 2019; Makarovič et al. 2014). Technologically intensive companies have more innovation, gain new markets, use available resources more productively, and generally offer more to the people they employ. High-tech companies are the ones whose products are expanding the fastest in international trade, and their dynamics help to improve efficiency in other sectors (Hatzichronoglou 1997, 4). The lower share of VTP in the EU is the reason for half of the EU's lag behind the US (ibid.).

The OECD Secretariat has identified the methods used to classify sectors and products by level of technology and has drawn up two lists: one for activities (sectoral approach) and the other for products (product approach). The data used in compiling the list by activity are based on the International Standard Classification of Industrial Activities, ISIC Rev 2. The new classification covers only the manufacturing industry. They set the intensity of research and development (R&D) as the only criterion, based on which they identified four groups: high, medium-high, medium-low and low technologies (Hatzichronoglou 1997, 4–5). The product-by-product approach has been developed to supplement the list by activity and provides a more appropriate tool for analyzing international trade. It is based on the Standard International Trade Classification, SITC Rev 3 (Hatzichronoglou 1997, 4).

We distinguish between two types of technologies (see European Commission, Eurostat 2014), namely production and knowledge-based technology. Eurostat uses aggregation of industrial production according to technological complexity. It identifies four levels: high technology, medium-high, medium-low and low technology[1]. Following a similar procedure as for manufacturing, Eurostat on subdividing the services sector as knowledge-based services and services based on the lower level of knowledge. Aggregation of services is done only at level 2 (European Commission, Eurostat 2014). We are pointing out the classification due to its strict differentiation and due to the general assumption, what high technology is. Companies might be using high-tech products and procedures, which does not qualify them high-tech companies.

## 2. The importance of the high-tech sector for the economy

In the global competition for competitiveness (European Commission, Eurostat 2016a), the creation, exploitation and commercialization of new technologies are essential. In the context of economic globalization, technology is a key factor in promoting growth and competitiveness in the business world. The high-tech sector and enterprises are a key driver of economic growth and productivity and generally provide high added value

[1] High technology (products): Manufacture of pharmaceutical raw materials and preparations, Manufacture of computer, electronic and optical products, Manufacture of aircraft and spacecraft.
Medium-high technology (products): Manufacture of chemicals and chemical products, Manufacture of weapons and ammunition, Manufacture of electrical equipment, Manufacture of other machinery and equipment, Manufacture of motor vehicles, trailers and semi-trailers, Manufacture of other transport equipment, Ship and boat construction, except Manufacture of aircraft and spacecraft, Manufacture of medical instruments, appliances and supplies.

and well-paid jobs. Investment in research, development, innovation and skills is therefore a key policy area for the EU, as it is essential for economic growth and the development of a knowledge-based economy (ibid.).

A study of a cluster of high-tech companies in Montana (USA) (Barkey et al. 2015) showed that the growth of high-tech companies by almost every criterion is outpacing other sectors of the economy in the country, both in terms of employment and expected revenues. Fold growth rate throughout the country. Employment in high-tech companies is paid much better than elsewhere in the economy. On average, high-tech companies are smaller, younger and more growth-oriented. High-tech companies that are members of the Montana cluster raised wage rates by 7% in 2013, which is significantly more than the 1.4% growth rate of real wages in the private sector. Cluster members planned more than 400 new jobs in 2015 or a 15% increase, which represents a much higher growth in the number of jobs compared to the economy as a whole (ibid.).

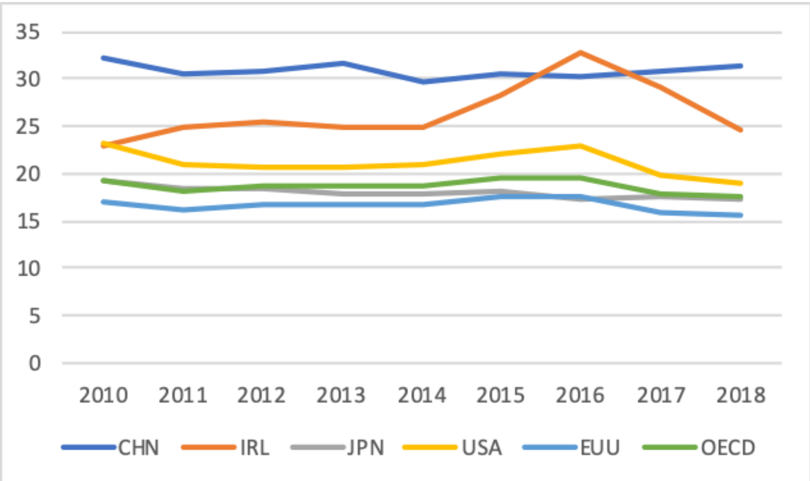
The dynamics of the high-tech sector can help to improve efficiency also in other sectors (European Commission, Eurostat 2016). The results of a study (Tongbin et al. 2015) on the effects of the high-tech industry on various areas of the Chinese national economy show that the high-tech industry has the most direct and significant impact on the secondary industry (mining, energy, industry, construction, A/N) it can have exceptional and strong effects on the growth of secondary industry production, but it can show itself in a longer time lag. The effects on the tertiary industry (services, transport, trade, tourism, A/N) cannot yet be shown or they are relatively weak, but their permeability is rapid. It was found that the impact of high technologies on capital accumulation in both the secondary and tertiary sectors has increased significantly (ibid.).

Certain specificities in the high-tech sector cannot be detected in other sectors. One of these is the role of the entrepreneur's personal capital in operating in high- and low-tech demanding industries. In Japan (Kato and Hunjo 2015), the survival factors of start-ups were studied, where exit routes were also considered, thus distinguishing between errors (eg. bankruptcy) and other forms of "failure" (eg. voluntary liquidation, merger, etc.). The results showed that entrepreneurs' personal capital, measured as education, and is important in reducing the likelihood of bankruptcy in high-tech sectors, but this is not the case for less-developed sectors. In addition, they found that in companies run by entrepreneurs with a high level of personal capital, mergers are likely to occur, especially in the high-tech sectors. They also found that entrepreneurs coming from the natural sciences are less in favour of mergers than those coming from the social sciences, especially in less developed sectors (ibid.).

Intellectual capital is relevant to each sector. It is of particular importance for maintaining a competitive advantage (Hsu and Chang 2011) in a fast-growing high-tech industry. Taiwan's high-tech industry has high added value, surpassing the global industry over the past decade. It seeks to expand its leadership in high technology by creating higher-value silicon intellectual property and increasing reuse. Since 2002, the Taiwan Stock Exchange has even gradually established a system of information disclosure and transparent ranking of all companies. The classification system assumes that more voluntarily disclosed information about companies could increase investor monitoring, reduce risk assessment and improve governance. However, high-tech companies are concerned that disclosure of intellectual capital could put companies at a competitive disadvantage. They have shown that the risk of this is less if these disclosures are voluntary (ibid.).

The high-tech industry is expanding most strongly in international trade (European Commission, Eurostat 2016). Graph 1 shows that High technology exports as in % of manufactured exports reach over 15 % in 2018, leading by China with over 31%. The Graph also show a drop in 2016 in the EU, OECD, USA and Israel. Since 2018 are the latest available data it will be interesting to see, how the current COVID 19 crisis affected the export.

Graph 1: High technology exports (% of manufactured exports)




Source: World Development Indicators, Last Updated: 09/08/2020

The connection between the possibilities of survival of high-tech start-ups in connection with a foreign market is also interesting. In India (Krishna, Subrahmanya and Bala 2015), a study was conducted based on 45 high – tech start-ups based in different locations in India, comparing transnational start-ups and those operating locally. The results of the study showed that transnational high-tech start-ups have a greater chance of survival compared to local high-tech companies. In addition, it was found that graduates of technical fields who gained entrepreneurial experience and early funding were also more likely to achieve the survival of their high – tech start-ups. The study was designed to reveal the forms and types of factors that need to be examined to enable a vibrant start-up ecosystem in the region. It is aimed at policymakers and investors who focus on emerging economies (ibid.). One of the more general objectives of economic policy is to provide quality jobs (Adkisson and Saucedo, 2010). In recent decades, high-tech jobs have been adopted as synonymous with high-quality jobs, and political efforts in this area have increased (Adkisson 2015).

## 3. The importance of the economic crisis and other factors for the high-tech sector

As a direct cause (Mrak and Rant 2011) of the current global economic crisis, we understand the collapse of the real estate market in the US in 2007. Due to the growing share of outstanding loans, there were severe liquidity problems in the US financial sector. By 2008, financial institutions around the world were affected. Wider, systemic causes, which relate in particular to the functioning of the international financial system and the increase in the balance of payments imbalances (ibid.). Also served as a precondition for the increase in risks and asymmetric information in the international financial environment.

Despite the belief that the European economy will remain largely unaffected (Štiblar 2008, 95), the economic crisis has gradually begun to manifest itself in Europe as well. The first signs appeared in 2008, when due to the interconnectedness of international financial centres and excessive investment in the US real estate market, the financial system, which included banks, insurance companies and central banks of European countries, was severely exposed to shocks in the subprime mortgage square. The problems were particularly pronounced in the United Kingdom, Luxembourg and Ireland. They were hit by a more pronounced real estate crisis, while Iceland and Switzerland faced mainly a banking crisis (ibid.).

The economic crisis (Berkmen et al. 2012) has had a different impact between developing countries and emerging markets. Even a small set of variables can explain the larger share of differences in the impact of growth. Countries with more advantage in the domestic financial system, stronger credit growth and more short-term debt mostly feel the greater impact of the crisis on economic activity, although the relative importance of these factors varies between countries. In emerging markets, it helps the trade financial channel. Exchange rate flexibility has helped mitigate the impact of the shock, especially for emerging markets. There is also evidence that the crisis had a smaller impact on countries that had a stronger fiscal position before the crisis. However, we find little evidence for the importance of other policy variables (ibid.).

The consequences of the economic crisis (see Svetličič 2015, 185–202) and dramatic changes in the world economy are reflected in the reduction of the share of Western Europe in world GDP to 20%.

The economic recovery (Sandua and Ciocanel 2014) and the restoration of sustainable economic growth in the EU are largely driven by exports, especially in the high-tech sector. Through theoretical and empirical approaches, various authors have proven the relationship between some indicators of innovation performance and the volume and implementation of high-tech exports (ibid.). Endogenous theories of growth explain the productivity growth of the new economy by drawing attention to technological innovations created through Research and Development (henceforth R&D) (Karahan 2015). There is a causal link (Sandua and Ciocanel 2014) between the volume of R&D expenditure, employment in the high-tech sector and international trade alliances, and the share of exports of high-tech companies to the EU. There is also a positive correlation between the total volume of R&D research expenditure and the level of high-tech exports. Data vary between EU countries. However, the impact of private expenditure on research and development is stronger than that of public expenditure (see also Chart 2.5). Current European and national policies are increasing the intensity of R&D funding. The goal is to raise the average level of EU R&D expenditure to 3% of GDP and to raise the average EU private expenditure to 2% of GDP, which can significantly increase exports and competitiveness (ibid.).

A survey (Karahan 2015), made based on European countries, sought to define the relationship between business expenditure on R&D and productivity growth through an indication of the role of transformation in the manufacturing sector towards high-tech manufacturing. Empirical findings show that there is a strong causality between the increase in the intensity of business entities in the field of R&D and the growing share of high and medium high technology production. The study finds that R&D expenditure by businesses is one of the main sources of improvements in high-value-added technological production capacity in Europe. From a policy perspective, the implication of these results is important. Public policies should create appropriate incentives for private investment in R&D to ensure a transformation in the manufacturing sector towards high-tech specifications and further growth in an innovation-dependent economy (Karahan 2015).

The positive correlation between R&D investment (Wanga, Yub and Liub 2013) and economic growth is also evidenced by comparative empirical data from 23 OECD member countries and Taiwan. The impacts of R&D expenditure in the high-tech sector are heterogeneous across income levels per capita (ibid.).

Furthermore, the research analyzed the factors of innovation performance of the high-tech sector in EU countries. Innovation performance is assessed through the application of patents, granted patents and trademark applications. The findings show that the number of employees in the high-tech industry has a positive effect on the number of patents, while R&D expenditure (per capita) has a negative impact. Other factors, such as education expenditure, government R&D expenditure, economic development, the number of science and technology employees and the level of exports, do not affect innovation performance in the high-tech industry. In the case of brand application, the situation is different, namely significant expenditures on R&D and human resources employed in science and technology. While exports have a positive impact on outgoing innovation, economic development has a negative effect. However, it should be noted that the data used are robust and have some shortcomings in terms of unavailability of data for all countries, the method of weighting, etc. (Baesu et al. 2015).

As a success story, however, we can present the case of Israel. In Israel, too, the high-tech industry has a major impact on the overall economy (Tamar 2011). Between the years 1970 and 2000 due to the success of the high-tech sector to the transformation of the Israeli economy. The success of the sector is due to the support of the Israeli government, which has promoted civilian research and industrial development (Berry and Grayeff 2009). As a result (Tamar 2011), the Israeli economy overcame the recession relatively well in 2008. Their economy is largely dependent on small high-tech multinationals (they have also implemented other measures, such as increasing foreign direct investment, etc.), while macroeconomic indicators showed good results compared to the EU and the US. The reasons for this are based on the predominance of high-tech companies, “born global” companies and small high-tech multinationals. Business strategies based on (1) size and flexibility (2) focused and tailored, and (3) innovation and globality have allowed small high-tech multinationals to continue to grow and achieve their goals despite the great recession (ibid.).

However, changes in the technological structure of production in the direction of the high-tech sector do not in themselves automatically lead to an improvement in labour productivity (see Šipilova 2015). They can also be a trap for economically less developed regions, which tend to increase the presence of the high-tech sector in the production structure but are unable to achieve the desired improvements and economic growth. Using structural changes and a specialization index and a shift-share analysis technique, the impact of structural changes on economic growth in the manufacturing sector was analyzed in the Latvian regions. The empirical results of the research emphasize that those Latvian regions that opt for a more technologically advanced production structure and pay less attention to improving labour productivity find themselves in a situation where strengthening specialization in the high technology sector is not reflected in regional economic growth (ibid.).

If we noted above the positive effect of investment in R&D in connection with the high-tech sector, it is also necessary to point out bad practices from which much can be learned. This was shown by the results of a survey assessing the effectiveness of national high-tech zones in China after the financial crisis (Baia, Yanb and Chiu 2015). They found that the efficiency of both the high-tech manufacturing and R&D sectors is low, partly because the links between the sectors are weak and transfers are not appropriate. The overall productivity factor showed that high-tech production depends mainly on improving technical efficiency, while the R&D sector relies on advanced technology (Baia, Yanb and Chiu 2015).

In addition to investing in R&D, some other factors are also important for high-tech companies and the rise from the crisis. In China (Wanga and Lestaria 2013), a study was conducted on the effects of three entrepreneurial competencies on the effective market entry of high-tech companies from emerging markets, namely business networks, new product development and marketing management. They found that marketing alone directly affects the success and market entry, while the other two competencies have no indirect effects. The research also showed the important role of the business network as a prerequisite for the entry process, and at the same time, the development of new products serves as a driving force of marketing by creating competitive products (ibid.).

Venture capital has also proved to be an important factor for the high-tech sector. A sample of 128 companies (Bertonia, Croceb and Guerinib 2015) that were supported by venture capital and 233 companies that did not receive venture capital was surveyed on how and when venture capital alleviates the financial constraints of portfolio companies. The findings show that venture capital regulates the investment curves of companies, which also means a reduction in financial constraints. This effect is economically and statistically significant only when the company moves into the next round of venture capital financing. These follow-up funding rounds do not, on average, involve larger investment amounts, but have stronger information content than initial investment rounds. Evidence regarding corporate access to venture capital loans confirms this interpretation of the results (Bertonia, Croceb and Guerinib 2015).

Venture capital investments can come from a variety of sources. A 2014 survey (see Grilli and Murtinu 2014) assessed the impact of state-managed venture capital and private venture capital on sales and employment growth in European high-tech companies. The results show that the main, statistically robust and economically significant positive effect on sales growth is related to private investors. In contrast, the impact of investment by the state appears to be negligible. A positive and statistically significant impact of consortium investments of both types of investors on sales growth was also found, but only in the case where the main investor was private. Overall, the survey casts doubt on the ability of governments to support high-tech companies through direct and active participation in the venture capital market (Grilli and Murtinu 2014).

