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Big Science as innovation intermediaries – micro- and meso-level effects from the collaboration with the European Space Agency

UNIVERSITY OF TARTU
Press

School of Economics and Business Administration, the University of Tartu, Estonia

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1. **Eerme, T.,** 2016. Indirect industrial effects from space investments. *Space Policy* 38, 12–21.

2. **Eerme, T.**, Nummela, N., 2019b. Capitalising on knowledge from big-science centres for internationalisation. *International Marketing Review* 36 (1), 108–130.

II. Conference publications

1. Võõras, M., **Eerme, T.**, Cohendet, P., Lillestik, O., Sepp, J., 2013. *Ex ante* assessment of economic and societal effects induced by space investments in a small emerging space country, in: *Proceedings of the International Astronautical Congress, IAC*. International Astronautical Federation, IAF, Beijing.

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3. **Eerme, T.,** Sepp, J., Võõras, M., Nummela, N. (forthcoming). Assessing the impact of space programs through multi-level behavioural additionality, in: *Proceedings of the International Astronautical Congress, IAC*. International Astronautical Federation, IAF.

III. Conference presentations

1. **Eerme, T.**, Nummela, N. "Capitalizing knowledge from big-science centres in internationalisation". *21st McGill Conference on International Entrepreneurship "Speed, Diversity, Complexity in International Entrepreneurship"*, 30 August –1 September 2017, NUI Galway, Ireland.
2. **Eerme, T.**, Nummela, N. "Value generation through public procurement of innovative earth observation applications: Service-dominant logic perspective". *70th International Astronautical Congress,* 21–25 October 2019. Washington, D.C., the United States of America.
3. **Eerme, T.,** Sepp, J., Võõras, M., Nummela, N. "Assessing the impact of space programs through multi-level behavioural additionality". *71st International Astronautical Congress (IAC 2020) – The CyberSpace Edition*, 12–14 October 2020.

INTRODUCTION

This thesis is based on three original papers listed below, which will hereinafter be referred to as Study 1, Study 2, and Study 3:

Study 1. **Eerme, T.,** 2016. Indirect industrial effects from space investments. *Space Policy* 38, 12–21.

Study 2. **Eerme, T.**, Nummela, N., 2019b. Capitalising on knowledge from big-science centres for internationalisation. *International Marketing Review* 36 (1), 108–130.

Study 3. **Eerme, T.**, Nummela, N., 2019a. Value generation through public procurement of innovative earth observation applications: Service-dominant logic perspective, in: *Proceedings of the International Astronautical Congress, IAC*. International Astronautical Federation, IAF, Washington, D.C.

Motivation for the Research

From the second half of the 20th century, large-scale collaborative efforts have become crucial for advanced research (Galison, 1992; OECD, 1995). This form of knowledge production is popularly known as 'Big Science' (Weinberg, 1967), which is clearly distinguishable from investigator-driven research usually performed at universities (Esparza and Yamada, 2007). Big Science projects and programs are undertaken to accomplish a demanding, widely agreed, scientific mission that is facilitated by cutting-edge instruments and technologies (Jacob and Hallonsten, 2012). Big Science stand out in terms of their unique size, complexity, or duration, and require long-term governmental commitment, often through international co-operation (Elzinga, 2012). In Europe, among the best known and most studied examples of Big Science organisations are the European Organization for Nuclear Research (CERN) and the European Space Agency (ESA). It is important to note, Big Science is not confined to nuclear physics and astronomy – this mode of research is becoming increasingly common in other branches of science (Meyer, 2009; Autio, 2014).

The deployment of Big Science to address problems of crucial social importance has been considered as a key element of mission-oriented innovation policies (Weinberg, 1967; Ergas, 1987). The mission paradigm of innovation policy assumes that the government sector should be engaged with research and development (R&D) activities to propose workable solutions to address social challenges since public interests are not readily served by private R&D efforts (Bozeman, 2000). National mission-oriented innovation policies were particularly prevalent in the 1960s and 1970s (Mowery et al., 2010; Schot and Steinmueller, 2018), "long before innovation policy or even innovation became part of their [policy-makers'] standard vocabulary" (Edler and Fagerberg, 2017, p. 5). A classic example of a mission-oriented program in this era is the Project Apollo (Mowery et al., 2010), which illustrates the innovation policy agenda at the time. On top of the economic objectives – such as economic growth and competitiveness – societal objectives – such as national pride from landing the first humans on the Moon – shaped policy (Diercks et al., 2019). A public US Federal agency exerted top-down centralized control over knowledge production in the Project Apollo; it funded the program and was the main customer of its outputs (Mowery et al., 2010; Nelson, 2011). In response to the extraordinary magnitude and staggering cost of such ambitious missions[1], ESA was established by ten European countries in 1975 to implement and coordinate European space programs (Cogen, 2012).

There is renewed scholarly interest in mission-oriented innovation policies targeted at present-day grand societal challenges to achieve transformative change (e.g. Mowery et al., 2010; Foray et al., 2012; Weber and Rohracher, 2012; Edler and Boon, 2018; Kuhlmann and Rip, 2018; Schot and Steinmueller, 2018). The new mission-oriented policies are directed towards solving complex, multi-dimensional, and systemic societal problems, which also imply decentralised coordination of policies (Wanzenböck et al., 2019). These aspects clearly differentiate new mission- and challenge-oriented policies from traditional technology- and government-led policies, such as the Project Apollo, which was oriented to achieve a particular, well-defined technological objective. In the contemporary context, Kattel and Mazzucato (2018) regard Big Science to be an important element in new mission-oriented policies, which they consider as a policy layer that translates ill-defined grand societal challenges into concrete and actionable problems.

To achieve their missions, Big Science organisations have developed complex procurement systems over the years to purchase products and technologies from the industry (for ESA, e.g. Petrou, 2008; for CERN, e.g. Åberg and Bengtson, 2015). Big Science typically procures single items, or small batches of innovative products with superior specifications for successful science experiments, preferably from industrial firms located in the member states of the respective Big Science[2]. Such purchases by the public agency correspond to the early definition of public procurement of innovation (PPI): "the purchase of a not-yet existing product or system whose design and production will require further, if not

[1] The Project Apollo cost about 25 billion US dollars, which is well above 100 billion US dollars in 2020, and more than 10 thousand industrial contractors were involved in the program (Launius, 2005; Turcat, 2008).

[2] For example, the focal point of the complex industrial policy of ESA is the principle of equitable participation in ESA programs. It means that the financial volume of contracts between companies and research organisations located in a certain member state and ESA should be proportionate to the respective member state's annual contribution to the ESA budget (Schmidt-Tedd, 2011). A more loosely regulated version of the equitable participation principle is also applied by CERN (Åberg and Bengtson, 2015).

completely novel, technological development work" (Edquist and Hommen, 2000, p. 5). This means that participation in mission-oriented Big Science organisations such as ESA or CERN constitutes an important channel for PPI (Castelnovo and Florio, 2019).