As an example of good practice, we can once again highlight Israel. From the perspective of start-ups (Wonglimpiyarat 2016), Israeli Silicon Wadi[2] ranks immediately behind American Silicon Valley. As already mentioned, Israeli state policy has an important role to play in fostering innovation and guiding the country towards a high-tech driving force. The success of high-tech clusters is a result of government policy and investment in venture capital programs. Also important in this was the fact that it did not exclude government funding but attracted a mass of private investors. Israel is an interesting example of the most successful economy modelled on Silicon Valley. The experience of the Israeli success story and the path to achieving

[2] Israeli Silicon Wadi is an area with a high concentration of high-tech industry in the coastal plain in Israel, similar to Silicon Valley in California, USA.

the goal of becoming a high-tech driving force is also useful for other countries and the transfer of knowledge about the system of promoting high-tech clusters (Wonglimpiyarat 2016).

The economic crisis has also affected the high-tech sector. However, the above data and research show that the high-tech sector can have a way out of the crisis and, due to its positive impact on other sectors, as well as on GDP and employment, can be a key help in getting out of it. In addition to the general state of the economy, investment, research, innovation, human capital and other factors, the state is also an important factor in the operation of the high-tech sector.

## 4. Europe 2020 grand strategies towards active support of HTCs

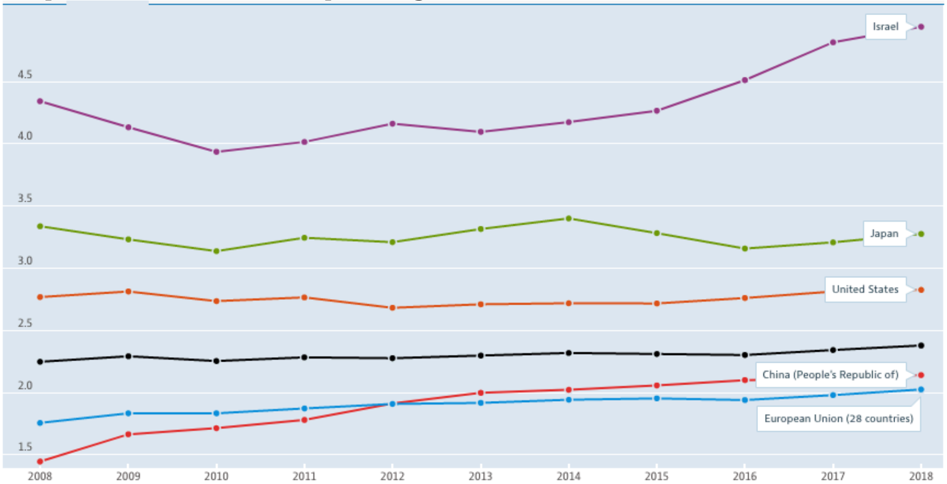
Given the research, done by different researchers around the world, we could summarize, that R&D investments, Venture capital investments and knowledge are the three factors that influence the high-tech industries. Further on, with these assets, the high-tech industries influence the international trade, value of exports and employment to the extent that it can help the national economy in the time of economic crisis. Since the technological classification is very narrow and some sectors have a high share of R&D and employ highly educated people one could argue, that the three mentioned factors can have a positive effect in all sectors and are generally important. In that manner, we scanned the EU grans strategies, not searching for specific addressing of high-tech industries but the three factors themselves. The most recent data available now is R&D spending.

Already in 2010, the European Commission acknowledged: "R&D spends less than 2% in Europe, compared to 2.6% in the US and 3.4% in Japan, mainly due to lower levels of private investment. It is not only the absolute amounts of investment in research and development that are important" (European Commission 2010). The *Strategy for smart, sustainable and inclusive growth* has set the bar of 3% of the EU's GDP that should be invested in R&D (see European Commission 2010).

To set specific focus, the European Commission published the European 2020 Flagship Initiative: "Innovation Union". Its aim is (European Commission 2011) to refocus R&D and innovation policy on the challenges facing our society, such as climate change, energy and resource efficiency, health and demographic change. The document assured the possibility to the Commission to work on completion of the European Research Area by developing a strategic research agenda and to enhance joint programming with Member States and regions; improve framework conditions for business to innovate; launch 'European Innovation Partnerships' between the EU and national levels to speed up the development and deployment of the technologies needed to meet the challenges identified; strengthen and further develop the role of EU instruments to support innovation; promote knowledge partnerships and strengthen links between education, business, research and innovation, including through the EIT, and to promote entrepreneurship by supporting Young Innovative Companies (ibid.).

The clarification about the target was that it (see European Commission 2011) has succeeded in focusing attention on the need for both the public and private sectors to invest in R&D but it focuses on input rather than impact. There is a clear need to improve the conditions for private R&D in the EU and many of the measures proposed in this strategy will do this (ibid.). As one can read further, the EC states that it is also clear (ibid.) that by looking at R&D and innovation together we would get a broader range of expenditure, which would be more relevant for business operations and productivity drivers. The EC proposes to keep the 3% target while developing an indicator, which would reflect R&D and innovation intensity (ibid.).

Graph 2: Gross domestic spending on R&DTotal, % of GDP, 2008–2018




Source: OECD 2020

If we keep in mind, that there was an extensive world economic crisis, roughly between 2007 and 2009 (depending on the country or region it started before and/or finished after that year) we can see an interesting comparison between few selected countries. Mainly, all the countries are pushing up the % of R&D spending. What is more interesting and worrying from the EU perspective is a level of R&D spending in EU countries, being the lowest from 2012 on. Even the OECD in total rises above the EU. The below graph is a visual display of the situation also raising the question of what does the 3% target mean? No one will be waiting for the EU to catch the train. In that manner, the 3% would mean the EU to stay in the game but not being in the big league, being the one who sets trends. Is it possible that the EU is not capable to reach higher than 3%?

Table 2 shows the R&D expenditure by all sectors of performance in EUR per inhabitant. The table was arranged based on the values of expenditure. 64% of the EU countries spend less than the Eu28 average for R&D per inhabitant. The lowest expenditure (Romania 52,5 EUR) is only 3,3% of the highest, being Denmark with 1580,9 EUR per inhabitant. The disproportions among the countries in the EU regarding the R&D expenditure are, seem like, light years apart, calling for a more complex, extensive breakdown of how to level the member states. Mainly we could argue that there are member states with no fundamental prerequisites for business and research.

Table 2: R&D expenditure (GERD) by sectors of performance, all sectors, Euro per inhabitant

| GEO/TIME | 2018 |
|---|---|
| Romania | 52,5 |
| Bulgaria | 60,1 |
| Latvia | 96,3 |
| Croatia | 122,2 |
| Cyprus | 134 |
| Slovakia | 138 |
| Malta | 148,8 |
| Lithuania | 151,8 |
| Poland | 158,5 |
| Greece | 202,5 |
| Hungary | 209,8 |
| Portugal | 269,1 |
| Estonia | 277,2 |
| Spain | 320,3 |
| Czechia | 377,6 |
| Italy | 406,4 |
| Slovenia | 431,8 |

| | |
|---|---|
| United Kingdom | 622,7 |
| European Union 28 | 656,8 |
| Ireland | 769,5 |
| France | 773,6 |
| Netherlands | 974,8 |
| Belgium | 1.115 |
| Finland | 1.167,7 |
| Luxembourg | 1.208,3 |
| Germany | 1.266,3 |
| Austria | 1.388,1 |
| Sweden | 1.544,6 |
| Denmark | 1.580,9 |

Source: European Commission, EUROSTAT 2020

The same could be argued when examining the High technology exports as in % of manufactured exports (see Table 3). The EU reaches over 15 % in 2018, but there are large differences between countries; from 32.21% in Malta to only 5.27% in Portugal. Comparing the EU to China, Israel and the USA one would argue, that the EU is lacking behind but again, as acknowledged before, the EU cannot be directly compared to them.

Table 3: High technology exports (% of manufactured exports)

| Country Name | 2018 |
|---|---|
| Portugal | 5,27 |
| Slovenia | 6,81 |
| Luxembourg | 6,97 |
| Italy | 7,51 |
| Croatia | 8,89 |
| Finland | 8,93 |
| Romania | 10,08 |
| Bulgaria | 10,27 |
| Belgium | 10,37 |
| Poland | 10,60 |
| Slovak Republic | 10,63 |
| Austria | 11,64 |

| | |
|---|---|
| Lithuania | 12,11 |
| Greece | 12,81 |
| Denmark | 13,89 |
| Sweden | 14,36 |
| European Union | 15,62 |
| Germany | 15,78 |
| Estonia | 16,84 |
| Hungary | 16,94 |
| Czech Republic | 19,63 |
| Cyprus | 19,86 |
| Latvia | 20,28 |
| United Kingdom | 22,64 |
| Netherlands | 22,68 |
| Ireland | 24,68 |
| France | 25,92 |
| Malta | 32,21 |

Source: World Development Indicators, Last Updated: 09/08/2020

The European Commission recognized the problem of significant differences (see European Commission 2011) and encourages the member states to offer a better Business environment by improving the business environment especially for innovative SMEs, including through public sector procurement to support innovation incentives; improving the conditions for enforcing intellectual property; reducing the administrative burden on companies, and improve the quality of business legislation; working closely with stakeholders in different sectors to identify bottlenecks and develop a shared analysis on how to maintain a strong industrial and knowledge base and put the EU in a position to lead global sustainable development (ibid.). Not to forget about the basic research, the member states were given guidelines by the European 2020 Flagship Initiative: "Innovation Union" to: reform national (and regional) R&D and innovation systems to foster excellence and smart specialisation, reinforce cooperation between universities, research and business, implement joint programming and enhance cross-border co-operation in areas with EU value-added and adjust national funding procedures accordingly, to ensure the diffusion of technology across the EU territory; ensure a sufficient supply of science, math and engineering graduates and to focus school curricula on creativity, innovation, and entrepreneurship; priorities knowledge expenditure, including by using tax incentives and other financial instruments to promote greater private R&D investments.

## 5. What about the future?

The Europe 2030 strategy (European Commission 2018) based on United Nations Sustainable Development Goals by 2030 set the key enablers for the transition towards a sustainable Europe by 2030. Among them are ones, that are in line with our basic link to the high-technological companies: education, training, science, technology, research, innovation and digitization (see (European Commission 2018). The EU and its Member States could focus on financing breakthrough and disruptive technologies and innovative companies that have the potential to become EU and global market leaders in the sustainability transition, as well as on the effective and timely uptake of these innovations (ibid.). The European Commission set so-called Key enabling technologies to invest in specific technologies to help the industry in Europe. EC acknowledges that fast and comprehensive changes in science and technology are transforming our economy, generating new markets and players. In that regard, Europe prioritizes research and innovation support: advanced manufacturing, advanced materials and nanomaterials, life-science technologies, micro/nano-electronics and photonics, artificial intelligence, security and connectivity (see Internet 1). There is no mentioning of high-tech industries, but there is a statement, that *"these KETs drive innovation throughout the economy and cut across industries with a trend towards full convergence and integration."* (see Internet 1). The path towards better innovation performance might include the usage and applicability of high-performance computing (Besednjak Valič 2019).

An important aspect for business R&D is also addressed The Commission acknowledges, that the EU and its Member States would also need to promote stronger links between researchers and business. EU research, development and innovation hubs and incubators are important to support sustainable development, not only in terms of business sustainability, but also in terms of environmental sustainability (Mileva Boshkosla et al. 2018; Fric et al. 2020; Džajič Uršič 2020) so researchers and businesses can meet, exchange best practices, and spur innovation. While large companies may have the means to develop their research activities in-house, this is often not the case for small- and medium-sized enterprises. Stronger and more direct links with the research community have the potential to bridge this gap (European

Commission 2018) and additionally the role of regional development agencies as intermediary organisations (Roncevic and Besednjak Valič 2019) need to be explored further. Technology, innovation and knowledge are forces that will enable the EU and its member states to survive even souring the crisis and the European Commission is well aware of that. However, the rise of the R&D expenditure along with knowledge transfer and % of FDI is not an agile thing to arise from a split decision for the EU. It is a long-term outcome of the EU policies and EU member states actions. The European Commission offers good foundations in their documents and policies, but even the Commission has its limits. Member states have to rise to the idea of national political support and appropriate business culture. With the help of European funds and transnational networking and benchmarking, they can assure business and research prerequisites, such as healthy business environment, knowledge transfer, institutional support, infrastructure, etc. If the economy and support system does not have solid foundations, we cannot anticipate moving along sustainable growth, green and economy.

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# EUROPEAN AUTOMOTIVE TECHNOLOGICAL INNOVATION SYSTEMS IN THE AGE OF DISRUPTION: THE SUPPLIERS' VIEW

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**Abstract:** *Although empirical studies show that suppliers' innovativeness enhances original equipment manufacturers' (OEM) total innovation performance, some evidence reveals that suppliers' innovation affects OEM in quantitatively and qualitatively limited ways. This study aims to explore innovation systems of European automobile producers, i.e., OEM. Technological innovation systems (TIS) remain relatively underexplored, but the approach is especially valuable for explaining why and how sustainable and circular innovation develop and spread. We applied a mixed-method approach and conducted patent analyses and interviews with 20 respondents from Slovenia, Austria, and Hungary, which are representatives of suppliers for the automotive industry and automotive clusters. We confirm that the European OEMs build innovation ecosystems that are more closed than their Asian counterparts. Furthermore, we define three paths of how inventions of suppliers can reach the OEMs, with developmental suppliers (large companies) having the highest probability of influencing the innovation activity of OEMs. The entry of small and medium-sized enterprises (SME) and start-ups with their inventions is difficult. However, it is not impossible, especially if they develop new solutions connected to current disruptive trends in the automotive industry: electric cars, autonomous driving and digitalisation.*

**Keywords:** European automotive industry, suppliers' innovation, technological innovation systems, patents, supply chains, disruptive innovation, OEMs' ecosystem

## 1. Introduction

Supplier innovativeness enhances original equipment manufacturers' (OEM) total innovation performance and is an essential source of both product and process innovations (Azadegan and Dooley 2010; Noordhoff et al. 2011; Oke et al. 2013). Firms must continuously innovate to remain competitive; although suppliers are frequently recognized as a source of innovation for OEMs (Kurpjuweit et al. 2019), a lack of knowledge about the coordination of innovation across firms in the supply chain (Bouncken 2015) and how suppliers are motivated or can be stimulated to innovate (Pihlajamaa et al. 2019) remains. The challenges addressing the cooperation in innovation are not only recognised by the individual companies and experts but implicitly also by the European Union grand strategies, such as Europe 2020 (Rončević 2019).

The network of suppliers concentrated around particular OEMs can also be observed as a technological innovation system (Wieczorek et al. 2015; Suurs and Hekkert 2009; Bergek et al. 2007, 2008; Carlsson 1997; Carlsson and Stankiewicz 1991) in which each connected entity has its specific role in this system that contributes to the final innovative product or service. The technological innovation system presents a system concept developed for a technology-specific perspective on innovation processes (Markard and Truffer 2008; Phirouzabadi et al. 2020). It is an a-spatial innovation concept (Ter Wal and Boschma 2011), which can be embedded in regional, national, or supranational innovation systems. To understand such an innovation system, it is important first to understand what were the key historical shifts in shaping the current suppliers' ecosystem, as well as to understand how the automotive supply chain is organized.

Historically, the automotive industry has not only been one of the leaders in technological innovation but also in innovation in production processes and management. First with Fordism, and later through Post-Fordism and Toyotism (Turi et al. 2015; Dekier 2012), an increasing understanding of suppliers as partners emerged and the focus also shifted to supply chains. Firms are increasingly organized into supply chains to increase value at decreased cost (Bouncken 2015) in several industries, including automotive, which is one of the most important industries in several developed countries. The automotive supply chain is, with over 20,000 parts in a single vehicle that are sourced from thousands of suppliers globally, one of the most complex supply chains in the world (Kern and Wolff 2019, 4).

Supplier innovation occurs when a supplier produces a novel and useful product, process, or service to a downstream buying organization (OEM) (Tingting et al. 2018). Studies show that due to the ongoing trend of outsourcing and shorter innovation cycles, the importance of using suppliers as a source of innovation has increased (Winter and Lasch 2016). Furthermore, along with digital transformation, which has become a high priority on leadership agendas (Cepoi 2019) and affects many industries, including the automotive industry (Winkelhake 2019), a new transformation of the automotive industry is on the horizon also due to other disruptive technological trends (Gao et al. 2016; Wittmann 2017). Kern and Wolff (2019, 4) claim that major technology-driven trends such as autonomous driving, electrification, car connectivity and multimodality are predicted to lead to the most significant transformation of the industry since the invention of the car in 1885. Therefore, more studies that will contribute to understanding the innovation process within the automotive supply chain and interactions between suppliers and OEMs, which can lead to new product or process innovations, are needed. Understanding and possible improvement of this innovation process can also lead from disruptive to more sustainable innovation.