PPI is a demand-side innovation policy instrument (Edler and Georghiou, 2007); it seeks to influence markets for innovative products or services. The capacity of public procurement to contribute to the creation of new markets for products and technologies, to lower risks associated with innovative activity, and to act as a testbed for innovative products has long been recognized by scholars (Rothwell, 1984; Geroski, 1990). Geroski (1990) argued that innovative public procurement is more effective than supply-side instruments, such as R&D grants, in stimulating private investments in R&D. More recent empirical studies confirm the positive effect of PPI on private expenditures in innovation activities (e.g. Guerzoni and Raiteri, 2015). PPI can take place at any level of governance – at the regional, national, or supranational level, or in combinations thereof in multi-level governance (Edler and Georghiou, 2007). The implementation of national innovation policies, in collaboration with international Big Science, is an example of the multi-level governance of PPI. By participating in various Big Science activities, the member states of Big Science delegate the procurement function to the supranational level and allocate respective budgetary means to perform the function on behalf of the member states.

Through the public procurement of high-performance products and technologies, the achievement of specific high-end technological objectives leads to knowledge spillovers, which spur industrial innovation (Chiang, 1991). Mazzucato (2013) highlights that many highly impactful innovations have emerged as the result of mission-oriented policies. For example, the internet – a general purpose technology thriving progress in many industrial sectors – is an offspring of the U.S. military R&D programs (Mowery et al., 2010) and the research carried out in CERN (Vuola and Hameri, 2006). These examples show that Big Science has various macro-level and industry-level effects on economic activity, which often unfold over long time periods (Florio and Sirtori, 2016; Clark et al., 2014). Also, collaboration with Big Science has shown to have a considerable effect on its supplier firms (Schmied, 1977; Cohendet, 1997; Bach et al., 2002; Nordberg et al., 2003; Autio et al., 2004; Castelnovo et al., 2018; Florio et al., 2018).

The promise of substantial knowledge spillovers has been one of the drivers behind the continuous expansion of Big Science organisations, such as ESA and CERN, into Central and Eastern Europe (Klock and Aliberti, 2014; OECD, 2014a). Potential member states keen on entering Big Science require a sufficient amount of knowledge-based industrial companies integrated to relevant value chains and capable to compete for tenders in the Big Science procurement system in order to justify the costs of membership (Cogen, 2012). This is one of the key issues that Big Science closely scrutinises during different stages of the accession process (e.g. Klock and Aliberti, 2014). Concurrently, membership in international Big Science organisations could be deliberately applied as a policy instrument to create new capabilities and contribute to creating new knowledge-intensive industries in new and would-be Big Science member states.

New member states in Big Science face the challenge to measure the effects of the membership in order to better manage national contributions to Big Science. The author of the thesis has been the prime investigator in a series of practical impact assessments in several Central and Eastern European countries – Estonia[3], Latvia, and the Czech Republic – related to collaboration with one of the Big Science organisations, namely ESA. Borrás and Edquist (2013) emphasise the strong contextual nature of innovation policy instruments, which affects the design and use of policy tools by policymakers. One instrument with a similar delivery structure – tackling a problem of the similar nature – might perform very differently in different contexts (Flanagan et al., 2011). In this particular case, the number of companies involved in the European space industry value chains in these countries was close to zero when the nations first approached ESA with the intent to accede to the organisation (Sagath et al., 2018). This clearly differentiates these countries from leading ESA members states with a strong presence of large system integrators of space industry (France, Germany, Italy) or mid-sized countries with long traditions in space domain (cf. Petroni et al., 2018), such as Belgium or Norway. Also, practical evaluation assignments have indicated the importance of various market- and industry-level effects, which have been largely neglected in the most widely adopted evaluation methodologies. Therefore, this thesis aims at understanding the mechanisms and pathways behind the firm- and industry-level effects from collaboration with Big Science in this distinctive context of new member states – countries from the Central and Eastern Europe.

Aim and research tasks

The main aim of this thesis is to add to current knowledge on various micro- and meso-level effects of collaboration with Big Science. The thesis studies the effects in a specific context – the membership to ESA, which grants companies located in the member state access to the programs and procurement tenders of this particular Big Science organisation. The research focuses on new ESA member states, such as Estonia, and would-be ESA member states, such as Latvia and Slovakia, which have started the accession process to become a full member of the organisation in the future.

The thesis is based on three original research papers. Studies 1 and 2 focus on the firm-level effects from doing business with Big Science. Study 3 is also concerned with meso-level effects, i.e. the role of Big Science in a multi-level institutional change process, which affects the behaviour of actors in an emerging market.

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3 Since 2015, Estonia is the 21st ESA member state. Appendix 1 offers a detailed account of the cooperation between the European Space Agency and Estonia.

To accomplish the overall aim of the thesis, the following research tasks have been set:

- To delineate theory-based rationales for public funding to the Big Science mode of knowledge production in different strands of innovation policy literature (Chapter 1.1).
- To provide an overview of how various dimensions of the additionality concept have been applied in innovation policy evaluations and connect the evaluation practice with theory-based rationales for innovation policy interventions in the context of Big Science (Chapter 1.2).
- To identify research gaps with respect to micro- and meso-level effects from the collaboration with Big Science in order to raise specific research questions (Chapter 1.3).
- To conduct a meta-analysis of the existing country-wide evaluations of micro-level effects from Big Science membership in the example of ESA (Chapter 2, Study 1).
- To contribute to the theory of the internationalisation process of knowledge-intense, resource-constrained firms and describe the role of Big Science in market and marketing knowledge acquisition and exploitation of the firms in the example of ESA suppliers (Chapter 2, Study 2).
- To offer exploratory insights into the institutional change induced by innovation intermediation of ESA in the nascent market of Earth Observation solutions (Chapter 2, Study 3).
- To discuss empirical results and highlight the theoretical contributions of the three empirical studies (Chapters 3.1 and 3.2, respectively).

Novelty of the thesis

The thesis is based on three research papers that study different aspects related to micro- and meso-level effects of collaboration with Big Science. The specific empirical context is ESA, which is one of the most widely known Big Science organisations. The empirical studies are rather heterogeneous in terms of the research gaps that were addressed, the theoretical background, and the applied research methods. Study 1 is positioned in the literature on evaluations of innovation policy instruments, more specifically evaluations of Big Science membership. Study 2 contributes to international business and international entrepreneurship literature, while Study 3 applies the rapidly evolving conceptual framework in marketing theory – service-dominant logic – to study endogenous institutional change in the emerging service ecosystem.

These different theoretical lenses enable new insights into the firm- and industry-level effects of membership in Big Science. In the following paragraphs, the novelty of the research will be discussed against both respective theoretical backgrounds and the extant literature on evaluating public investments to ESA, a Big Science organisation.