There are indications that entities in the supply chain are today increasingly interconnected and interdependent, so some argue that we can no longer speak about the 'supply chain', but rather about an 'ecosystem' (see Sloane and O'Reilly 2013). Within such an ecosystem, several types or tiers of suppliers with interconnecting relationships appear. However, there is a gap in our knowledge about the relationships inside these particular ecosystems in relation to the generation of innovation. Hence, we enrich our present knowledge on technological innovation systems, contributing towards multi-scalar conceptualizations of innovation systems (van Lacker et al. 2016), and their horizontal and vertical integrations.

This paper aims to explore the possibilities of automotive suppliers to cooperate in the innovation of multinational automotive producers (OEMs). The study is placed in a particular socio-historical context: the age of disruption and the European innovation system, in particular within the innovation systems of semi-peripheral European countries (Adam et al. 2005). Qualitative research approach (in-depth interviews with semi-structured questionnaires) is combined with a quantitative approach, i.e., a patent analysis. The sample of the qualitative study includes different tier suppliers from Slovenia, Austria, and Hungary as well as other business entities who are innovative in the automotive field but are not a part of OEMs' ecosystems.

We show that the European automotive supplier innovation is constrained by the rigidness of the systems, but also that automotive suppliers have three different innovation paths. We also point out that the demand-pull innovation is more prevalent within the OEMs' ecosystems and discover some additional attributes of European automotive innovation systems, especially in connection to the relationships between actors when creating and absorbing the automotive innovations.

## 2. Problem Formulation – Background and Theory

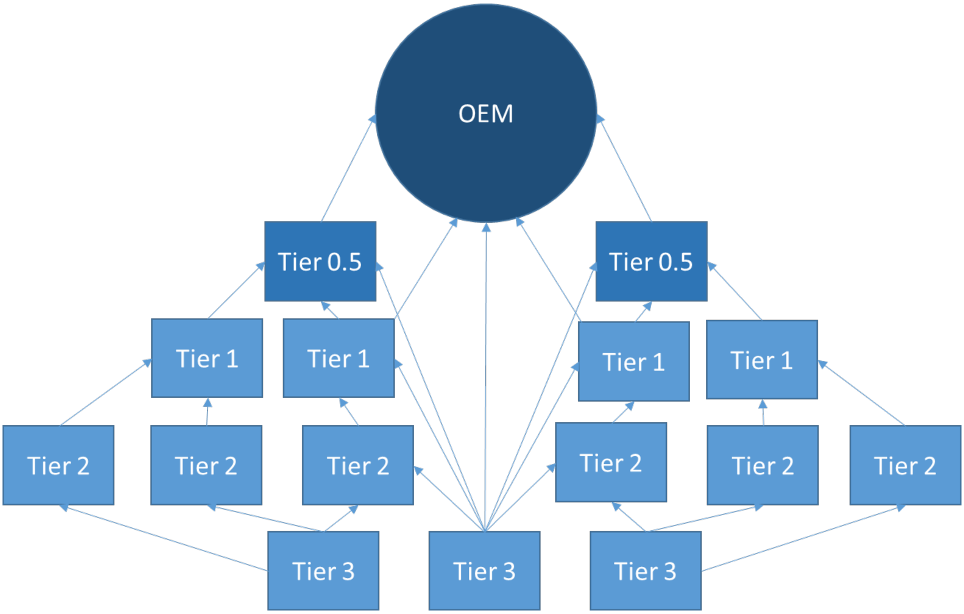
Henry Ford was the first to introduce a conveyor belt assembly line (in the early 20th century) and thus ensured cheaper mass production, which enabled cheaper products and thus also mass consumption and higher wages for employees. This concept, which has also been adopted by other industries, is called 'Fordism'. After more than half a century of dominance, while shifts and changes in the market have begun to challenge this concept in both car manufacturing and the global economy, Post-Fordism emerged. Compared to Ford's demand 'push' system, Post-Fordism relied on the opposite principle of 'pull', a system that adapts to customer orders, needs, and requirements. The principle of the supply chain is also different, which was another significant change brought about by Post-Fordism, which involves individual specialized companies as suppliers to the car manufacturer. This change meant that OEMs no longer manufactured all the necessary components themselves, but hired appropriate subcontractors or suppliers, while OEMs focused mainly on activities at the end of the production chain (Turi et al. 2015).

The next shift was Toyota's production system (TPS or Toyotism), developed by Taiichi Ohno and Eiji Toyoda between 1948 and 1975. In essence, Fordism and Post-Fordism emphasize production principles and supply chain design, while Toyotism focuses primarily on the organizational culture aspect and its importance for the competitiveness of the OEM. Another interesting change within Toyotism was that suppliers were no longer seen as 'suppliers' but as 'partners', which meant a whole new level of trust and mutual respect between the various links in the supply chain that would also be seen in productivity of OEM and supply chain efficiency (Turi et al. 2015).

Until 1973, other companies in the US and Japan showed little interest in TPS, until the need to reduce production cost arose. Since then, the success that Toyota has achieved has received much attention, and there has been great interest in its management concept (Dekier 2012). Thus the nurturing of the supplier chains, also concerning their innovation potential, began.

Today, the transformation of the automotive industry is exacerbated by disruptive technological trends (Gao et al. 2016; Wittmann 2017; Winkelhake 2019; Lazard and Ronald Berger 2019; Kern and Wolff 2019), which can also cause significant changes in supply chain structure, i.e., the stability of the automotive ecosystem and the relationships within it.

Figure 1: Automotive supply chain or ecosystem




Source: authors

The OEM's ecosystem consists of a hierarchical network of suppliers. Traditionally, first-tier (Tier 1) suppliers are direct suppliers of vehicle components to OEM; second-tier (Tier 2) suppliers are suppliers to Tier 1, and third-tier (Tier 3) suppliers supply raw materials to Tier 1, Tier 2 or OEM. Over time, due to the expansion of automotive markets in Europe and the US, some of the first-tier suppliers evolved into so-called mega-suppliers (Tier 0.5), taking over full design and market research and logistical integration of comprehensive modules for OEMs (Wang 2014; Volgina 2011).

According to Carlsson and Stankiewicz (1991: 93), a technological innovation system (TIS) is defined as a 'dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology'. Technological innovation systems remain relatively underexplored, but the approach is especially valuable for explaining why and how sustainable technologies develop and diffuse (Bergek et al. 2007).

Furthermore, Bergek et al. (2008) point out the need to make several choices regarding the technological innovation system studied in the present paper: regarding the focusing device (product orientation vs focusing on a particular knowledge field); breadth versus depth orientation; and the spatial domain.

Firstly, in regard to the focusing device of TIS, instead of focusing on a particular product, we focus on a particular knowledge field (Bergek et al. 2008). There are two reasons for this. Firstly, whilst the traditional notions of innovation systems focused mainly on geographical proximity, newer conceptualizations, such as that of technological innovation systems, now focus more on collective learning. In the automotive sector, the increasing emphasis on supplier chains of OEM and the rise of so-called mega suppliers – both increasing the potential for collective learning – lead to the emergence of (innovation) ecosystems. In line with this, many scholars turned their attention to the phenomenon of the network of actors involved in developing and in commercializing innovations (de Vasconcelos Gomes 2011), their interdependence, as well as the non-redundant knowledge they bring into the innovation ecosystem.

Secondly, we define the breadth of the study. We focus on the suppliers' innovations in the automotive sector. We do so, as our understanding of the system dynamics of the innovation systems, as well as technological systems, remains limited. The usual approach to studying innovation systems is from an aggregated perspective of, for example, a national innovation system; thus the investigations are performed as if these would be relatively static phenomena (Suurs and Hekkert 2009). At present, there is a lack of studies in newly emerging fields, and consequently emerging (technological) innovation systems, but which can still be influenced to a higher degree (Collingridge 1980, Suurs and Hekkert 2009). The paradigmatic changes inside the industry (Lazard and Roland Berger 2019) warrant a particular focus on automotive innovations by suppliers. This technological innovation system is an emerging one, similar to, for example, the Swedish TIS for biocomposites, but from the industry and from the policy perspective (Bergek et al. 2008, 412) in would make sense to 'work towards integrating these into one overall TIS, since this may increase learning, knowledge development and, thereby, the rate of development of the system as a whole'.

Thirdly, the researched TIS might have a spatial focus, such as ours. In terms of actors (entities) or agents of TIS, we focus on the suppliers, especially from Slovenia, as well as Hungary and Austria, which are embedded in peripheral and semi-peripheral parts of Europe. The specific focus entities are thus Slovenian, Hungarian and Austrian Tier 1 and Tier 2 suppliers, depending mostly on German (but also French and Italian) automotive OEMs.

Our focus on the collective learning, i.e., innovation creation and absorption, is contributing to enriching and mitigating the problem of the spatial conceptualization of the innovation systems (Oinas and Malecki 2002; Rutten and Boekema 2007). We need to take into account that TIS, as (non-state) fields, are thus embedded in a complex web of other fields (Fligstein and McAdam 2012); vertically with national and macro-regional innovation systems; and a horizontally, with other proximate fields such as sectorial innovation systems. In our case, these are the macro-regional innovation system of European semi-peripheral countries, and the sectorial automotive innovation system.

The automotive innovation ecosystems involving automotive suppliers and their relationships are thus an interesting and relevant manifestation of an innovation technological system; as the influence of the OEM and mega-suppliers is increasingly strengthening, the institutional infrastructure also changes in the field of generating innovations and their absorption into the OEM. Furthermore, the new paradigmatic changes inside the industry are shifting the focus towards more sustainability.

As mentioned above, the dynamics of this system are an interesting issue. Kurpjuweit et al. (2018) distinguish between suppliers' push and pull innovations. Innovations initiated by OEM (pull innovations) are often customized to the needs of the OEM, offer limited market opportunities for suppliers, and tend to produce increased dependency on the OEM. For this reason, suppliers engage in an innovation push strategy, developing new products on their own and pushing them to OEM at some stage of the development process. Innovation push can mitigate the disadvantages of innovation pull while allowing suppliers to access the innovation competencies of OEM and strengthening the supplier's relationship with OEM. Their study showed that supplier innovation push could be a viable alternative to the innovation pull approach, which is currently the standard practice in most industries; however, OEMs also raised concerns about the push behaviour of some suppliers: they complained that suppliers offered innovations that did not fit their needs, they were vague about the potential of the innovations offered, suppliers also proposed solutions for problems that did not even exist. By analysing examples, researchers identified factors that should shape suppliers' decisions about the timing and target of innovation push efforts. Therefore, the right timing and the choice of OEM to push have a substantial impact on a pushed innovation's chances of success. Their study of 15 respondents (7 OEMs, 6 suppliers and 2 consulting firms) is not limited to the automotive industry, although five respondents came from this sector. Our study continues their work with the difference that we did not include any OEM in our research sample, so the results are based only on the suppliers' view. Furthermore, we want to identify how a position in the supply chain influences the ability of suppliers to innovate.

We focus on the following research questions. Firstly, we focus on the scope of the cooperation of the automotive industry suppliers with their customers (i.e., the car manufacturers (OEM)). We focus on how the suppliers cooperate with them, and which channels are at their disposal. Secondly, we focus on the issue of the suppliers' pull or push innovations (i.e., who determines what to invent: supplier (push innovation) or OEM (pull innovation)); this allows us to understand what possibilities suppliers have in the development of their inventions and how much they have to adapt to the OEM's requirements. Thirdly, we distinguish between the suppliers' product and process innovations and their possible connections with the hierarchical position of the supplier in the supply chain. We are also interested in the automotive ecosystem 'outsiders' (entities not included in the system) which, however, invent in the field of automotive components: what possibilities do they have to penetrate in the OEM's ecosystem?

Our propositions are:

1) The innovation of European automotive suppliers is more pull- than push-driven.
2) Tier 1 suppliers may also push innovation and are more likely to innovate in the product field than Tier 2 suppliers.
3) Business entities which are not included in the supply chain (i.e., outsiders) have very little chance of pushing innovation to OEM, and their technology transfer channels are more likely to be incidental than planned.

## 3. Methodology

The study[3] started in the second half of 2017, with in-depth interviews conducted in the second half of 2018 in Slovenia, and in 2019 extended to two neighbouring countries, Austria and Hungary.

We performed a patent analysis using the database of European Patent Office PATSTAT, 2019 spring edition. We examine the patenting activity of the top 20 automotive patent holders in the last ten years, from Europe and Asia, and compare their joint patenting activity as a proxy for their openness to

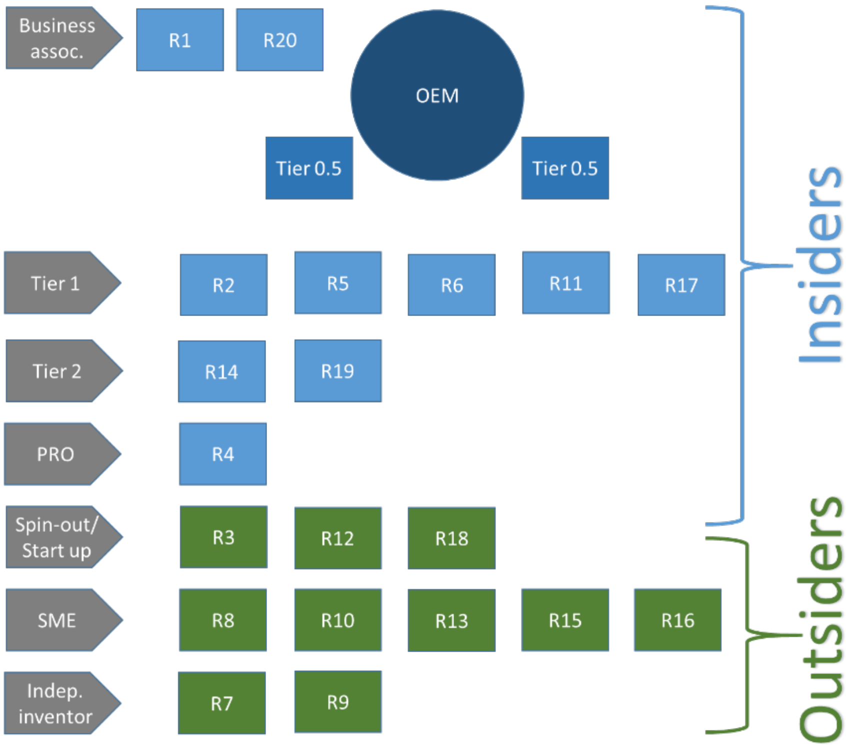
[3] The study has been supported by European Union, ERDF, and Republic of Slovenia, Ministry of Education, Science and Sport (Operation No. C3330-17-529006 »Researchers-2.0-FIŠ-529006«).

absorb outside innovation. To determine patented inventions belonging to the automotive industry, we used the categories of International Patent Classification (IPC) codes proposed by the European Patent Office, which performs annual statistics for the European Automobile Manufacturers Association ACEA (ACEA 2019, 68): B60: Vehicles in general; B62: Land vehicles for travelling otherwise than on rail; F02: Combustion engines; hot-gas or combustion-product engine plants; and F16: Engineering elements or units; general measures for producing and maintaining effective functioning of machines or installations; thermal insulation in general.

In Slovenia, we conducted semi-structured interviews with representatives of selected 16 units from the automotive industry (or scientists and inventors in the field of new solutions for the automotive industry). In the case of SMEs, our respondents were mostly directors, while in large companies, they were the heads of R&D departments. The interviews lasted approximately 45 minutes.

Two smaller and three large Slovenian companies were selected according to a larger number of patents, one large one due to successful business, two smaller companies were spin-off companies of public research organizations, and four were selected due to the technological importance of their current inventions. We also decided to conduct interviews with two representatives of the supportive environment: in the first case, this is a business association, and in the second a technology transfer office. In the following year, we supplemented this sample with four chosen Austrian and Hungarian respondents, three of them are automobile suppliers, and one is a business association. Therefore, our participants are very diverse, but such a sample was intentionally chosen because we wanted to cover as many different aspects of the entities, active in the field of automotive inventions, as possible.

Figure 2: Respondents placed within OEMs' innovation ecosystems




Source: authors

Respondents that are integrated into the OEMs' innovation ecosystems may be called 'Insiders' while the respondents who are (successfully or unsuccessfully) trying to push their inventions into the system are 'Outsiders'.

With the exception of two business associations (Slovenian and Hungarian automotive cluster), all respondents are patent owners. Table 1 (in the appendix) shows the approximate number of patents for each respondent. We have taken into account patent families based on the Espacenet database (May 2020). We took the total number of all patents of a given entity; although not all of them correspond to the automotive industry, most do. In the criteria for determining the size of the company, we took into account the definition of the European Commission (2020).

# 4. Problem Solution – Results

## 4.1. Results of the preliminary quantitative study

Since our focus is on the European automotive industry and the role of suppliers' innovations in Europe, we first look into whether or not the most innovative (based on their patenting activity) European OEMs or Tier 0.5 suppliers are open to seeking innovation from outside. These innovative companies are important actors of the technological innovation systems in the automotive sector.

We analysed the PATSTAT patent database data, focusing on the patenting and joint patenting activity of the top 20 automotive patent holders in the world in the last 10 years.

We discovered that Asian OEMs are more inclined to cooperate (with other companies and universities) than European and American (Table 2). While European and US patent owners are engaged in an average in 13.5% of joint patents, the average share of joint patenting by their Asian competitors is 43.4%.

Table 2: Top 20 world patent holders in the automotive industry

| | Company | Country | Automotive patent applications (last 10 years) | All patent applications between 2010 and 2019 | Number of joint patent applications (2010 / 2019) | % of joint patent applications |
|---|---|---|---|---|---|---|
| **1** | TOYOTA | Japan | 55157 | 91427 | 32641 | 36 |
| **2** | ROBERT BOSCH | Germany | 40346 | 75492 | 13257 | 18 |
| **3** | HONDA MOTOR COMPANY | Japan | 32759 | 46374 | 11476 | 25 |
| **4** | FORD GLOBAL TECHNOLOGIES | USA | 28870 | 45540 | 4502 | 10 |
| **5** | HYUNDAI MOTOR COMPANY | South Korea | 27985 | 63526 | 16472 | 26 |
| **6** | GM GLOBAL TECHNOLOGY OPERATIONS | USA | 24636 | 30388 | 5038 | 17 |
| **7** | SCHAEFFLER TECHNOLOGIES & COMPANY | Germany | 22639 | 24453 | 2454 | 10 |
| **8** | DENSO CORPORATION | Japan | 21751 | 22727 | 13110 | 58 |
| **9** | DAIMLER | Germany | 14776 | 19710 | 1822 | 9 |
| **10** | NISSAN MOTOR COMPANY | Japan | 13427 | 18030 | 6884 | 38 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **11** | GE (GENERAL ELECTRIC COMPANY) | USA | 13286 | 47325 | 10525 | 22 |
| **12** | ZAHNRADFABRIK FRIEDRICHSHAFEN | Germany | 13274 | 12987 | 1565 | 12 |
| **13** | PEUGEOT CITROEN AUTOMOBILES | France | 11701 | 10010 | 1322 | 13 |
| **14** | BMW (BAYERISCHE MOTOREN WERKE) | Germany | 11690 | 16146 | 1404 | 9 |
| **15** | TOYOTA MOTOR CORPORATION[4] | Japan | 11407 | n/a | n/a | n/a |
| **16** | BRIDGESTONE CORPORATION | Japan | 10623 | 13585 | 3208 | 24 |
| **17** | AUDI | Germany | 10503 | 15902 | 1932 | 12 |
| **18** | VOLKSWAGEN | Germany | 10417 | 12280 | 1824 | 15 |
| **19** | KIA MOTORS CORPORATION | South Korea | 8925 | 11625 | 11238 | 97 |
| **20** | RENAULT | France | 8774 | 8978 | 1349 | 15 |

Source: authors' analysis based on PATSTAT 2019

Our results are in line with the earlier, but narrower, study by Hertenstein and Williamson (2018) who compared German and China OEMs and Tier 1 suppliers. They similarly show that the two countries have different approaches in OEM-supplier relationships: Germans have a more in-house driven approach to development with close interaction with suppliers over a long cycle, while Chinese are more open to externally available technologies what opens up the potential for them to bring disruptive competition to the global automotive industry, especially in emerging markets. Therefore, based on our analysis and the conclusions of Herstenstein and Williamson (2018) we conclude that the European automotive innovation systems seem to be more rigid and less prone to jointly innovating than its Asian counterparts.

### 4.2. Results of the qualitative study

Our research shows that there is a significant difference between established suppliers which are well integrated into the supply chain (insiders of OEM's ecosystem) and potential newcomers (outsiders). In our sample, R2, R5, R6, R11 and R17 are large companies, Tier 1 suppliers that communicate directly with OEM or in some cases (for some products) through Tier 0.5 suppliers. Most of them have the status of so-called 'developmental supplier'. The development of new car components is entrusted to suppliers, but the OEM

[4] Toyota Motor Corporation appears in the database also as トヨタ自動車株式会社.

gives clear guidelines of what they want to have and how much space there is for this solution in the car.

> R11: 'Customer (OEM) prepare a quality technical basis of what they want to have, in a sense, here must be something, we are not interested in what this is, it is important that it is at a good price and that it satisfies the function.'
>
> R2: 'The car is designed at the highest (OEM) level. We get the shapes, these lines, surfaces, and we have to squeeze our solution into that by satisfying the legal regulations as well. What's inside is our own invention. So you are limited by space and exterior design, but the solution is your own. However, when we find the solution, a lot of negotiation with customers (OEM/ Tier 0.5) follows.'

After the development of a prototype, the supplier is again in contact with the OEM, which can suggest possible adaptations; there are many negotiations, so the final invention is a result of mutual communication and suggestions. This fact is also emphasized by R17 below.

> R17: 'Our customers (OEMs) know what they develop and what will be on the market in a couple of years. We are trying to be included in development and have tight relations with customers – this is how we can support them, and they can support us.'

When Tier 1 suppliers develop a new solution, they usually apply for a patent.

> R5: 'From a purely industrial point of view, the aim of filing a patent – also because of examination – is to see if the route is safe or not, so maybe the investment may need to be stopped quickly. […] So the purpose of a patent is to make you feel at least a little safe for all the investments you will make. The other thing is to prevent another company from making the same solution.'

However, can these suppliers develop something completely independently from OEMs and then offer this solution to them (this would therefore be the 'push' innovation)? They can, but the chances of acceptance of this invention are low.

> R6: 'We can also give our suggestions. When we were dealing with [field] XXX, we developed this [invention] ZZZ. That was entirely our idea. We made it and offered it to car manufacturers (OEMs). A lot of interest was shown, but then it's all a matter of money. Manufacturers are interested in incorporating the novelty, but only in the case that it will not be more expensive than the solution they already have. They are not willing to pay much for it.'

Public research organisations (PRO), in contrast, mostly cooperate with OEM or Tier 1 suppliers under such agreements that they are engaged in the development of a new solution; however, a patent belongs to a company.

> R4: 'We cooperate with companies a lot, but we had for example such cooperation with XXX that we left our intellectual property to them. We also have a very big project together with YYY, but we don't patent together there either. I don't think we have any joint patents yet.'

Tier 2 suppliers are, in contrast, limited with all inventive proposals.

> R14: 'It is very hard to come on the position of Tier 1, but not because you don't have knowledge to be in this position but because there is a whole procedure which works under the specific principles and standards where the stability of supply chain structure is the most important; stability in two senses: timely logistics and product quality. […] Until this moment you work under the system: this is documentation, do this for us. So if the question was: do we only follow their instructions? I believe we have knowledge to do more, but the problem is how to penetrate the system. Small Slovenian companies definitely cannot enter with their inventive proposals.'

Tier 2 suppliers have the possibility of introducing process innovations that are kept as trade secrets. The majority of automotive suppliers' innovation, as R1 believes, actually comes from the field of technological processes.

> R1: 'But these innovations are not patented because you will never let a competitor into your production and show him what you have done. These solutions are not visible to the public, and therefore patents are not necessary.'
>
> R5: 'If you're a Tier 2 manufacturer, you usually get a drawing from the manufacturer. Then there is the (technological) process, which, however, has the advantage of being a trade secret. […]. But if you are Tier 1, where you are the one who enters the market with the product, a patent is necessary.'

Even more limited with suggesting inventive proposals from Tier 2 are small innovative companies and start-ups that simply cannot enter the OEM's ecosystem. For example, R8 has already attempted to connect with larger Slovenian companies and state institutions and describes his experience as follows.

> R8: 'I sent this documentation (about invention) to all major companies, but no one even answered me. I was also at the XXX Ministry […], and they said: we can't help; it's best to sell it abroad.'

Pretty much the same experience is also shared by R7, R13 and R16. They attempted with great effort, however, to make contact with OEMs. They mostly rely on their personal acquaintances.

> R10: 'After trying several things, since (OEM) XXX is a reputable company, we finally established a connection with someone who claims he can open the door for us to come to them, since this is the biggest problem (how to come to them) and here we will start.'

For small companies that are not already a part of the supply chain, it is very difficult to make direct contact with OEM. Most OEMs allow the possibility of submitting and describing an inventive proposal through a form on their websites; however, none of our respondents used this option. They prefer to rely on their personal contacts. Start-ups and independent inventors are thus in a relatively unenviable situation in the automotive industry:

although their inventions may be more breakthrough when compared to those of large companies, they cannot even present them to anyone except a narrow circle of acquaintances. The problem is not the NIH (Not Invented Here) syndrome (e.g., Chesbrough et al. 2014, 41), as a representative of the automotive cluster is convinced.

> R1: 'Small companies may have brilliant ideas, but if these are not taken into account in the concept of a car that has already gone through pre-development, development, preparation for production […] this means that any intervention with a solution brought by someone new means endless changes and costs. […]. This is the mistake of start-ups: they develop a circle, and they want to push it in every way into something with a square opening.'

However, due to disruptive technology trends and digital transformation, start-ups have more and more opportunities to be noticed by OEMs, especially software companies. Nevertheless, the channels of how they make contact with them seem to be very incidental, as the experience of R18 shows.

> R18: 'In 2016, we solved a logistic problem with a camera that recognizes different containers. The first prize was to become a supplier and the second prize was to experience driving with different OEM XXX cars. And in this event, we met a guy at Oktoberfest in Munich. And this guy told us: look, you can recognize containers and also food items like chicken, so you can also recognize different surfaces. We said, yes we can do this. So we went to Oktoberfest and XXX bought our software. They said they want to own it, so they paid for the model we created. It is not software-as-a-service; we created software for them; it was a one-time fee.'

> R1: 'Start-ups are interesting, especially in the IT field. Big manufacturers are intensively looking for start-ups, not so much for bringing them inventions, OK, for that too but, above all, they want to integrate them into their process and employ them.'

According to the statements of our respondents, we can define three different paths of how suppliers' inventions reach the OEMs:

1) An invention is proposed and designed by OEM: this is usually in the case of Tier 2 suppliers. OEM provides detailed technical documentation of the component they want to implement in a vehicle. A supplier can (or even must) however still invent in the process field: how to make something faster, cheaper and with higher quality than the competition. These innovations are protected as trade secrets.
2) The invention is developed mutually with the OEM and supplier (pull innovation): this is the case of Tier 1 suppliers, which are also developmental suppliers. In this case, the OEM explains the function of a new component and defines a space in a vehicle where the component should fit in. The supplier proposes the final solution and, of course, the OEM has to accept it; therefore, some corrections of the

solution are frequently needed. That kind of invention has to be patented, and the patent usually belongs to the supplier unless otherwise agreed (which is frequently the case of public research organisations that have contracts under which they undertake development work, but the patent belongs to the client).

3) The invention is proposed and developed by a supplier (push innovation): this is the least common path, but still possible for Tier 1 suppliers and start-ups. OEMs are particularly open to innovations in the field of information and communications technology.

Our findings also confirm our three propositions:

1) The innovation of European automotive suppliers is more pull- than push-driven: OEMs and Tier 0.5 suppliers provide the most inventive proposals. Tier 1 suppliers may be responsible for the development of these proposals, while Tier 2 suppliers only manufacture what is already developed.
2) Tier 1 suppliers may also push innovation and are more likely to innovate in the product field than Tier 2 suppliers: Tier 1 suppliers may communicate directly to OEMs, so they have possibilities to present inventions that they developed independently and, since they are in direct contact, they are also aware of the OEM's needs. Tier 2 suppliers do not have this possibility, and they can thus invent only in the process field.
3) Business entities (SMEs, independent inventors and, in many cases, public research organisations) that are not included in the supply chain do not have much chance of pushing innovation to OEMs. Successful examples of technology transfer, however, do exist, but it seems that this happens rather randomly and rarely. This fact also indicates that the established channels to reach OEMs are predominantly rigid and structured with very limited possibilities for outsiders to enter the system. Such attempts of push innovation should not be mixed with developmental cooperation agreements between OEM and PRO: these agreements are quite frequent, but again, it is the OEM who decides what should be developed and not the PRO.

## 5. Discussion

In recent years, the automotive industry has been facing several challenges, which started before 2020. The COVID-19 pandemic has had fatal consequences for the economy as a whole, and for especially for specific industries, such as tourism and the car industry. The changes that led to a decline in the profits of European OEMs in 2019 began some years earlier and are probably connected with what we can call 'disruptive trends' in the automotive industry. According to some authors and research organizations (Lazard and Ronald Berger 2017; McKinsey 2016; Fu et al. 2019), these trends are electrification (and other alternative drives), connectivity (digitization) of vehicles, autonomous driving, and shared mobility. However, connected with electrification and the problem of battery recycling along with other environmental requirements, we can certainly add the circular economy to the group disruptive trends. As one of our respondents (R5) explained, high investment in electrification is especially responsible for the decline of profits before the COVID-19 pandemic. The decline in profits of European OEMs, of course, has also affected suppliers.

Another problem is the uncertain and reckless policy of the European Union: it is not sure when and how the internal combustion-powered cars will be banned, and consumers are finding it increasingly difficult to decide to invest in such a car, while electric cars still have many disadvantages, including a lack of fast-charging infrastructure. This problem has to be solved as it was made – at the policy level – claims one of our respondents (R20). In contrast, all our respondents are convinced that they are well prepared for the transition to electric vehicles that will undoubtedly come.

The decline of profits due to COVID-19 pandemic is visible also now in the Asian OEMs; however, it seems that they cope better with these disruptive trends. China is certainly the world leader in electric drives, but not only because of their air pollution, as one of our respondents (R3) stressed, they own most of the raw materials needed for batteries and electromagnets. There is also another explanation: to adapt to new technological trends, you need to become more open and actively seek innovation outside of your ecosystems. Our quantitative analysis has confirmed that the OEMs pertaining to the European innovation system, and being integral actors of the automotive technological innovation systems, are less inclined to innovate jointly.

So the question is, does willingness to cooperate outside a relatively closed ecosystem (supply chain) also open up the potential for disruptive competition to the global automotive industry? Studies that would confirm this assumption are still lacking; however, Potter and Graham (2019) studied firms in the Toyota supplier association and revealed that supplier electric and hybrid capabilities are associated with a significant increase in the degree of eco-innovation co-patenting.

Despite that, when we asked our respondents if it would make sense to attempt to connect with Asian manufacturers (who are obviously more prone to external cooperation), large Slovenian companies were against such attempts. Not only because of their loyalty to European OEMs: they also emphasize several obstacles, such as language barriers, different culture, transport costs and inability to compete with competitors there. These elements are related to both the geographical proximity as well as collective learning as building blocks of the innovation system. However, the relative closeness of the European automotive supply is seen as an advantage, and the rigid hierarchy of supply chains is, surprisingly, also not understood as a weakness by our respondents.

Based on our study, we define three different paths of automotive suppliers' innovation: product pull innovation (most frequent for Tier 1 suppliers), process innovation (most frequent for Tier 2 suppliers) and product push innovation (which is possible for Tier 1 suppliers, but also for entities outside OEMs' technological ecosystem, such as start-up companies). Our study does not confirm the findings of Kurpjuweit et al. (2018), who claimed that suppliers could readily engage in an innovation push strategy but only when the timing is right. In the European automotive industry, successful suppliers' push innovations are very rare, and most inventions are developed on the basis of OEMs' requirements; therefore, they are pull innovations. However, suppliers who find new technological solutions according to an OEM's needs may file a patent for this solution independently of the OEM.

## 6. Conclusion

This paper explores the technological innovation system and the relationships between the actors, which are formed in order to create and absorb innovations in the European automotive sector. Thereby, we focus on the innovation potential of the suppliers from the European semi-periphery innovation systems: Slovenian, Austrian, and Hungarian.

The three innovation paths that were have distinguished based on our study reflect a relatively rigid hierarchy of the European automotive supply chains and closed innovation ecosystems in which OEMs and Tier 0.5 suppliers are responsible for the majority of innovation proposals which are later developed by Tier 1 suppliers, while Tier 2 suppliers can innovate only in the process field. Our study confirms that Asian automotive OEMs are more open to external collaboration according to the number of joint patents with other organizations.