International organisations, such as the Organisation for Economic Co-operation and Development (OECD), have provided analytical frameworks and methodological guidelines for collecting data on the space economy and measuring the effects of public space programs (e.g. OECD, 2011; OECD, 2012). In the case of small and mid-sized European countries, these investments are largely associated with the programs of ESA that funnel the financial payments of ESA member states to purchase innovative products and services from knowledge-intensive firms (Petroni et al., 2018). Also, progress has been made with delineating the full range of economic and social effects from such programs (e.g. Clark et al., 2014). Despite these efforts, there is still a lack of knowledge about the methodological foundations of different country-wide policy evaluations that measured firm-level additionalities of public investments to space programs, such as ESA programs. By conducting a meta-analysis of the existing body of academic and grey literature, Study 1 addresses this gap by highlighting the key underpinnings of the existing methodological approaches, identifying various methodological caveats for measuring the firm-level effects, and discussing issues related to the comparability of the existing policy evaluations.

Study 2 contributes to the theory on the internationalisation process of the firm. Two schools of thought have dominated academic debates on the internationalisation process of the firm. Early theories on the internationalisation process of the firm explained internationalisation as being driven by an active but incremental collection of knowledge from preselected markets (Johanson and Vahlne, 1977). Two decades later, research on international new ventures suggested that the process was not accelerated by knowledge created during the process, but rather by the active utilisation of knowledge already possessed by key actors before a company's inception (Oviatt and McDougall, 1994; Knight and Cavusgil, 2004). However, both literature streams assume that internationalising companies hold proprietary assets (including products or technologies) prior to entering foreign markets. Recently, this premise has been questioned (Hewerdine et al., 2014; Kriz and Welch, 2018) with a proposition that the internationalisation of small knowledge-intensive firms is driven by a constant need for financial and knowledge resources for R&D. Connecting to this emerging literature strand, Study 2 challenges the underlying assumptions of existing theories on the internationalisation process of the firm. Study 2 seeks a deeper understanding of the role of knowledge acquisition in the non-linear and irregular internationalisation process of resource-constrained companies, and how this newly acquired knowledge can be used in exploring and exploiting opportunities in international markets. The study examines how knowledge-intensive firms capitalise on collaboration with Big Science, which offers an opportunity for acquiring and leveraging knowledge resources.

In the context of Big Science organisations, the extant literature has focused predominantly on various aspects related to technological knowledge, looking at Big Science as a unique environment for inter-organisational learning that is supportive to the development of innovative products and technologies with superior characteristics (Autio et al., 2004). Research performed at Big Science is also a source of novel technologies for a wide range of applications (e.g. Byckling et al., 2000; Szalai et al., 2012). Despite acknowledging collaboration with Big Science as a highly valuable marketing reference (Cohendet, 1997; Nordberg et al., 2003; Florio et al., 2018) and a driving force in the evolution of the business networks (Bach et al., 2002) for their suppliers, there are no studies concentrating on the internationalisation processes of Big Science supplier firms and the role of Big Science, or more specifically the ESA, in market and marketing knowledge acquisition and exploitation. Study 2 aims at addressing this research gap.

Study 3 contributes to the three streams of literature. The paper adopts the service-dominant logic perspective (Vargo and Lusch, 2004; Vargo and Lusch, 2008), which foundational premises postulate that "value co-creation is coordinated through actor-generated institutions and institutional arrangements" (Vargo and Lusch, 2016, p. 8). Empirical studies on how actors in service ecosystems challenge prevailing institutional order and are engaged with deliberate actions that lead to institutional change are scarce (e.g. Kleinaltenkamp et al., 2018). Study 3 responds to the calls for more studies to gain better understanding on how changes in micro-level institutions, i.e. at the level of individual actors, endogenously evolve into multi-level shifts within service ecosystems.

Study 3 also connects to theoretical and empirical research on the public procurement of innovation. This growing research stream has mostly dealt with the rationales for using public procurement to stimulate innovation (e.g. Chicot and Matt, 2018) and PPI's innovation outcomes (e.g. Uyarra and Flanagan, 2010). Scholars have also identified barriers associated with the implementation of PPI hindering the realization of the impacts (e.g. Uyarra et al., 2014). Rolfstam (2009, 2012) applied multi-level institutional analysis to investigate the role of institutions in PPI and the interplay between institutions and innovation outcomes from PPI. While he discussed dynamic micro-level institutions, which are shaped by organisational learning, he downplayed entrepreneurial efforts to transform the institutional order at higher levels. Study 3 focuses on this overlooked aspect. Furthermore, Uyarra *et al.* (2017) argued that the extant literature neglects the multi-level dimensions of PPI. Study 3 addresses this research gap by identifying additionalities from procuring innovations at the supranational level instead of the national level.

Institutional aspects have recently been addressed in space studies by Wong et al. (2018) and Sagath (2019), who applied the institutional logic perspective (cf. Thornton and Ocasio, 2008) to study how sectoral institutional logics in the space domain enable and constrain entrepreneurial action in the empirical contexts of Austria and the Netherlands. The development of space industry in such mid-sized countries largely resides in the hands of ESA (Petroni et al., 2018). Consequently, the identities of ESA suppliers are forged by the need to conform to the institutional logics that relate to the participation in ESA programs. While acknowledging the dynamic nature of the institutions, and the role of entrepreneurial behaviour in changing the institutional order, the focus of these contributions was rather narrow as the researchers mainly dealt with the embeddedness of firms within prevailing institutional logics. Study 3 adds a more dynamic perspective to these works by highlighting the role of institutional entrepreneurship in the absence of stable institutional logics.

Table 1. The novelty of the thesis

Study	**Literature stream**	**Approach of study**	**Research gap that the thesis addresses**
Study 1	Policy evaluations of membership to ESA	Secondary analysis and synthesis of past evaluations	Knowledge gap regarding the methodological foundations of the extant evaluations of the effects of Big Science.
Study 2	Internationalization of small knowledge-intensive firms	Longitudinal study of the internation-alization process of companies devel-oping new-to-the-world technologies	Knowledge gap in understanding the role of Big Science in the acquisition and exploitation of market and marketing knowledge by a Big Science supplier firm.
Study 3	Public procurement of innovation (multi-level and institutional aspects) Service dominant logic	Multiple case study on the multi-level institutional change	Knowledge gap in understanding the role of Big Science as an innovation intermediary in multi-level institutional change in service ecosystems.

Source: compiled by the author

Table 1 summarises the novelties of the Studies. The three studies combined contribute to the literature on the evaluations of innovation policy instruments. Study 1 reveals potential problems with data quality in survey-based evaluations when the total number of beneficiaries of the evaluated innovation policy instrument is low and stable over time. The data quality issues may result in biased estimates of input and output additionality of the policy instrument, thus undermining the value of such concepts in *ex ante* and *ex post* evaluations. Interdisciplinary qualitative Studies 2 and 3 illuminate processes that lead to persistent changes in behaviour of the suppliers of Big Science. This knowledge regarding various pathways of micro- and meso-level behavioural additionality could be used for elaborating new approaches to the evaluation of demand-side instruments, which would encompass a full range of theoretical rationales behind policy intervention.