However, since a disruptive transition is on its way, there are indications that European OEMs are becoming more open to outside innovation, especially in the software field. It is still not too late for the European automotive industry to catch up with the rest of the world (specifically Asia) and make the most of this transition; however, the technological ecosystems around European OEMs will probably have to become even more open and susceptible to external innovation. This situation is also a great opportunity for SMEs, start-ups and universities that are developing new solutions in the field of electric vehicles, alternative propulsion systems, connected cars, autonomous vehicles, eco-innovation, the circular economy, and digitalization.

One limitation of this study is its small and very diverse sample of respondents. However, we emphasize that we have reached a point of saturation in terms of new knowledge attained. Nevertheless, we do believe that similar studies would be beneficial if conducted for similar geographies, to allow a common picture of the European automotive TIS as well as sectoral innovation systems to arise. These results could cross-fertilize our knowledge on the regional innovation systems as well as on the European innovation system insofar relating to the innovation-related relationships between suppliers and OEMs, which are present in the majority of important industries.

It is also necessary to emphasize that only a part of the automotive technological innovation system was analysed (i.e., the supply chain) since we do not address innovation and related relationships between OEMs and other actors of the TIS after the production of the final product (car dealers, maintenance and recycling services). These could represent another promising area for further research. In this context, and in light of expanding car electrification, studies on battery recycling innovation should also be a priority. We encourage further research, which would support or reject our assumption about the openness of technological innovation systems and the ability to integrate disruptive innovation.

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## Appendix

Table 1: Sample of respondents and their innovation activity

| | | Number of patents | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Respondent no. | Type of respondent | 0–1 | 2–3 | 3–10 | 11–20 | 21–50 | 51–100 | 101–200 | 200 –> |
| R1 | Automotive cluster | X | | | | | | | |
| R2 | Large company | | | | | | | X | |
| R3 | Micro-enterprise (spin-out) | X | | | | | | | |
| R4 | Technology transfer office of PRO | | | | | | | X | |
| R5 | Large company | | | | | X | | | |
| R6 | Large company | | X | | | | | | |
| R7 | Independent inventor | | X | | | | | | |
| R8 | Micro-enterprise | | | | X | | | | |
| R9 | Independent inventor | | X | | | | | | |
| R10 | Small enterprise | X | | | | | | | |
| R11 | Large company | | | | | X | | | |
| R12 | Medium size enterprise (spin-out) | | | | X | | | | |
| R13 | Micro-enterprise | | | X | | | | | |
| R14 | Small enterprise | | | | | | X | | |
| R15 | Micro-enterprise | | X | | | | | | |
| R16 | Micro-enterprise | X | | | | | | | |
| R17 (AT) | Large company | | | | | | | | X |
| R18 (AT) | Small enterprise | X | | | | | | | |
| R19 (HU) | Medium-sized enterprise | | | X | | | | | |
| R20 (HU) | Automotive cluster | X | | | | | | | |

# SYSTEMATIZED ANALYSIS USING DATA MINING'S METHODOLOGY ON THE TOPIC OF REGIONAL INDUSTRIAL SYMBIOSIS AND ITS NETWORKS

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**Abstract:** *The aim of this paper is the analysis and a presentatition of texts and terminological ontology of scientific and professional publications in the field of regional Industrial Symbiosis and Industrial Symbiotic Networks. With computer-aided text analysis it is possible to have a comprehensive overview of the publications of works in this field and a more detailed presentation of the most fruitful concepts of publications.*

**Key words:** Data mining, knowledge, industrial symbiosis, industrial symbiotic networks, ontology, OntoGen

## 1. Introduction

The development of European society is based on knowledge and the ability to implement it in all areas of human activity. Knowledge is, for example, also present in the recent EU grand strategy Europe 2020, aiming to achieve growth, which is also *smart* (Rončević 2019), although pursuit of this strategy is not always completely successful (Makarovič et al. 2014). In addition to its growth being smart, the European Union also strives for it to be inclusive and sustainable, hence the immense focus on circular economy (Mileva Boshkoska et al. 2018; Fric et al. 2020). In this article we are going to focus on the knowledge relating to the the phenomena of industrial symbiosis and its networks.

We must know how to properly present our own or acquired knowledge and attract attention to individuals or/and organizations that can use this knowledge usefully in their work or field. It is the organizations themselves making sure the differences among them exist mainly due to ability to detect and absorb knowledge (Rončević and Valič 2019, 330).

Knowledge modeling provides a comprehensive overview of the issues under consideration or the domain being studied, so this paper focuses on the field of knowledge modeling and its presentation in the form of terminological ontologies.

The following organization of the data from the visible journal on web into the text analysis of published titles of articles, will be supported by a computer programme. This programme will enable semi-automatic construction of ontologies from texts. By modelling the domain knowledge in the form of ontologies based on the titles of articles, is intended to examine the main research areas, which can be reflected from the publications. The result of the analysis was performed as a picture of areas in which the research activities of the topic on regional industrial symbiosis and industrial symbiotic networks was the most outlined and representative. It was take into account that was selected only one Journal at this stage and a determinated nomber of titles in terms of publications during the examined period of the last 25 years.

## 2. The concepts of Industrial Symbiosis and Industrial Symbiotic Networks

A resource sharing among co-located firms referenced in the Industrial Ecology (IE) literature as Industrial Symbiosis (IS) is concerned with the cyclical flow of resources through networks of businesses. Industrial symbiosisis is mostly characterized with the cyclical flow of resources through networks of businesses as a means of cooperatively approaching ecologically sustainable industrial activity. As such it is motivated by economic considerations such as lowering costs for waste disposal, as well as by environmental ones (Beers et al. 2007). The main goal of industrial symbiosis is to aid in industrial organization by pushing firms to think beyond individual firm boundaries into a broader systems level (P7 Modelling industrial symbiosis to find the potentials and barriers in Aalborg, Denmark 2017). Firms belonging to an industrial ecology utilize industrial symbiosis as a collective approach to competitive advantage and simultaneously realize economic and environmental benefits, but also emerge social considerations, in our case Industrial Symbiotic Networks (ISNs).

Industrial symbiosis, in other words is a few dozen partners, means for trust-building include personal meetings, regular communication, sharing of information and knowledge, and stable rules of the game (Fric 2016).

In 1947, the term “industrial symbiosis” was first utilized by Renner in the economic geography literature to describe “organic relationship” between dissimilar industries, including the use of the waste products from one as input to another. The development of industrial symbiosis in an international perspective gas grown substantially since the late 40's until now (Chertow 2000, 313–37; Džajić Uršič 2020).

## 2.1 Industrial symbiosis and the social sciences

When was tried to construct a proposed hierarchy in this paper, it has been "reduced" a perceived reality of industrial symbiosis systems so the research encompasses and gives importance to the social interactions as trust and willingness (Black Sea Industrial Symbiosis Platform 2017). For the success of industrial symbiosis (Schiller et al. 2014; GILG 2013) is firstly vital the exchange of material by-products and energy, secondly some forms of social exchange, in other words, inter-firm networking, trust and collaboration. Many attempts of regional projects to build industrial symbiosis failed because is it hard to find firms willing to co-locate and link their processes with other firms they do not yet know or trust. This is perceived as simply too great a risk to take. Trust is needed in exploring the possibilities for by-products exchange because firms need to share (possibly sensitive) information about their inputs and outputs (Gilg 2013; Fric 2016).

New economic sociology also pays a little attention to the influence of institutions; might be, that the institutional approaches play a secondary role in the new economic sociology in general, while networks and cultural explanations prevail. Even in studies that are informed by institutionalism, the concept of institution that is being used leans towards the new sociological institutionalism (CRESSI 2017; Kalundborg Symbiose 2017) (and focuses on questions of legitimacy and diffusion of institutional models). Although sociology has lagged behind other social sciences in appreciating new methodologies and a distinctive sociological contribution is evident here. Information about relative data of various titles can assist in the analysis of dozen of titles" texts and following hierarchical ontologies (Džajić Uršič 2020).

The development of industrial symbiotic networks is complex and can be, as a consequence of several factors influencing the evaluation process, uncertain and unclear. The complexity of the process has increased in the period. Even though the exchanges of waste were not called industrial symbiosis or synergies of networks, the early process began at that time. Even if the term of industrial symbiosis may appear to have fully grown onto the sustainability stage, resources exchange and processes of trading are basic aspects of the developing world (Chertow 2000, 313–37).

The importance of the social dimension of industrial symbiosis is very commonly acknowledged in the literature. Trust and willingness on some level is definitive to cooperate and it is seen as requirements for "industrial symbiosis proper" (exchange of materials and energy) to take place (Ehrenfeld 1997; Gibbs and Deutz 2005; Gibbs and Deutz 2007; Tudor et al. 2007). Many of those industrial symbiosis projects failed because is it hard to find firms willing to co-locate and link their processes with other firms they do not yet know or trust. This is perceived as simply too great a risk to take. Trust is needed before interdependencies through by-products exchange can be set up, because certainty and continuity of supply are extremely important to industrial firms (Tudor et al. 2007).

## 3. From data to information and knowledge

Data are chaotic, unprocessed essentials that tell us nothing in themselves until they are properly processed, but only when we process the data and/or compare between, we find out their meanings. Data doesn't tell us anything about motivation, the quality or characteristics of the analyses, by which they were obtained, but are a prerequisite for information obtained as a result of researches. The problem arises when we have too much data and we do not know what decisions make to reach the desired goal (Bizjak 2014, 9–11).

The knowledge is a base in this case because helps us at work, in everyday life and has several meanings depending where it is applied. The knowledge is not just information like even information is not just data and knowledge comes from information in the same way as information comes from data.

Awad and Ghaziri (2007) argue that information helps to understand relationships between them and give meaning to the unorganaized data, that can be later reorganized, statistically analyze, avoided from errors, or otherwise process them to obtain their meaning. Only when we collect enough information, we understand a phenomenon or problem and talk about knowledge (Girard and Girard 2015; Awad and Ghaziri 2007; Szilva et al. 2018).

Processes for discovering useful knowledge from data are usually based on data mining, which allows the use of special computer algorithms obtaining and displaying meaningful models from input data. Knowledge discovery processes can also be based on text collections and the procedure from an input text extracted structured information is called *text mining.* Similar to how databases can be analyzed by data mining in the case of text databases (example: bibliographic databases of scientific records, professional publications, etc.) uses text mining procedures (Sebastiani 2002; Feyyad 1996). Modern databases offer fast-growing volumes of text and other formats of data. Finding the proper data and getting information based on it, among such a crowd of data, is difficult, especially, if we want understanding areas on which we are not professionally knowledgeable. Therefore, there is a growing need for methods and tools that would be able to extract useful knowledge from the mass of data (Fayyad et al. 1996).

Exploring data means looking for characteristics and display them for the group we are processing. This includes some important steps (Awad and Ghaziri 2007):

- definition of primary hypotheses and prediction of further measures,
- identification of outliers who are outside the expected crowd results,
- display of key features and
- selection of interesting data groups for further research.

For this case, we can use modern program tool that enable automatic or semi-automatic analysis displaying data. The tool called OntoGen in this research is used for textual analysis of dozen of titles of article where we can present results in the form of content *hierarchies* called *ontologies.*

### 3.1 Data mininig

Data mining and machine learning have a goal to extract knowledge (in a human-understandable structure) from large quantities of data (for example to illustrate relations between observed variables). The automatic or semi-automatic data mining process analyzes data and discovers new outlines to extract previously unknown remarkable outlines such as simplifications that can predict values of a certain variable in previously unseen examples from the known values of other variables (inquiring groups of data records, rare records and needs in the data).

The process of data mining can be seen as a procedure where signify terms from the collection of input texts used *Bag of words*, which show the analyzed texts by extracting terms from them, without taking into account grammatical rules and word order.

Firstly, what we need to do is to collect different groups of data and display from them statistically significant data to display characteristic for the group we are processing. At this stage are important some steps: (1) definition of initial hypotheses, (2) presentation of key attributes, (3) recognition of outliers outside of the crowd results (4) and selection of remarkable data for further studies.

### 3.2 What are the ontologies in this case?

An ontology is a presentation of a multitude of concepts on some field of human knowledge where those concepts can be categorized. The term *"ontology"* comes from philosophy and is often used to define philosophical disciplines for displaying some basis, reasons and typical characteristics of reality. Ontologies can be used as a model of formal structure for unchanging picture and semantics of information (Lavbič and Krisper 2005). Depending on the degree of formality, ontologies are:

- descriptive (defined by terms that are often used to present knowledge and describe a specific thematic area),
- formal (consists only of formally accepted descriptive terminology ontologies, which denotes different aspects or types of a given area), or
- formalized (contain formal specifications of a field in the strictest meaning of the formalization of the presentation (Poli and Seibt 2010).

Formalized ontologies are glossaries of terms (words and their synonyms) that semantically structure a particular area and at the same time allow to show the hierarchical structure of relations between concepts. In this sense, ontologies have great potential especially in areas of knowledge management, information gathering, integration of intelligent systems and e-commerce (Lavbič and Krisper 2005).

The philosophy of the regional industrial symbiosis is concerned with identifying the kinds of things that exist in industrial symbiotic networks so, ontological (and epistemological) ideas guide not only to the selection of the research focus but also to the methodology assumed and the expected outcomes. Industrial symbiotic networks are in this research observed as social structures that are simultaneously constructed and reflected upon by the researcher and the stakeholders that participate into the system – this approach understands their identification first as a singular phenomenon, and then as a sustainable instrument, part of the process of co-creation of meaning and social interaction (Džajić Uršič 2020).

This ontological (and epistemological) position explains the focus on a small part of this research on the social processes. These processes are behind the articulation of industrial symbiotic networks and the emphasis given to structural and discursive dimensions in the analysis. When trying to conceptualize a proposed research and "reduce" a perceived reality of industrial symbiosis systems, we encompasse and give importance to social interactions (Džajić Uršič 2020).

However, the new economic sociology pays just a little attention to the influence of the important *institutions* (from authors' perspective); might be that the institutional approaches play a secondary role in the new economic sociology in general, while networks and cultural explanations prevail. Even in studies that are informed by institutionalism, the concept of an institution that is being used leans towards the new sociological institutionalism

(Howard-Grenville and Paquin 2008; Scott 2004) and focuses on questions of legitimacy and diffusion of institutional models. While sociology has padded behind other social sciences in valuing this new methodology, a distinctive sociological contribution is evident here (Macy and Willer 2002, 143–166). Theoretical interest focuses on dynamic social networks that shape and are shaped by agent interaction and to perform experiments to test macro-sociological theories by manipulating structural factors like network topology, spatial mobility and social stratification here (Macy and Willer 2002, 143–166). In the following chapter are presented and discussed ontologies in terms of informal ones, as semantic conceptual representations of domain knowledge. Sowa (2000) defines such ontologies as terminological, showing general concepts and relations of particular domain knowledge, as opposite to formal ontologies that precisely represent domain expressions and specific types of relations (such as is-part, is-case) among them. Terminological ontologies are characterised by the words and axioms in natural language, while formal ontologies are obtainable in a logical language, based on concept dictionaries and sentences that show the relationships between concepts. Ontologies representing domain knowledge can enable a common understanding of the domain (Lavbič and Krisper 2005), which simplifies communication among people (terminological ontologies) and computer systems (formal ontologies).

## 4. Methodology

The data are obtained primarily from website *Sciencedirect* (Sciencedirect 2020), where scientific and professional publications on the topic of "Industrial Symbiosis", and topic "Industrial Symbiotic Networks" is built a model of knowledge. Those two topics or better keywords are analyzed. The data from the website are organized into a collection of posed titles, in plain text with a text editor. This was the basis for the text analysis performed with the computer tool OntoGen (Fortuna et al. 2001; 2006; 2007), which enables the semi-automatic construction of knowledge models in the form of ontologies (Ontogen 2020; OntoGen 2020).

Semi-Automatic means that "*a system is an interactive tool that aids the user during the ontology construction process. The system suggests relations, concepts, names, automatically assigns cases to concepts and provides a good overview of the ontology to the user trough concept browsing and visualization. At the same time, the user can fully adjust all the properties of the ontology by manually adding or deleting concepts, relations and reassigning cases*" (Fortuna et al. 2001, 1).

In this case, for this paper, somehow it is very difficult to manage a lot of web pages and textual documents and in this case ontologies play a very important role for them. Ontologies offer additional help to reduce overloaded information for a specific area.