Structure of the thesis

This thesis is structured into three chapters. The first chapter provides a theoretical framework for studying membership in international Big Science, such as ESA, as an innovation policy tool. Chapter 1 is further divided into four sub-chapters. The first sub-chapter establishes connections between theory-based policy rationales in three dominant innovation policy paradigms and the role of the Big Science mode of knowledge production in addressing market, system, and transformative failures pinpointed in these paradigms. The second sub-chapter discusses the use of input, output, and behavioural additionality in evaluations of innovation policy instruments. This sub-chapter also discusses various approaches to assess the effects from the collaboration with Big Science organisations focusing on the firm- and industry-level effects. The third sub-chapter poses research questions based on the knowledge gaps identified in the literature. Finally, the fourth sub-chapter describes the research methods and data used in the thesis.

The second part of the thesis presents three original research papers, which deal with different aspects of the micro- and meso-level effects of collaboration with Big Science (Figure 1). The empirical context of the studies is membership in ESA, investigated from the perspective of new and would-be member states in Central and Eastern Europe. Study 1 is a systematic review of the extant country-level studies on public investments to ESA programs. Study 2 studies the internationalisation processes of ESA supplier firms and the role of ESA in the acquisition and exploitation of market and marketing knowledge by the firms. Study 3 looks into the institutional change processes, linked to the innovation intermediation by ESA, resulting from the transfer of the innovation procurement function from the national level to the hands of this international organisation.

The third chapter is composed of four sub-chapters. The first sub-chapter highlights the main empirical findings of the three studies. The main conclusions and theoretical contributions that are drawn from the empirical work are outlined in the following sub-chapter. This thesis emphasises the practical utility of the research results. Therefore, the implications for policymakers and managers of companies are discussed in the third sub-chapter. The thesis is concluded with delineating the limitations of the studies and proposing avenues for further research.

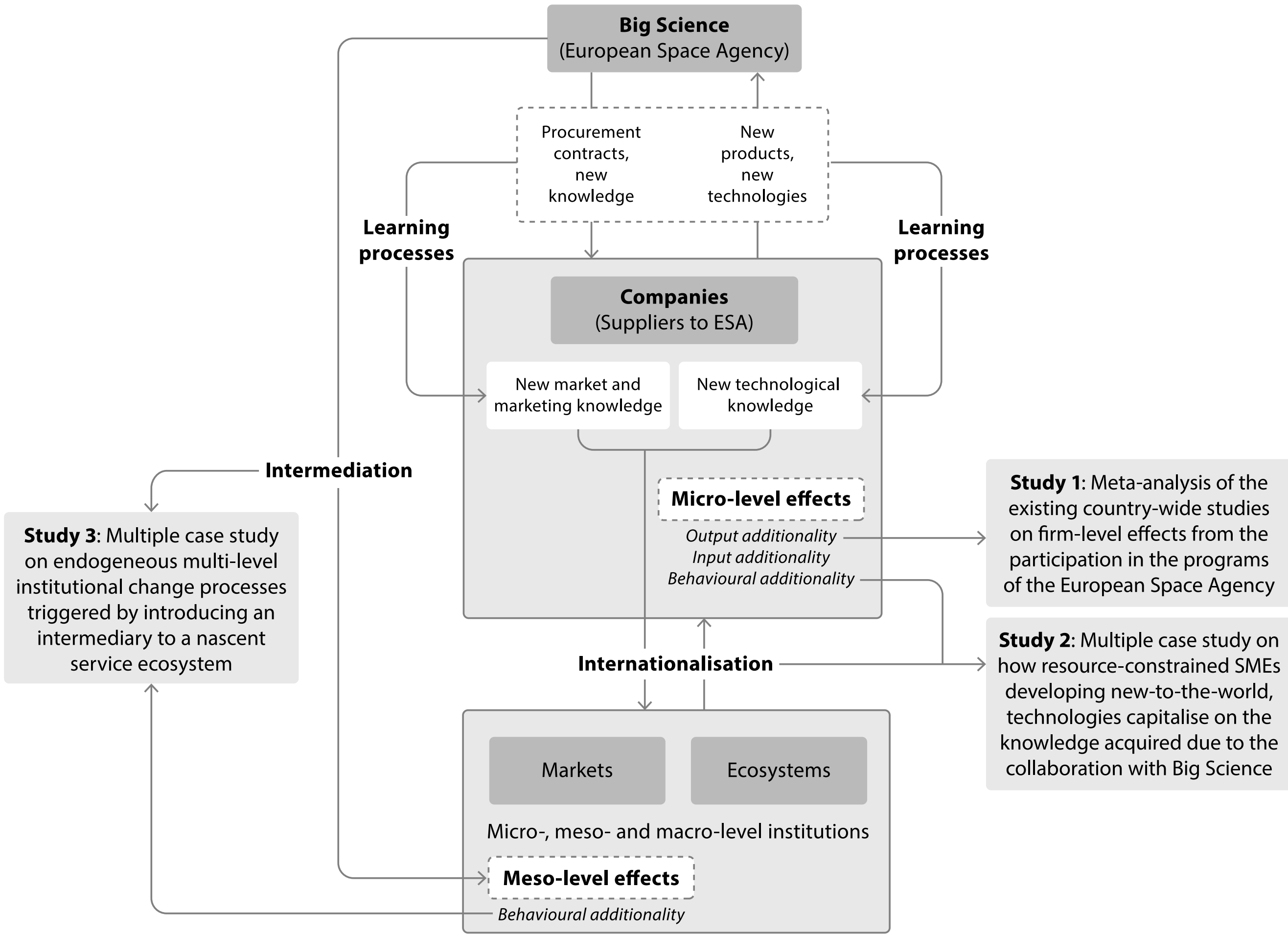

Figure 1. Positioning of the three empirical studies with respect to the studied phenomena (compiled by the author)

Contributions of individual authors

Study 1 was authored by Tõnis Eerme. Studies 2 and 3 were co-authored with Professor Niina Nummela; however, the author of this thesis is the main author of both studies – identifying research gaps and proposing the overall study design to address the research gaps. In Study 2, the co-author wrote the theoretical part of the paper, contributed with the methodological guidance of the paper, and improved the manuscript before and during the reviewing process. The author of this thesis was responsible for fieldwork to collect data, analysing data, and writing respective parts of the manuscript. In Study 3, the co-author mainly contributed with methodological assistance. The author of the thesis was responsible for all other aspects of the research process and manuscript preparation. The PhD candidate is solely responsible for any errors or omissions in this thesis.

Acknowledgements

This dissertation is the tangible output of my exploratory PhD journey, which was immensely impacted by interactions with many brilliant academics as well as inspirational entrepreneurs and capable managers. I would like to use this opportunity to express my sincere gratitude to those who had the most enduring impact on my scholarly endeavours.

Firstly, I would like to thank my supervisors, honourable Professors Jüri Sepp and Niina Mariia Nummela. His wide mental horizon and a sharp eye for details made discussions with Professor Sepp thoroughly enjoyable, exemplifying the true purpose of academia – human-to-human interaction for knowledge diffusion and personal growth. The same applies to Professor Nummela. Without her capability to navigate in the ocean of peer-reviewed journals, methodological knowledge and, even more importantly, contagious optimism, my PhD cup would probably have stayed half-empty. In the era of COVID, it is good to have positive infections, for a change.