OntoGen is a "data-driven and semi-automatic" system which is used for generating topic ontologies. "*The functionality of the system (machine learning algorithms, data handling and ontology visualization) is based on the Text Garden library [Grobelnik06] and is efficiently implemented in C++. The user interface is written in C# and requires Microsoft .NET framework 2.03 for running. The heavy-duty functionality is now compiled in native code and stored in DLL library. The library is accessed from the C# and used to provide the functionality to the user interfaces. Previous version used Managed C++ so the whole program was compiled into bytecode. By compiling the core functionality directly into native code the machine learning algorithms used in OntoGen run approximately twice as fast as in the previous version"* (Fortuna et al. 2001, 1).

"*The old version of OntoGen is only used to edit the different types of ontology which was connected with different kinds of relations. It is difficult for user because user spend lot of time to edit ontology. But the new version of OntoGen is providing attractive interface for user which reduces time and complexity for user. The system is attractive and provides helps for user during the ontology construction process. It give suggests about concepts and relations between concepts and automatically assigns cases to concepts. For the construction process of ontology in OntoGen, data is provided by user. OntoGen is providing support for user to give automatic concepts and also describe the relationship between these concepts according to data*" ( Fortuna et al. 2001; Bajwa et al. 2019).

The next main steps with the semi-automatically managed OntoGen program are:

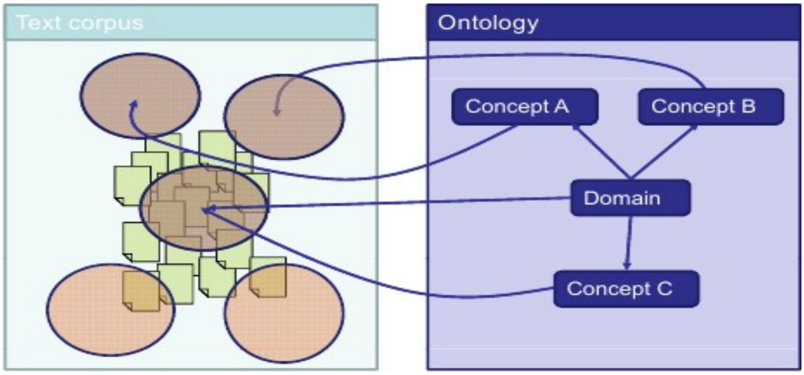
- presentation of knowledge modeling, from when the data are captured to information acquisition and knowledge demonstrations;
- definition of knowledge representation in the form of ontologies, classification of ontologies and the importance of terminological ontologies in knowledge modeling;
- presentation of a case study with a more detailed description of the preparation of data, for text analysis and the sequence of text mining with the computer tool OntoGen;
- presentation of the results of text analysis (Guarino 1995).

## 5. Case Study

The data included in the study refers to publications from 2000 to the end of 2019 and contains the titles of scientific publications on the topic of industrial symbiosis and its networks. With the tool for word processing and analysis, are processed then the titles. Due to the needs of textual address analysis publications, is chosen the format of the XML output format. On this way, we got 267 titles of units.

With OntoGen is build a "topic *ontology*" from a multitude of documents and this topic ontology is a set of topics related to relations and each topic has a set of documents (see Figure 1).

Figure 1: Topic ontology example



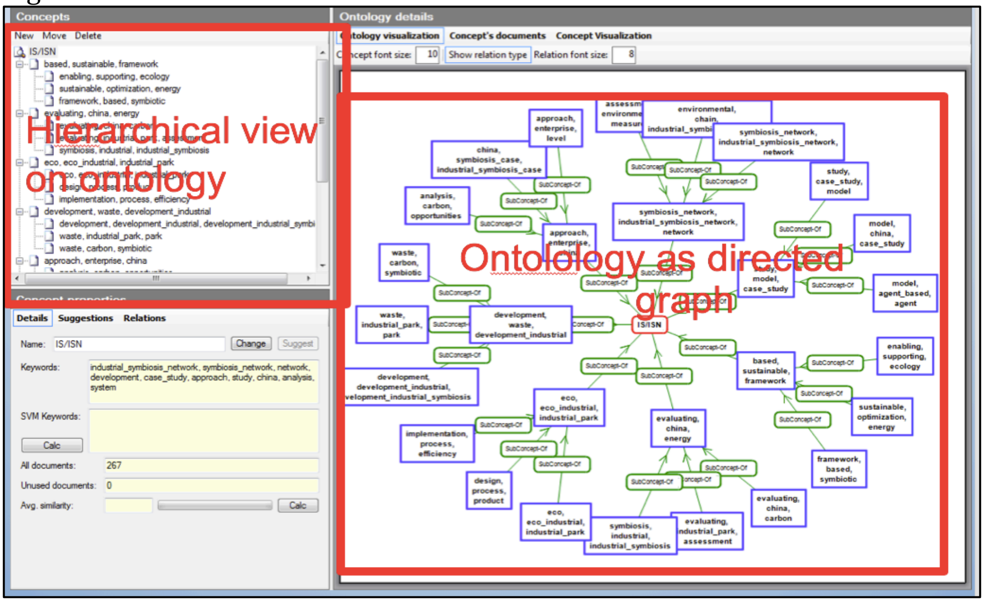

Source: Ontogen (2014)

The data can be processed with the program OntoGen after we prepared a file format as *"naked text"* in which each line contains data – title of the individual publications. In our case, each line of the input file contains the title address of individual publications of the topic on industrial symbiosis and industrial symbiotic networks. With this purpose are data obtained from Web source in XML format and edited with Microsoft Word text editing program. Thus, we obtained a collection of relevant data of industrial symbiosis and industrial symbiotic networks publications which contained titles of publications, among which appeared the titles of collections of scientific papers and electronic books. The consolidated text was then saved in file in plain text format and used then as an input file to be analyse with OntoGen.

The program itself suggests keywords and automatically assigns examples allows text to match the content of the suggested keywords. It allows examples of texts combined in concepts and provides a hierarchical overview of *concepts and subconcepts* of ontology. The user may accept it at all or in part, or rejects the proposed results of the analysis of the texts that the system automatically offers him.

Figure 2 shows the OntoGen user interface that appears when the program is open and is in the starting point for further work. The starting window is divided into two smaller and one larger window. The larger window is for viewing ontologies and managing input texts, where are named documents in the program. In the upper left is a hierarchical tree with all the concepts and subconcepts of the ontology. In the lower left window, the user can add, change or edit concepts and subconcepts in further text analysis. The functionality of the system, which includes learning algorithms, analysis and text management, relies on a collection of programs called *Text Garden library* (Fortuna et al. 2001; 2006; 2007).

Figure 2: OntoGen user interface version 2.00 version




Source: Own data in OntoGen (2020)

In the user interface appears five components of ontologies:

- *classes* (concepts, types, or types of things),
- *cases* (concrete cases of classes),
- *properties* (attributes, characteristics of classes and cases),
- *relations* (between classes, cases) and

- *other*: restrictions, rules, axioms, events.

The relations into OntoGen have two relations: *is-a (subconcept-of)* and *is-similar* (Ontogen 2014).

Building ontologies the OntoGen program use a sorting technique in groups with the *k-means algorithm*, which classifies input elements into k-groups based on similarity of elements and looking for the most appropriate value of the *parameter k* for this case study. The k-means algorithm sorts the units from the input collection data by groups, so that the similarity of the cases is within individual groups greater compared to the similarity between specimens from different groups. For simplicity and efficiency, the k-means algorithm is one of the most commonly used classification algorithms in practice (Duda et al. 2012). There are three clustering methods implemented in OntoGen: already mentioned k-means, LSI and PH k-means. "*The first two were already part of the first version while the last method is newly added in the latest version. There is also a suggestion method called category which just groups the cases according to the labels included in the input data. The user can select which method the system should use for generating suggestions" (*Fortuna et al. 2001, 4).

In the case study, we founded 267 titles, that had been obtained from articles containing a total of 4546 words. To the list of blocked words, we added conjunctions, numerators, pronouns, etc., that have no special substantive weight. Into OntoGen we can also construct three types of ontologies: visualization – typically in a 2D grouping of documents, method of k-means grouping – mainly used and the third construction of ontologies can be possible as active learning; that means that a user can help a computer program to learn the concepts.

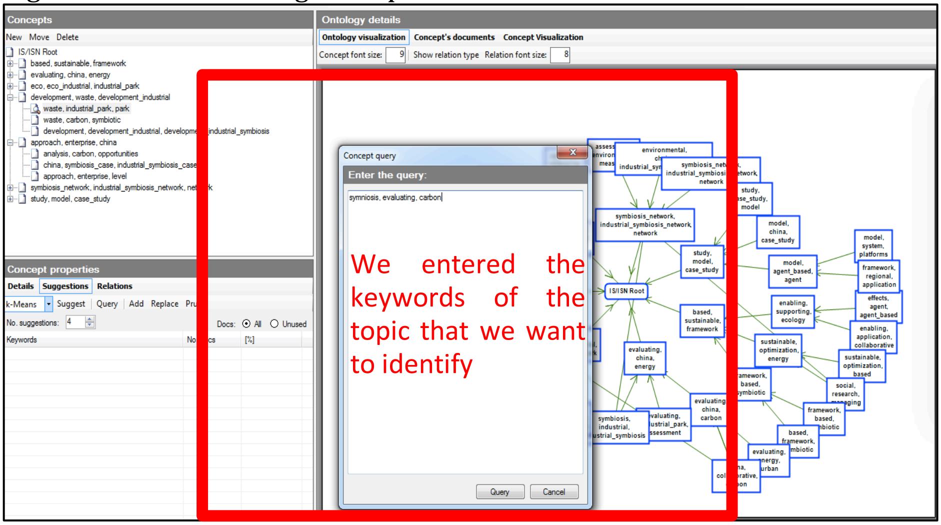
When building ontologies with OntoGen, we decide to have a higher parameter k = 7 (number of text groups) relative to the input size of the files, which in our case contained 267 article titles. With this value, we then looked for intermediate settings that the program shows us as a homogeneous as possible and at the same time sufficiently representative groups of titles, which the program names with concepts or keywords. Then we built an ontology with seven automatically proposed concepts (parameter value k = 7) at the first level of classification of article titles and added three subconcepts each, that were automatically suggested from OntoGen. In the first concept were sorted 35 titles where the program assigned the following keywords: *development, waste, development_industrial, development_industrial_symbiosis, resource, regional, case_study, industrial_park, park, application.* In the second cocept were sorted 33 titles where the program assigned the following keywords: *approach, enterprise,* *china, case_study, analysis, carbon, study, symbiosis_case, industrial_symbiosis_case, opportunities*. In the third concept were selected 52 titles where OntoGen assigned keywords: *symbiosis_network, industrial_symbiosis_network, network, environmental, performance, measures, assessment, economic, indicators, environmental_performance*. In the fourth case, the OntoGen assigned keywords as *study, model, case_study, product, integrating, system, case, china, effects, building* using 35 titles. For the next concept, the fifth, the program sorted 41 titles and assigned *based, sustainable, framework, social, optimization, symbiosis_based, symbiotic, managing, review, application* as keywords. In the sixth case the program assigned keywords: *evaluating, china, energy, case, carbon, assessment, benefits, industrial_park, industrial_symbiosis, park* sorted and selected 27 titles. In the final case, the seventh, OntoGen used 44 titles and assigned *eco, eco_industrial, industrial_park, design, eco_industrial_park, park, system, process, product, analysis.*

The obtained results show that the largest group of publications use the general term of s*ymbiosis and networks and environmental performance and measures.* Right afterwards are used words as *eco/eco industrial parks and sustainable, framework.*

This feature in OntoGen is a controlled method for adding concepts, based on SVM (Support Vector Machine) active learning method. Enquiring and active learning is only applied to the cases from the selected concept. The idea of this function is that a user can tell/write the concept and some documents related to this concept and than OntoGen can learn the description of this concept and other related documents and discover if those documents are connected and related to the concrete concept.

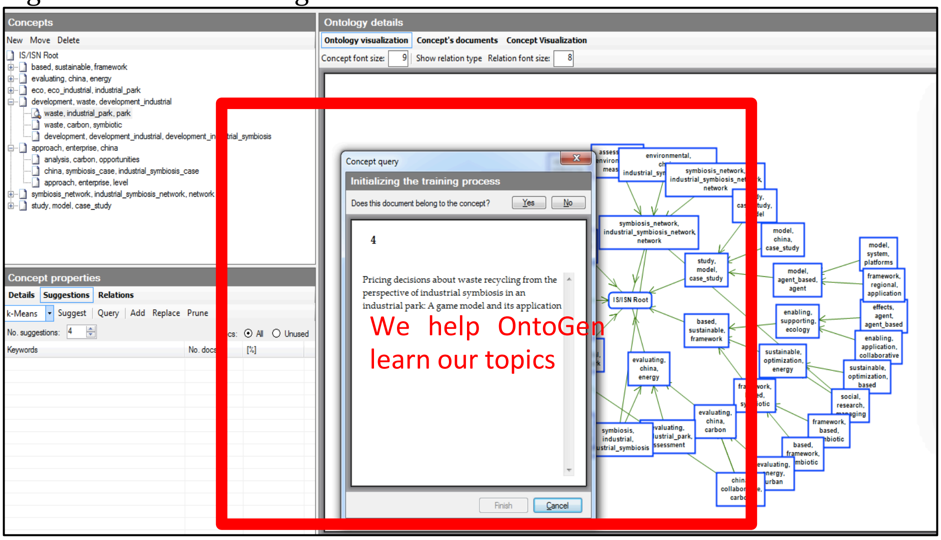
In the feature of *active learning*, a user can start a method by clicking *"Query"* button in Figure 3. So the system launches a dialogue box that takes the query from the user and after the user enters a query the active learning system starts asking questions and labelling the cases (in Figure 3). On each step, the system asks if a particular case belongs to the concept and the user can select "Yes or No" (Figure 4). *"Questions are selected so that the most information about the desired concept is retrieved from the user. After some initial labelled sample is collected from the user the system displays some additional information about the concept. It displays the current size (number of documents positively classified into the concept) and most important keywords for the concept (using SVM keyword extraction). The user can continue answering the questions or finish by clicking on the Finish button. The more questions that the user answers the more correct assignment of cases in the final concept* are" (Fortuna et al. 2001, 5).

Figure 3: Active learning 1. step




Source: Own data in OntoGen (2020)

Figure 4: Active learning 2




Source: Own data in OntoGen (2020)

With the function *Concept Visualization* (see Figure 5) in OntoGen we can observe four evident groups of keywords from the titles. The group appeared as four white areas.

Figure 5: The grouping of four concepts

Source: Own data in OntoGen (2020)

From Figure 5 we can see that some words are repeated several times in certain documents. Those words are for example *anslysis, network, symbiosis, energy, case, China, industrial, etc*. That words can not be added to just one concept, also because the documents were very similar and in this case, we got a fairly diffuse distribution of concepts. However, with the help of the map, we can also identify the main content sub-areas, adding them to the ontology as a subconcepts. This method is also called a map of divided words.

Ontology in this research has seven concepts and content areas, each of which is divided into three subconcepts (see Figure 1). The first concept *eco, eco_industrial, industrial_park, design, eco_industrial_park, park, system, process, product, analysis* is divided into three subconcepts and these have assigned keywords: (1) *eco, eco_industrial, industrial_park, eco_industrial_park, park, system, analysis, social, urban, economy;* (2) *design, process, product, experiences, energy, objective, system, optimization, multi, design_industrial;* (3) *implementation, process, efficiency, methodology, role, economy, circular, circular_economy, institutional, building .*

The second concept *development, waste, development_industrial, development_industrial_symbiosis, resource, regional, case_study, industrial_park, park, application* has (1) *waste, industrial_park, park, case_study, application, resource, symbiosis_industrial, model, perspective, collaborative;* (2) *waste, carbon, symbiotic, managing, approach, data, technology, exploring, integrating, organize;* (3) *development, development_industrial, development_industrial_symbiosis, emergence, regional, analysis, resource, experiences, clusters, network.*

The third concept *approach, enterprise, china, case_study, analysis, carbon, study, symbiosis_case, industrial_symbiosis_case, opportunities*: (1) *analysis, carbon, opportunities, system, low_carbon, low, case_study, technical, approach, industrial_symbiosis_networ,* (2) *china, symbiosis_case, industrial_symbiosis_case, study, case_study, enterprise, carbon, promote, process, emergence* and (3) *approach, enterprise, level, network, enabling, technology, innovation, study, input_output, output.*

The fourth concept: *symbiosis_network, industrial_symbiosis_network, network, environmental, performance, measures, assessment, economic, indicators, environmental_performance* is divided into (1) *assessment, environmental, measures, indicators, approach, effects, energy, emission, reduction, benefits,* (2) *environmental, chain, industrial_symbiosis_network, supply_chain, supply, symbiosis_network, economic, performance, improve, collaborative* and (3) *symbiosis_network, industrial_symbiosis_network, network, environmental, performance, comparable, case, performance_industrial, role, structural.* The fifth concept *study, model, case_study, product, integrating, system, case, china, effects, buildings* composed by subconcepts: (1) *study, case_study, model, case, building, product, integrating, development, study_industrial, business,* (2) *model, china, case_study, effects, insights, optimization, flows, product, integrating, resource* and (3) *model, agent_based, agent, agent_based_model, based_model, system, data, framework, platforms, product.*

The sixth concept is *based, sustainable, framework, social, optimization, symbiosis_based, symbiotic, managing, review, application* divided in (1) *enabling, supporting, ecology, platforms, application, review, collaborative, enabling_industrial_symbiosis, enabling_industrial, effects,* (2) *sustainable, optimization, energy, based, managing, symbiosis_based, industrial_park, social, park, research* and (3) *framework, based, symbiotic, social, optimization, analysis, role, business, symbiosis_based, symbiosis_system,* subconcepts. And the final – seventh concept *evaluating, china, energy, case, carbon, assessment, benefits, industrial_park, industrial_symbiosis, park* is constructed from three subconcepts: (1) *evaluating, china, carbon, energy, urban, benefits, product, reduction, collaborative, case,* (2) *evaluating, industrial_park, assessment, park, case, china, cycle, life_cycle, life, energy* and (3) *symbiosis, industrial, industrial_symbiosis, agent, agent_based, evaluating, simulation, based_simulation, indicators.*

## 6. Discussion

In the first concept of ontology, denoted by the keywords *eco, eco_industrial, industrial_park, design, eco_industrial_park, park, system, process, product, analysis* is 44 titles describing the structure of Eco-Industrial Parks (EIP) composed by several examples of industrial symbiosis, which allow energy/material exchanges among the different industrial enterprises within. Social, economic and environmental performances can be improved in these cases.

The second concept of the ontology includes 47 titles that include *development, waste, development_industrial, development_industrial_symbiosis, resource, regional, case_study, industrial_park, park, application.* In this group, we find the titles including insistent ecological challenges that danger social progress and economic prosperity in the regions, including unsustainable resource management and natural resource reduction, ecosystem degradation and bio-variety damage, contamination, waste and climate changes. This concept is also combining thematics as values of regional cooperation and of the means of implementation of the 2030 Agenda for Sustainable Development to join benefits and promote keys for better environment (Desa 2016).

The third concept of ontology: *approach, enterprise, china, case_study, analysis, carbon, study, symbiosis_case, industrial_symbiosis_case, opportunities*, includes 33 titles considering the specific situation where there are so many state-owned big firm groups as in China and uncovered opportunities of a low-carbon cities promotions with the industrial system.

In the fourth concept of ontology: *symbiosis_network, industrial_symbiosis_network, network, environmental, performance, measures, assessment, economic, indicators, environmental_performance* have 52 titles, among which are studies on ecological characteristics, impacts, whose activities are planned in the actions and socio-economic aspects; firms that measure, achieve and communicate their environmental performances are integrally well placed, by improving their processes, reduce costs, conform with regulatory requirements and stakeholder expectations and take advantage of new market opportunities (Oertwig 2017).

The fitfth concept with keywords: study, *model, case_study, product, integrating, system, case, china, effects, building* include 35 titles where the main context focuses on the influence of micro-mezzo-macro economic factors and the social distances to the integration process in industrial symbiotic networks. Projects of macro-economic factors and social distances influence on the integration process of new business objects in some region (Schiller et al. 2014).

The next concept – the sixth is composed of keywords: *based, sustainable, framework, social, optimization, symbiosis_based, symbiotic, managing, review, application* and covered by 41 tittles. Point groups or categories including industrial symbiosis points, circularity points, eco-innovation points, sustainability and resource efficiency points, and network strength studies points, were evaluated. Through reviews, a lot of strategies of implementation industrial synergies were stressed and argued for each of the above-mentioned categories (Department of Economic & Social Affairs – United Nations Publications 2008).

The seventh concept within 27 titles: *evaluating, china, energy, case, carbon, assessment, benefits, industrial_park, industrial_symbiosis, park* primarly deals with the issue of the plan stages of the removals and treatments in landfills. These stages generate an important economic and environmental cost, mainly caused by carbon dioxide emissions due to the transports. Therefore, several actions have been taken to encourage and disseminate eco-industrial development, such as the implementation of eco-industrial parks (EIPs) and their networks (Demirbas et al. 2004).

## 7. Conclusion

In the construction of terminological ontologies based on the titles on a field of industrial symbios and industrial symbiotic networks, we found that the precision of modeling and demonstrations of domain knowledge mostly depends on the settings of the text analysis parameters as in this case (paper) is the value of the parameter "k". K-means algorithm is used to sort input elements (article titles in our case) in "k groups" based on the substantive similarity of the elements. As the best choice in the case study was the division of input texts into seven groups (concepts) that was established at the first hierarchical level of the ontology and with three subgroups (subconcepts) at the second level. The size of the input file is also important and in present the number of titles covered in the primary reserch. Input data must be sufficient quantitatively, so the program tool would be able to analyze them and obtain meaningful analysis and representative results.

The fourth concept of ontology is numerically the most extensive, as it includes 52 titles. The articles that are mostly categorized in the fourth concept of ontology are: *environmental performances, measures, assessment, economic indicators*. Much of the articles describe the development of industrial symbiosis and their combination with other analytical methods. Among the results, we also expected more data about the networks that are spinning arround into the regional cases of industrial symbiosis.

OntoGen is recognised to be a useful tool for modeling domain knowledge. OntoGen is very logical in a detailed review of keywords that are automatically identified. Another plus of OntoGen is, that helps to recognize keywords displayed that could be manually improved or renamed (Bizjak 2014, 35−39). For an even more detailed implementation of domain knowledge it would also make sense to include summaries of articles from the period under consideration and thus obtain even more detailed demonstrations of publications about the field of industrial symbiosis and their networks.

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# PROSPECTS FOR INNOVATION PERFORMANCE ON EUROPEAN LEVEL

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**Abstract:** *In 2004, the European Commission implemented the Decision No 1608/2003/EC of the European Parliament and of the Council concerning the production and development of Community statistics on innovation. This triggered the awareness of the role of innovation and R&D on national and European level and thus the opportunity to step towards in-depth monitoring innovation performance through various indicators. The paper aims to investigate the trends in the selected innovation indicators (i.e., public funding, expenditures and innovation activities, types of innovation and products introduced, hampered innovation activities) to outline the development direction on the enterprise level using the Community innovation survey data for the 2002–2016 period. Using the basic time series analysis, the paper evaluates the progress according to the European Strategy on research and innovation. Furthermore, using the autocorrelation and autoregression methods, the paper also outlines the future direction in innovation performance on European level.*

**Key words:** innovation, performance, progress, future direction, European Union, Community innovation survey

## 1. Introduction

In 2010, European Commission (EC) presented the strategy for smart, sustainable and inclusive growth known as Europe 2020. It focused on the need for transformation as a response to the recent economic crisis, which negatively influenced the European economic and social progress. To reinforce economic progress, Europe 2020 outlined three main priorities regarding smart, sustainable and inclusive growth. In this context, it emphasized knowledge and innovation as important forces for successful economic development (Unspecified 2010; Rončević 2019).

The implementation of Europe 2020 followed the provisions of the Treaty establishing European Community (European Union 2002), and in particular Article 157 thereof, according to which the Community and the Member States are to provide the conditions for the competitive Community's industry. Following the aim of this paper, we focus on the part, which refers to the exploitation of the industrial potential that science, technology and innovation policies have for Member States.

As pointed by EC, innovation is a prerequisite for Europe's sustainable growth, which is influenced by several systemic factors set by the regulatory framework. To foster the innovations, one of the important actions outlined by EC, is the reduction of the main administrative burdens set by the EU legislation. This means that innovation and regulatory environment should be interacting to set an optimal level of regulations in innovation domain. To set an innovation-friendly regulatory framework, the Better Regulation Agenda and the third strand of the Investment Plan for Europe have already constituted mutually connected instruments. These include further improvement of the existing and future regulations design focusing on their impact on innovation, achievement of the best possible balance between regulatory environment and technological and scientific progress, overall assessment of the impact that regulations have on innovations, and search for innovation-friendly approaches for the future (European Commission 2016).

To support and monitor the performance of these regulations and policies, in 2004 the European Commission implemented the Decision No 1608/2003/EC of the European Parliament and of the Council concerning the production and development of Community statistics on innovation. This triggered activities to build foundations for governing the process of providing R&D and innovation statistics, which would ensure the usability and comparability of the data.

In providing these statistics, an important role has been attributed to the Community Innovation Survey (CIS), which has been carried out in some European states since 1992. Being driven mainly by academics, CIS provided data that were of high value primarily for researching innovation in conjunction with economic theories. With the implementation of the Decision No 1608/2003/EC of the European Parliament and of the Council, the content and implementation of CIS has gradually shifted from academics to policy analysts and national statistical agencies with Eurostat being the coordinator of changing the standard CIS questionnaire. Furthermore, in order to ensure comparable statistics on R&D and innovation, the implementation of Commission Regulation No 1450/2004 has determined the use of CIS to provide innovation indicators, thus also being incorporated into the European law (Arundel and Smith 2013).

Today, CIS is considered the largest innovation survey in the world regarding both, the number of participating countries and the number of responding enterprises. It follows the standard definitions of R&D from the Frascati Manual (OECD 2015), which provides methodological guidelines for collecting, using and reporting data on research and experimental development. It is also based on the Oslo Manual (OECD 2005), which outlines the guidelines for collecting and interpreting innovation data. The newest edition of the Oslo Manual was released in 2018 (OECD 2018) and represents the foundation for future preparation and implementation of CIS (Arundel and Smith 2013).

The main aim of the paper is to evaluate the trends in general innovation indicators, i.e., the number of innovative enterprises, their source of funding (public vs. non-public) and enterprises' innovation expenditures, and to expose prospects for innovation performance on European level. Furthermore, the overview of the main factors hampering innovation activities, the paper aims also to outline main obstacles that enable the enterprises to be more successful in innovations.

The following chapter describes data and methods used to meet the main aims of the paper, which is followed by the presentation and interpretation of analysis results. In conclusion, we summarize our key findings and propose ideas, which should be considered in the area of innovation regulation.

## 2. Data and methods

To answer to our research question, we used Community innovation survey data for the 2004–2016 period. Namely, since 2004 the area of statistics on Community innovation is continuously regulated, both in terms of concepts unifications as well as and the compulsory transmission of data by the Member States. Consequently, the data are of better quality in terms of their validity, reliability, as well as comparability.

We used Eurostat database to download the data from Community innovation survey[5] for the observed period. To follow innovation

[5] The statistical unit is the enterprise, which is defined as "the smallest combination of legal units that is an organisational unit producing goods or services, which benefits from a certain degree of autonomy in decision making, especially for the allocation of its current resources. It may carry out one or more activities at one or more locations and it may be a combination of legal units, one legal unit or part of a

performance, we used the following indicators: (1) total number of enterprises in the population, (2) number of product and/or process innovative enterprises[6], (3) number of product and/or process innovative enterprises that received any public funding, and (4) total innovation expenditure (in thousand Euros) of product and/or process innovative enterprises. All of these are presented as time series data.

We firstly presented the selected indicators for the observed period, which allowed us to outline the development trends thereof. These were also used to calculate annual growths as well as average annual growth rate (AAGR) and compound annual growth rate (CAGR).

Following the demonstrated trends, we further investigated the correlations of individual time series with their past values. To do so, we used autocorrelation analysis, which represents the correlation of a time series with itself at differing time lags. The autocorrelations are calculated as normalized version of autocovariance function (Shumway and Stoffer 2017):

$$r_k = \frac{c_k}{c_0} = \mathrm{Cor}(x_t, x_{t+k}) \qquad \text{(Eq.1)}$$

where $x_t$ is the observed time series with $n$ observations, $c_0$ is the autocovariance of the time series at lag 0 and equals the variance of the time series, and $c_k$ is the autocovariance function for some lag $k$, that is:

$$c_k = \frac{1}{n}\sum_{t=1}^{n-k}(x_t - x)(x_{t+k} - x) \, \text{(Eq.2)}$$

Following the normalized autocovariance function, we calculated the autocorrelation function ($ACF$) for each individual time series, which represents a set of correlations between the time series $x_{t+k}$ and its past values $x_t$ for lag values $k = 0, \pm 1, \pm 2$, and so on. The value of $r_k$ ranges from $-1$ to 1. To present the results of autocorrelation analysis, we used graphical representation of ACF using correlation plots. The x-axis represents a time lag ($k$), and y-axis represents the value of autocorrelation. These presented autocorrelation coefficients correspond to one lag value $k$. When $k$ = 0, the value of autocorrelation ($r_0$) equals 1, since it refers to the correlation of a time series $x_t$ with itself. When $k$ = 1, the value of autocorrelation ($r_1$) measures the association between $x_t$ and $x_{t-1}$, when $k$ = 2, the value of

legal unit." (Council Regulation (EEC) No 696/93 of 15 March 1993, OJ No L76 of 3 March 1993)

[6] Note, that the category of "product and/or process innovative enterprises" includes all innovative enterprises, i.e., enterprises that implemented new or significantly improved production process, goods, services, marketing concept or strategy, and/or organizational method. These are referred to as product and/or process innovative enterprises, regardless of organizational or marketing innovation (including enterprises with abandoned/suspended or on-going innovation activities).

autocorrelation ($r_2$) measures the association between $x_t$ and $x_{t-2}$, and so on. Blue dotted lines represent the approximate 95% confidence intervals, which are calculated as

$$-\frac{1}{n} \pm \frac{2}{\sqrt{n}} \qquad \text{(Eq. 3)}$$

where $n$ is the number of data points used in the calculation of the ACF. The approximate 95% confidence intervals serve as the threshold used to identify statistically significant values of autocorrelations.

Following the findings based on ACF analysis, we further performed autoregression (AR) analysis, which is actually an extension of linear regression modelling. When analyzing a time series, the AR analysis regresses the time series against itself. We can present the AR model of order $p$ as:

$$x_t = c + \phi_1 x_{t-1} + \phi_2 x_{t-2} + \cdots + \phi_p x_{t-p} \qquad \text{(Eq.4)}$$

where $c$ is a constant, $\phi_i$ ($i$=1,2,...,$p$) represent the estimated parameters, and $p$ determines the order of the model, which is expressed by the optimal number of lags $k$. We can perceive the AR model similarly to the multiple regression model with lagged values of time series $x_t$ as predictors.

According to the results of regression and autocorrelation analyses, we finally estimated expected future trends for the observed indicators in two ways. We first used estimated regression models, which enabled us to calculate the predictions for the observed indicators as a function of time. Secondly, we also used estimated AR models to predict future trends for the observed indicators as a function of past data of the same time series. In both cases, the predictions were estimated using ordinary least squares (OLS) method.

## 3. Results

To evaluate the progress of innovation performance, we fist present the population of enterprises divided into innovation and non-innovation enterprises from 2004 to 2016.

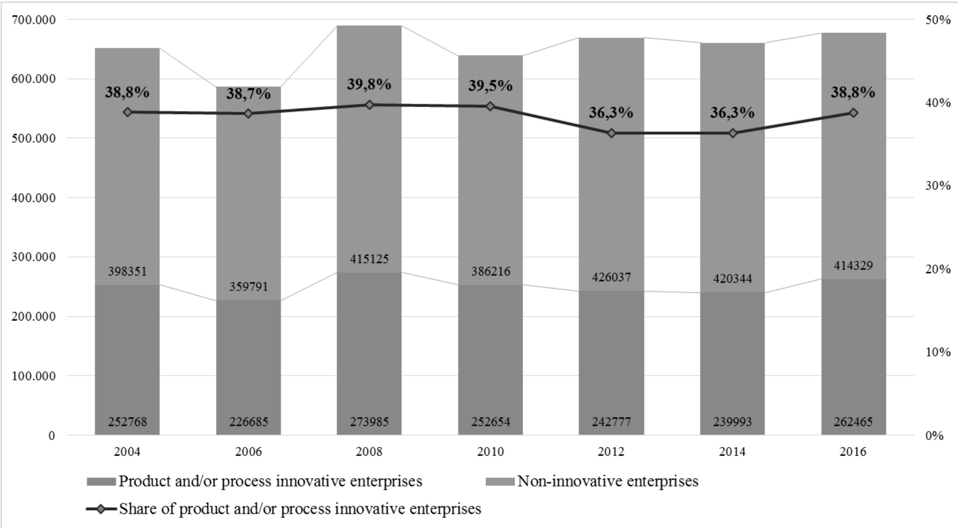


Figure 1. Number of innovative and non-innovative enterprises, and the share of innovative enterprises in the population in 2004–2016.