Along the doctoral journey, I drew inspiration from discussions and e-mail exchanges with several highly knowledgeable experts in the specific domain of this thesis. Professor Patrick Cohendet, one of the pioneers of the evaluations of space programs in Europe, helped to put me on track, while Professor Giancarlo Graziola made me appraise the theoretical diversity in this domain.

The final version of the dissertation greatly benefitted from the comments from the opponents of the pre-defence of this thesis, Professor Urmas Varblane and Adjunct Professor Tarmo Kalvet. The comments from the pre-defence committee members, Dr Tiia Vissak and Professor Priit Vahter in particular, were equally valuable for improving the thesis.

I am happy to have an opportunity to collaborate with Big Science myself. The European Space Agency has definitely been a learning environment for me. The organisation has attracted some of the brightest minds to investigate and explore space for the good of European citizens. Herewith, I feel obliged to bring out the support from two persons – Mr. Miquel Pastor Vinader and Mr. Stephen Phil Airey – who have explained me how this huge clockwork operates in order to make sure that my theoretical knowledge is aligned with practical knowledge.

Over the past decade, I have closely worked together with the Estonian Space Office to facilitate links between ESA and the emerging Estonian space community and study the impacts of ESA membership. Mr. Madis Võõras, the head of the Estonian Space Office and one of the visionary architects of Estonia's accession to ESA, has been always thinking along and ready to put unconventional ideas into evaluation practice.

Over the years, my teammates contributed to a considerable number of impact assessments, which eventually steered me towards academic research. I am indebted to Mr. Oliver Lillestik and Mr. Silver Toomla, who – among other things – were great fun to work with.

I am endlessly grateful to all my interviewees, the talented and dedicated managers of innovative companies. This thesis would not have happened without your kind assistance and openness!

Last but certainly not least, I was lucky to have the unconditional support and patience of my family – wife and three kids. Thank you!

1. THEORETICAL BACKGROUND

1.1. Theory-based rationales for procuring innovations through Big Science

The development of science, technology, and innovation policy domain since the 1950s has been characterised by shifting dominant paradigms. Hall (1993) defines a policy paradigm as „a framework of ideas and standards that specifies not only the goals of policy and the kind of instruments that can be used to attain them, but also the very nature of the problems they are meant to be addressing" (p. 279). A number of recent papers (Schot and Steinmueller, 2018; Diercks et al., 2019; Grillitsch et al., 2019; Hekkert et al., 2020) distinguish between three main paradigms on grounds of the core understanding about the innovation process, policy objectives, and policy rationales[4]. These innovation policy paradigms are (Figure 2):

- science and technology policy, which builds on the linear model of innovation and refers to market failures as the justification for policy intervention;
- innovation systems policy, which emerged in late 1980s and early 1990s (Freeman, 1987; Lundvall, 1992; for an overview, Sharif, 2006) focusing on the interplay between technological, social, and institutional factors in the process of economic development (e.g. Gerschenkron, 1962; Kim, 1997);
- and emergent transformative innovation policy, which stresses that the so-called grand societal challenges plaguing mankind (Foray et al., 2012; Kuhlmann and Rip, 2018) cannot be tackled by mere incremental changes in the structure of the innovation system. For this purpose, a system-wide change is necessary that involves changes across technological, institutional, political, economic, organisational, and socio-cultural dimensions (Markard et al., 2012; Steward, 2012; Lindner et al., 2016).

In this thesis, different innovation policy paradigms are viewed as complementary to each other. An emerging policy paradigm does not render the earlier innovation policy framings obsolete. Bleda and del Río (2013) lend support to this sentiment by noting that even though systemic failure rationale has toppled market failure rationale as the most dominant theoretical justification for innovation policy intervention in recent years, both rationales are still often used in combination. Also, Weber and Rohracher (2012) see systemic failures to be partly compatible with market failures.

[4] Rationales are understood as "more or less formalised models implicitly or explicitly drawing upon academic theories or concepts that could inform policy design, implementation and evaluation" (Laranja et al. 2008, p. 823).

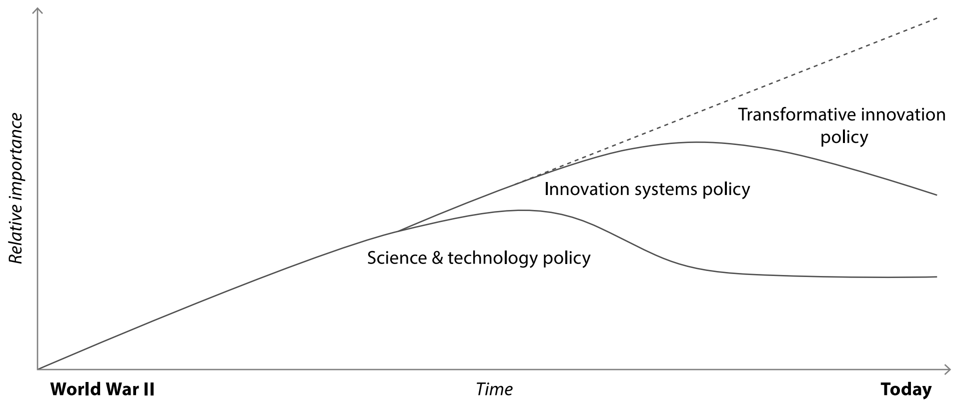

Figure 2. Consecutive innovation policy paradigms (Diercks et al., 2019, p. 881).

The thesis adheres to the tradition of the so-called public interest theories of regulation (Hertog, 2010). The thesis does not delve into the possible incongruence between public interests and private interests of economic agents and interest groups – such as public agencies with regulatory powers and legislators or their staff – and the effects of the incongruence on the policy-making process. One of the main implications of the chosen perspective is, for example, that the explanatory power of a market failure as a rationale for public intervention does not depend on whether decision making rights have been centralized or decentralized.

In the following chapters, connections are established between policy rationales in each of the three innovation policy paradigms and the role that the Big Science mode of knowledge production plays in addressing problems highlighted by economic theories (chapter 1.1.1). The dominant innovation policy thinking associates demand articulation, through public procurement with improvements in innovation outcomes, and ability to create new markets; these links and the possible roles of Big Science are discussed in chapter 1.1.2. Chapter 1.1.3 consolidates the arguments suggested by theories to clarify the role of international Big Science in the overall repertoire of innovation policy instruments available to governments. The concluding chapter also discusses the effects of different types of knowledge accessible through the collaboration with Big Science on the micro and meso level.