The data in Figure 1 show some minor fluctuation in the number of enterprises in the population. On the other hand, the data also show consistently lower share of innovative enterprises compared to non-innovative ones. Share of innovative enterprises in the observed period ranges from 36,3 % to 39,8 %, exhibiting AAGR of only 1% and CAGR of 0,5%. Focusing on the innovative enterprises, we divided them according to whether they received any public funding or not.

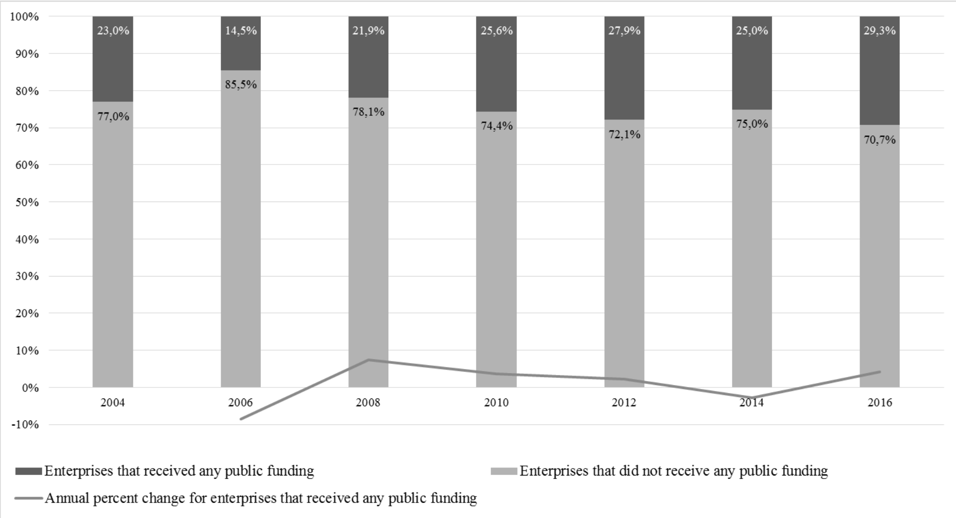


Figure 2. Share of innovative enterprises that received any public funding vs. share of innovative enterprises that did not receive any public funding, and annual percent change for innovative enterprises that received any public funding in 2004–2016.

Following the data in Figure 2, we notice that the share of enterprises that received any public funding decreased for 8,7% in 2006 as compared to 2004, but started to increase again from 2008 onwards. A minor decrease of 2,8 % can again be perceived in 2014, but in 2016 the share of innovative enterprises that received any public funding increased for 4,2%. The data exhibit AAGR of 11,3% and CAGR of 4,0%.

In addition to funding, innovative enterprises also exhibit expenditures, which are directly or indirectly associated with innovations and are presented in Figure 3.

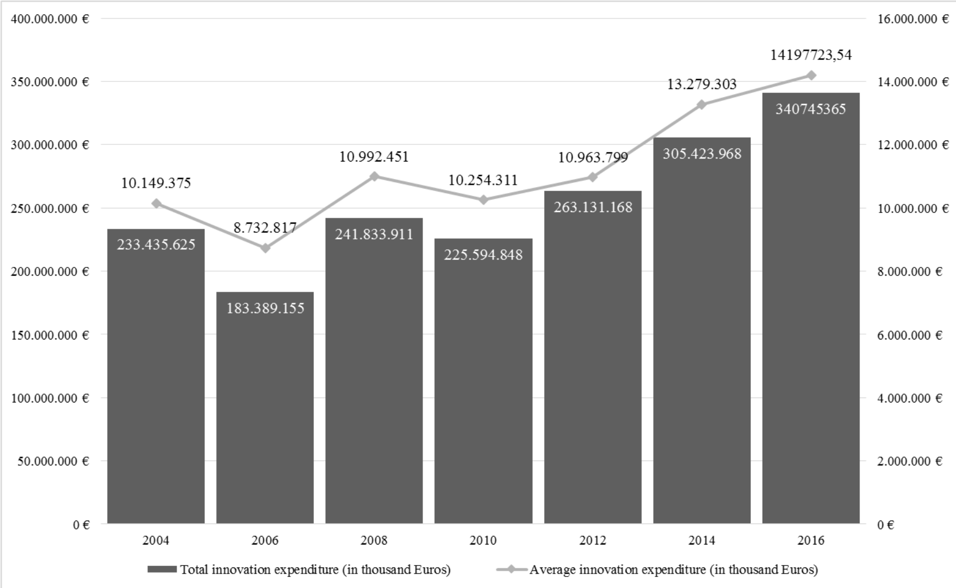


Figure 3. Total and average innovation expenditure in thousand Euros in 2004–2016.

We can observe a similar trend in total and average innovation expenditures, and the number of innovative enterprises in the population (see Figure 1). It is obvious that decreased number of innovative enterprises means also lower expenditure on innovation and vice versa. Namely, when the number of innovative enterprises drops, there remains fewer entities spending on innovation. Following the observed trends, data exhibit AAGR of almost 8,0% and CAGR of 9,3%.

Finally yet importantly, we also focused on the factors hampering the innovation activities. In Figure 4, we present main factors that innovative enterprises outlined to be highly important in terms of hampering the innovation activities. Note that the data refer to 2004, 2010 and 2016, as these data are only collected in every second round of CIS implementation, i.e., every four years.

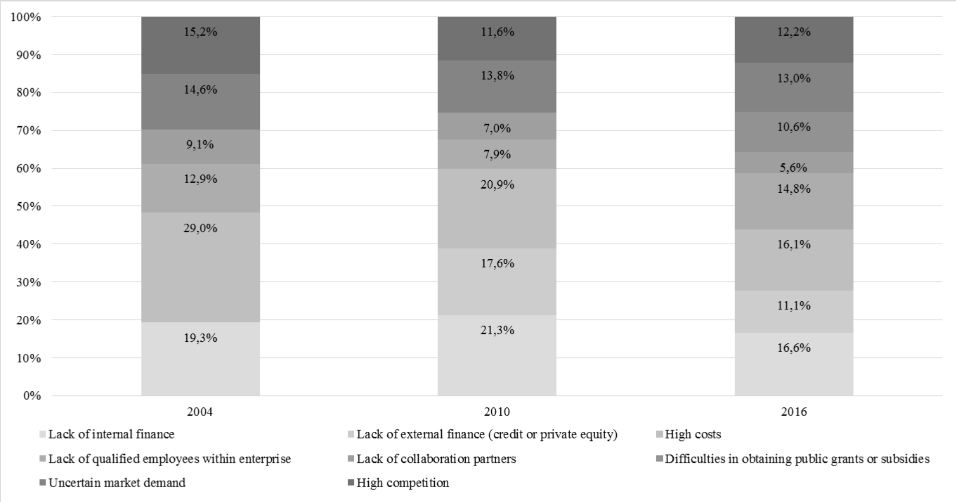


Figure 4. Main highly important factors hampering innovation activities in 2004–2016.

The data show that innovative enterprises as highly important factors hampering innovation activities expose lack of internal finance, lack of external finance, high costs, lack of qualified employees within enterprise, lack of collaboration partners, difficulties in obtaining public grants or subsidies, and uncertain market demands. Looking at these factors, we can divide them into two main groups, i.e., factors whose importance in hampering innovation activities has somewhat declined from 2004 to 2016, and factors whose importance in hampering innovation activities is still high or even higher in 2016 as compared to 2010 and 2004. As it turns out, lack of qualified employees within enterprise is the only factor that significantly gained on the importance in hampering innovation activities. Although in 2010 a share of innovative enterprises for which lack of qualified employees represented an obstacle for implementing innovation activities dropped as compared to the share in 2004, but in 2016, their share almost doubled as compared to 2010. As regards to other presented hampering factors, the data show that the share of innovative enterprises for which these factors represented an obstacle for implementing innovation activities in 2016 dropped as compared to 2010 as well as to 2004.

In addition to growths and shares (Figures 1, 2 and 3), we also tested the data regarding the association between time-specific data points in each individual indicator. However, note, that the association for hampering factors is not assessed, since the data are measured for three separate years only. Hereafter we present the results of autocorrelation analysis for product and/or process innovative enterprises, enterprises that received any public funding, and total and average innovation expenditures.

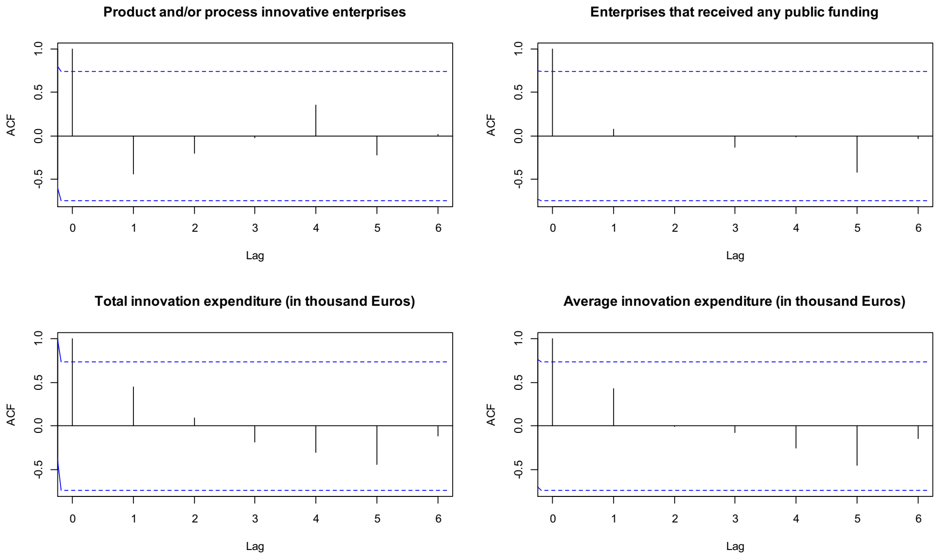


Figure 5. Autocorrelation functions (ACFs) for product and/or process innovative enterprises, enterprises that received any public funding, total innovation expenditure and average innovation expenditure in 2004–2016.

According to Figure 5, in case of all four indicators, when time lag equals 0, the value of autocorrelation equals 1. That is, the correlation is perfect, since it represents the correlation of individual time series with itself. In case of the number of product and/or process innovative enterprises, the value of autocorrelation at time lag 1 is negative, indicating that the number of these enterprises in the 2004–2016 period is negatively correlated with the number of the same enterprises between in the 2004–2014 period. When observing the number of enterprises that received any public funding, the value of autocorrelation at time lag 1 is otherwise positive, but close to zero. In cases of both, total and average innovation expenditures, the value of autocorrelation at time lag 1 is positive, which indicates that innovation expenditure in the 2004–2016 period is positively correlated with the innovation expenditure in the 2004–2014 period.

However, in case of all four indicators, the values of autocorrelations are not significant (they do not reach the blue dashed line on the graph, which represents a threshold for the values to be statistically significant). This finding points to the fact that each individual time series is not related to its past values.

Although there is no obvious tendency of association observed in case of the observed indicators, we conducted AR analysis to predict future trends for each indicator. These are presented in Figure 6.

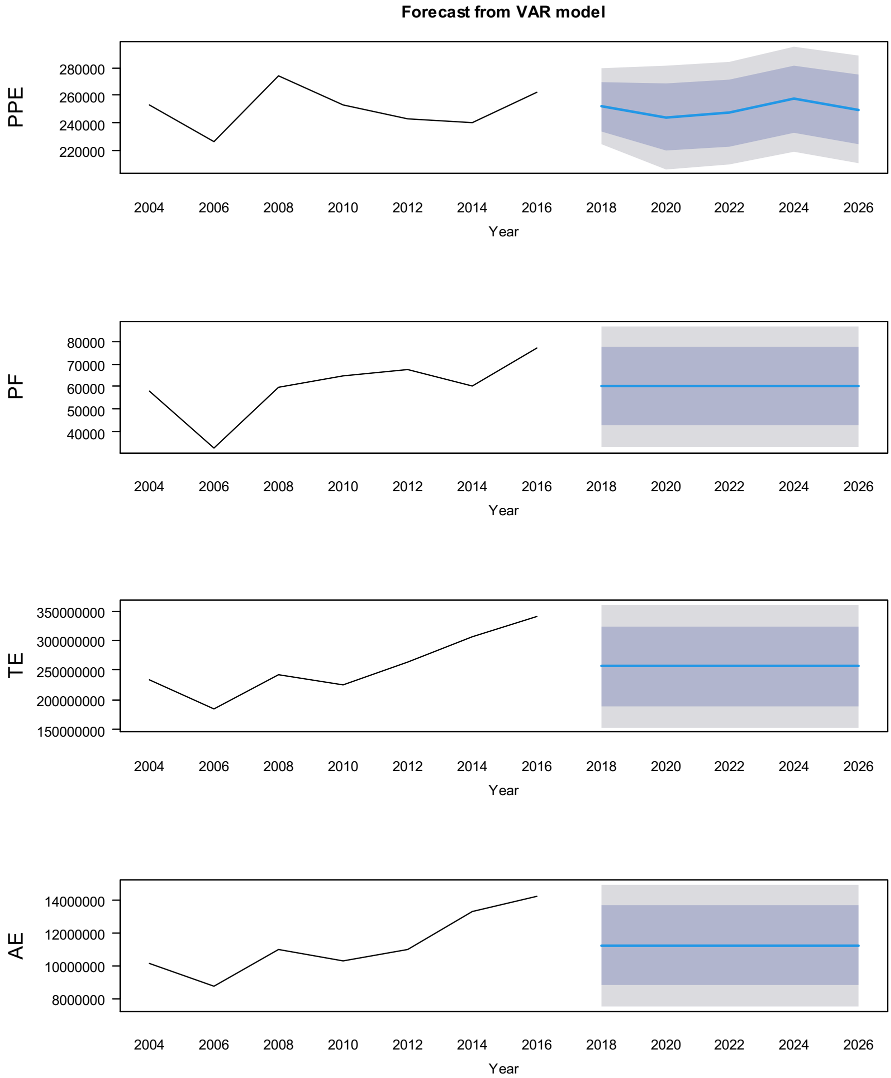


Figure 6. Predicted values for product and/or process innovative enterprises (PPE), enterprises that received any public funding (PF), total innovation expenditure (TE) and average innovation expenditure (AE) based on AR models (2004–2016 historical, 2008–2026 predicted).

The left side of the figure shows the actual data for the observed 2004–2016 period, and the right side represents the predictions for the next 10-year period based on each individual autoregression model. The predicted values for each individual indicators are presented as lines, and the shaded areas represent 80% and 95% confidence intervals thereof.

As it turns out, in the coming 10-year period, we can expect some fluctuations in the number of innovative enterprises, whereas the shares of innovative enterprises that received any public funding will not change much. On the other hand, as regards to total and average innovation expenditures, it is expected that these will settle down at 256.222.006 and 11.224.254 thousand Euros respectively.

## 4. Conclusion

Europe's sustainable growth largely depends on the innovation, which undergoes a lasting regularization process. The data used in our study show that in the 2004–2016 period, the main effort was directed towards achieving qualitative rather than quantitative improvements in reaching an optimal level of regulations in innovation domain. Namely, the share of innovative enterprises in the population of all European enterprises did not change significantly in the observed period and their share is about 38%. There was also lower share of those innovative enterprises that received any public funding as compared to the ones that did not received any public funding in the observed 2004–2016 period. However, the share of publicly funded innovative enterprises from 2004 to 2016 has grown for 11% on average. Regarding innovation expenditure, this indicator follows the numbers of innovative enterprises, meaning that in the years for which higher share of innovative enterprises has been observed, innovation expenditures were higher as compared to the years in which the share of innovative enterprises dropped.

These findings lead us to some important features regarding innovation domain. Although in European population the share of innovative enterprises remains almost unchanged, obtaining public funding is more accessible. This is most likely due to an increase in public funding, but the finding can presumably be attributed to greater informative of companies in the field of obtaining public funds.

Furthermore, the review of factors hampering innovation activities shows that the innovation domain is clearly expanding, since innovative enterprises to a lesser extent outline the problems regarding acquiring collaboration partners as one of the main hampering factors. But there is still a need for regulation and improvements in European educational and employment systems, since there is a shortage of qualified employees (especially within innovative enterprises). In fact, more and more innovative enterprises exposes this as one of the highly important hampering factors.

Although there has already been done much in setting the most optimal regulatory framework in innovation domain, there is still a room for improvements. From this point, we propose and encourage further work in this area, as well as to further explore available data on innovations since they are a real treasure trove of information.

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