1.1.1. Roles of Big Science in addressing market and systemic failures

If policymakers' intervention logic is based on the traditional market failure approach, Big Science can be viewed as a specific knowledge production locus in society – an instrument to narrow the gap between the sub-optimal and optimal allocation of resources to knowledge creation (Clò and Florio, 2019). The peculiar nature of information and various information problems rooted in demand and supply interactions in unregulated markets cause this gap. Already, Nelson (1959) and Arrow (1962) put forth the idea that knowledge and information are not normal economic commodities but, rather, possess unique attributes. First, information – the output of knowledge production – has attributes of a pure public good; it is non-rival and non-excludable. Therefore, as the generator of the information is not able to prevent others from using it, the information cannot be kept proprietary. This means imperfect appropriability of investments aimed at creating knowledge and the existence of positive externalities of knowledge-generating efforts (Arrow, 1962). Consequently, private benefits from knowledge production are smaller than social benefits, and an economic agent has insufficient incentives to engage with knowledge generation. Also, outputs of knowledge production activities are uncertain. Nelson (1959) argued that basic research projects have very large variance of the profit probability distribution. Because of this property, a risk-averse economic agent assigns a value to a basic-research project, which is much lower compared to its social value. Due to the gap between the private and social value of new information, markets fail to efficiently allocate socially optimal resources to knowledge production and governments need to intervene as a remedy to market failures (Steinmueller, 2010).

Rationales for innovation policy intervention in the national systems of innovation (NSI[5]) perspective stem from the notion that the basic structural elements of a national system of innovation, or multiple links that connect these, may not function efficiently in serving their purpose with respect to knowledge generation and diffusion. A range of 'systemic failures' is the basis for policy intervention in the NSI approach (Klein Woolthuis et al., 2005; Chaminade and Edquist, 2010). The widely cited assortment of systemic failures proposed by Klein Woolthuis et al. (2005) is comprised of imperfections, such as infrastructural failures, transition failures, path dependency failures, hard and soft institutional failures, strong and weak network failures, and capabilities failures that should be tackled with various policy instruments.

The weak network failure refers to the lack of linkages between actors in an innovation system, which hinders interactive learning and the productive use of complementarities required to create new ideas. Innovation intermediation is proposed as one of the fixes to the weak network failure. Innovation intermediaries establish or facilitate the links between different agents to support knowledge generation and diffusion (Howells, 2006; Edler and Yeow, 2016). Already Braun (1993) noted that publicly funded mission-oriented research organisations, such as Big Science, are important structural elements in the innovation system that act as innovation intermediaries. They seek to connect various agents in their partner network with the aim to combine their complementary capabilities

[5] Lundvall (1992) defined NSI as comprised of "the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge" (p. 2). This definition highlights the economic importance of diffusion and assimilation of new knowledge generated in research organisations by industry, e.g. in the form of knowledge transfer.

to create innovations in order to solve technological challenges that Big Science faces. This intermediation is supported by a high-level of technical expertise in Big Science organisations and their market power (Fernandez et al., 2014; Landoni, 2017), as well as their reputation (Leyden and Link, 1999).

Infrastructure failure draws attention to missing elements in science and technology infrastructure, such as physical infrastructure. Also, underdeveloped channels for knowledge transfer constitute a facet of infrastructure failure (Klein Woolthuis et al., 2005). The unique size and complexity of scientific facilities are two defining attributes of Big Science. The extant literature on knowledge transfer from Big Science is diverse and covers different modes of knowledge transfer, which are all shaped with the aim to unlock the full potential of the research performed in Big Science (e.g. Autio et al., 2004; Lauto and Valentin, 2013; Venturini and Verbano, 2014; Nilsen and Anelli, 2016).

In the technological innovation systems (TIS) perspective that also emerged in the 1990s (e.g. Carlsson and Stankiewicz, 1991), policy makers are prescribed to focus their attention to blocking functional mechanisms that hinder the overall performance of the innovation system (Wieczorek and Hekkert, 2012). The TIS approach offers a functional perspective to the innovation system by paying attention to the key activities and processes that contribute to the creation and diffusion of knowledge, which is the main objective of a TIS approach (Hekkert et al., 2007; Bergek et al., 2008; Markard and Truffer, 2008). On top of the structural elements of innovation systems (actors, networks, institutions), there are generic key functions that an effective innovation system should perform. Functions are the basis for TIS evaluation – the identification of system weaknesses and suggestions for policy actions to remove these barriers.

The sets of functions and models of their interaction vary in the literature. Both Hekkert et al. (2007) and Bergek et al. (2008) distilled seven basic system functions out of a review of many years of innovation systems literature. These two key papers in TIS literature consider knowledge development to be prerequisites within the TIS (function ‘knowledge development’). The TIS needs to be able to consolidate human, financial, and other types of resources for the development of new technologies (function ‘resource mobilization’). International Big Science is a vehicle for achieving scientific breakthroughs that pools together resources to build and equip scientific facilities and implement ambitious long-term programs that lie beyond the means of any single nation. Therefore, Big Science contributes to knowledge development and resource mobilization functions.

The activities of entrepreneurs are essential to reduce the uncertainty intrinsic in technological and industrial development (function ‘entrepreneurial experimentation’). Big Science, the ESA in particular, often procures R&D works from its industrial partners. Such contracts correspond to the definition of pre-commercial procurement (PCP). PCP involves the purchase of research by a contracting authority and, usually, the development of a prototype with the objective of stimulating innovation (Rigby, 2016); the benefits from the resulting innovations, such as intellectual property rights, are shared between the procuring authority and the firm which supplies the solution (Iossa at al., 2018). PCP is a procurement mechanism that is intended to offer suppliers possibilities for de-risking the following phases of procuring novel technologies and products (Bedin et al., 2015), thus PCP is supportive to the entrepreneurial experimentation function.

For the better use of limited resources, a system has to support selection between alternative technologies by affecting the visibility of specific wants and needs among technology users (function 'guidance/direction of search'). Encouraging new niche markets is required for diffusing new technologies (function 'market formation'). A well-functioning innovation system should offer institutional support to new technologies (function 'legitimation'). The market formation, legitimation, and guidance/direction of search functions stress the importance of articulating demand from competent 'lead users' who are capable of anticipating the user needs that will eventually prevail in an economy (Von Hippel, 1986). In extant literature, Big Science organisations have been viewed as lead users with quite distinctive characteristics in terms of their technology demands and motivations in interactions with other actors (Andersen and Åberg, 2017). For example, Big Science may be too occupied with their own scientific challenges. It is argued that the diffusion speed of innovative solutions developed to meet the lead user's requirements depends on the attributes of the solution – too narrow of specifications hampers the adoption of the solution by other users (Uyarra and Flanagan, 2010).

The functions proposed by Hekkert et al. (2007) and Bergek et al. (2008) interact and may amplify each other (Suurs and Hekkert, 2009). Different system building and evolution processes are characterised by different interaction patterns. Big Science has multiple roles to play in the functional performance of a TIS. Many Big Science organisations (including ESA) are distributed facilities (Jacob and Hallonsten, 2012) – multi-located and multi-disciplinary – which potentially embeds them in a number of different TIS.

The extant literature provides multiple arguments for funding Big Science in order to address market and systemic failures. From the perspective of traditional science and technology policy, Big Science is a specific knowledge generation locus in society. It stimulates knowledge production towards the socially optimal level. In systems of the innovation paradigm, Big Science helps to tackle systemic failures in the NSI approach – such as weak network failure and infrastructure failure – and improve the performance of different functional mechanisms supportive to knowledge diffusion in the TIS perspective.

1.1.2. Demand articulation through public procurement – the role of Big Science

Demand articulation for creating and supporting markets has emerged among the key functions and core processes of a well-working innovation system in the innovation systems policy perspective. Issues related to public demand are addressed through public procurement. The goal of public procurement is to obtain the goods and services necessary to deliver public services. However, public procurement may also serve needs outside government domain; such procurement type is denoted with a term 'catalytic procurement' (Edquist and Hommen, 1998; Edquist and Zabala-Iturriagagoitia, 2012). Governments are increasingly urged to use their purchasing power to support innovation. Public procurement of innovation (PPI) is defined as such "purchasing activities carried out by public agencies that lead to innovation" (Rolfstam, 2012, p. 303). Uyarra (2016) notes that this broad definition covers the five types of Schumpeterian innovations, inclusive of new ways to organize business. While PPI initiatives are aimed directly and explicitly at promoting and diffusing innovations, Cave and Frinking (2003) note the random nature of innovations; they may easily be unintentional by-products of purchasing activities.

Schmookler (1962) argued that demand is a source of economic incentive for invention due to increased profits as the larger the volume, the smaller the share of the fixed cost of knowledge production effort in a unit cost. Fontana and Guerzoni (2008) call this the 'incentive effect' of demand in innovation. Guerzoni (2010) suggests that, in addition to the size of potential demand, the sophistication of the potential demand affects a firm's choice to bring a new product or service to the market. As a considerable share of the budget of Big Science is allocated to purchases of innovative products and technologies with superior characteristics, such as satellites and scientific instruments in case of ESA, the high degree of the sophistication of demand expectedly correlates with the better innovation performance of its suppliers.

An implicitly assumed by-product of PPI is the positive impact on the internationalisation activities of companies supplying innovations in the framework of public tenders. The results of surveys conducted among public sector suppliers (e.g. Edler et al., 2015) have provided evidence of this capacity of PPI to help to increase the exports of companies that benefit from PPI. A recent literature review by Paul et al. (2017) concludes that small- and medium-sized companies (SME) experience more severe exporting challenges than larger companies. Among a few other key problems, mostly related to the capabilities of the firms, the review brings out the problem of demand insufficiency as one of the main external barriers to internationalisation. Membership of Big Science grants companies located in the member state access to the tenders of international Big Science organisations. This exposure to foreign demand may have a stimulating effect to the internationalisation processes of SMEs. Edler and Georghiou (2007) indicate that the incentive effect can be leveraged by a procuring authority such as Big Science by setting sufficiently generic requirements to new products during procurement process to allow for agile expansion into international markets with innovations.

The importance of demand articulation and public demand has become more pronounced in the recent literature on transformative innovation policy. To complement market and systemic failures, Weber and Rohracher (2012) proposed new types of failures. The transformative system failures that have "emerged as new reference points for innovation policy" (Wanzenböck et al., 2019, p. 5) are comprised of directionality failure, policy coordination failure, reflexivity failure, and demand articulation failure.

The directionality failure refers to the current innovation system's inadequacy to guide the innovative activity of economic agents in a direction that is supportive to achieving transformative change objectives (Weber and Rohracher, 2012; Schot and Steinmueller, 2018). The policymakers' worries about the direction of the innovation are not new. The directionality failure can be seen as an extension of the path dependency failure in the systems of innovation perspective, which was concerned with the innovation system's inability to facilitate transitions to new technological paradigms (Klein Woolthuis et al., 2005). Also, the TIS literature has paid attention to the directionality of technological innovation. One of the TIS functions in both Hekkert et al. (2007) and Bergek et al. (2008) – guidance of the search – explicitly refers to the activities that may drive the change in a specific direction. However, the question of directionality – or 'what future citizens want?' – is becoming principal for the innovation policy formulation. Therefore, the transformative innovation policy paradigm is increasingly considered as the 'normative turn' in innovation policy (Kattel and Mazzucato, 2018; Uyarra et al., 2019). The 'extra-economic' goals (cf. Cantner and Vannuccini, 2018), such as climate change mitigation, are of inherently political and normative nature (Boon and Edler, 2018). In addition to directionality, other fundamental issues must be addressed, such as legitimacy ('Who is entitled to define goals?') and responsibility ('Who are assigned with the responsibility to coordinate the transformation?') (Schlaile et al., 2017).

Demand articulation failure reflects a deficit in learning about societal needs, including future needs. This problem has an adverse effect on market uptake of socially desirable innovations (Weber and Rohracher, 2012). In their classic paper about the role of demand-side policies to facilitate the diffusion of innovations, Edler and Georghiou (2007) focus on information problems that can be solved with PPI; those wishing to supply innovative products often do not have knowledge about unsatisfied needs of other economic agents. Fontana and Guerzoni (2008) label this information problem as the origin of the 'uncertainty effect' of demand in innovation. The intrinsic uncertainties associated with the market entry of innovative products can be relieved through channelling useful market information to the supply side (Von Hippel, 1978). Chicot and Matt (2018) speak of user-supplier interaction failures as a rationale for PPI, concluding that user-supplier interaction and communication is necessary to correct the adverse effects of uncertainty.

The systems of innovation perspective stresses the importance of knowledge and inter-organisational learning of agents in markets (Edler and Georghiou, 2007; Hommen and Rolfstam, 2008) to tackle the systemic failures hindering innovation. In a knowledge-based view, procuring agents possess tacit knowledge about (often latent) needs for which innovative solutions could be developed. Therefore, innovation policy must devise mechanisms for iterative interactions between economic agents to translate the needs of potential customers into increasingly concrete and explicit users' requirements (Boon and Edler, 2018). PPI is applicable as an instrument to address poor interaction between supply and demand through communication of this tacit knowledge to other economic actors (for products, e.g. Edquist and Zabala-Iturriagagoitia, 2012; for services, e.g. Pelkonen and Valovirta, 2015). The interaction between supply and demand is also expected to bring into conversation tacit knowledge of multiple suppliers, i.e. potential bidders in a procurement process. Georghiou et al. (2014) point at a widely shared belief that an increase in the number of potential bidders can increase the chances for successful innovation. Various authors have argued in favour of gearing public procurement towards SMEs by referring to a range of gains for the procuring agency, such as increased innovativeness and encouraged entrepreneurship (e.g. Karjalainen and Kemppainen, 2008).

Lember et al. (2015) note that the interaction mechanisms, and even project level technical skills related to effective interaction between procurement stakeholders, have received a lot of scholarly attention in PPI literature. Even though public procurement is expected to connect demand and supply, the actual conduct of PPI often fails to deliver appropriate interaction (Uyarra et al., 2014). The lack of procurement capabilities and managerial and technical skills at the demand side are considered the main reasons for the inadequacy of PPI (Loader, 2013; Georghiou et al., 2014; Kattel and Mazzucato, 2018). The challenges posed by the complexities of transformative policies may worsen the problem of insufficient procurement capabilities. Applying PPI to react to the urgency of grand societal challenges requires new types of dynamic capabilities in the public sector (Mazzucato, 2016; Kattel and Mazzucato, 2018; Uyarra et al., 2020). The capability problem is claimed to be more acute in smaller countries (for Latvia, see Cepilovs, 2014) and at lower (e.g. regional and municipal) levels of governance. As the problem appears to scope-dependant, a concentration of expertise and procurement budgets could be a possible countermeasure. It can be anticipated that procuring sophisticated products and services to solve societal problems at the highest possible governance level – e.g. by a competent supranational body, such as a Big Science organisation – may have positive effects in terms of innovation outcomes from PPI compared to procurement conducted at the national level or lower administrative levels. Autio et al. (2004) argue that Big Science organisations possess skills and capabilities that enable its suppliers to cope with high levels of technical complexity, which is ultimately supportive to entrepreneurial experimentation.

Chicot and Matt (2018) bring out another user-supplier interaction failure – lack of interactive learning spaces. The literature on transformative policy points at the lack of interaction spaces where economic actors could signal their needs and wants, often because relevant markets to exchange such signals have not emerged yet (Frenken, 2017; Grillitsch et al., 2019). Big Science has a role to play in organising interactive learning spaces. It can initiate catalytic procurement to satisfy the future needs of end-users outside the organisation and activate companies in its business network to promote crossovers between unrelated technical capabilities in order to facilitate the emergence of radical recombinant innovations as a solution for grand societal challenges and a source of long-term growth (Castaldi et al., 2015; Edler, 2016; Frenken, 2017). For Kattel and Mazzucato (2018), purposeful actions to initiate interactive learning spaces constitute one of the pillars of the mission-oriented innovation policy, which they also describe as "a market-shaping public investment and policy framework" (p. 789).

Demand articulation, through public procurement, stimulates the formation of new markets (Edler and Georghiou, 2007; Borrás and Edquist, 2013; Mazzucato, 2016; Frenken, 2017). Bleda and Chicot (2019) appreciate the scholarly attention to the idea that markets[6] can be created by public procurement but, nevertheless, argue that the extant literature fails to develop this idea or provide explanations about how PPI contributes to the market creation process. Influenced by the works by evolutionary economists (e.g. Dopfer et al., 2004), Bleda and Chicot (2019) elaborate that procurement instruments can be used to support different types of knowledge coordination processes that take place both at the company-level (micro) and agent population level (meso). According to their view, a market forms when certain new knowledge, (e.g. new technology embodied in a new product) with all its associated technical, social, cognitive, and behavioural knowledge components, becomes 'institutionalised', i.e. repeatedly used by a population of agents in their economic exchange practices (cf. Kjellberg and Helgesson, 2007).

1.1.3. Big Science as a systemic innovation intermediary

In the previous chapters, the roles that Big Science could perform in an innovation policy toolbox to counteract problems hindering knowledge generation and diffusion in an economy were discussed. Inspired by the integrated framework of market, systemic, and transformative system failures by Weber and Rohracher (2012, p. 1045), Table 2 summarises how various failure types could be tackled by Big Science.

By performing these roles, Big Science influences the resource base and capabilities, and ultimately the competitive position and financial performance, of its contractors. Collaboration with Big Science has been described as "a learning environment for their industrial supplier companies" (Autio et al., 2004, p. 125). From the systems of innovation perspective, competence building through various types of learning is one of the most crucial activities in the innovation process along with the creation of new knowledge (Edquist, 2011).

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[6] In this thesis, market is not understood as merely an abstract price forming mechanism coordinating economic exchanges between firms and customers. The comprehensive definition of markets by Nenonen et al. (2019) as "complex adaptive socio-technical-material systems, consisting of institutions, actors, practices, and discourses that organize particular economised exchanges" (p. 252) covers the important elements beyond the relationship between firms and customers.

Table 2. Roles of Big Science in tackling market, systemic, and transformative system failures

Type of failure		Big Science's role in tackling the failure mechanism
Market failures	Information asymmetries	Knowledge production towards a socially optimal level to advance single or multiple scientific disciplines, such as nuclear physics and astronomy, and channelling market information to other economic agents to overcome the adverse effects of information asymmetries.
	Knowledge spillovers	
Systemic failures	Network failure	Systemic innovation intermediary that connects economic actors with complementary capabilities and facilitates inter-organisational learning.
	Infrastructure failure	Consolidates and makes available resources – such as scientific and applied knowledge and skills, or dedicated testing facilities – and establishes mechanisms for knowledge transfer.
Transformative system failures	Directionality failure	Big Science consolidates targeted funding to demonstrate technologies that are supportive to socio-economic transitions.
	Demand articulation failure	Big Science organisations possess high-level of technical expertise, market knowledge, and procurement capabilities enabling the anticipation of (future) users' needs.

Source: compiled by the author on the basis of Weber and Rohracher (2012), Foray (2004), Clò and Florio (2019), Howells (2006), van Lente et al. (2020), Robinson and Mazzucato (2019)

Developing the instruments necessary to conduct scientific experiments in compliance with the research missions of Big Science mandated by its member states requires the integration of diverse technical capabilities[7]. Therefore, these organisations are reservoirs of the most up-to-date technological knowledge in multiple technology domains. Depending on the absorptive capacity (cf. Cohen and Levinthal, 1990) of its supplier firms, innovations emerge from the collaboration with Big Science. Also, Åberg and Bengtson (2015) highlighted the role of mutual involvement in a dyadic relationship[8]. The deeper engagement of Big Science by suppliers facilitates the acquisition of technical knowledge and better innovation outcomes (Florio et al., 2018). Big Science, as an innovation intermediary, is in the position to facilitate interactions between a large number of contractors with heterogeneous knowledge bases and complementary technological capabilities. The supplier firms' capabilities to assimilate this accessible

[7] For example, ESA has structured its technologies of interest into ten competence domains, ranging from propulsion and space transportation to life sciences (European Space Agency, 2018)

[8] The term 'dyad' denotes a relationship between two organisations.

knowledge (combinative capabilities, cf. Kogut and Zander, 1992) are crucial to generate innovations on the basis of the interactions with the other parties in Big Science's business network.

Knowledge has a central role in internationalisation (Åkerman, 2015). The two theories on the internationalisation process of the firm that have dominated scholarly debates over the past 40 years – internationalisation process theory by Johanson and Vahlne (1977, 2009) and research on international new ventures (Oviatt and McDougall, 1994; Knight and Cavusgil, 2004) – treat internationalisation as a learning-intensive process. Fletcher and Harris (2012) discuss three types of knowledge that are important in the internationalisation process – technological knowledge, market knowledge, and internationalisation (marketing) knowledge. Market knowledge, i.e. an increased understanding of markets and customers, includes the behaviour of clients, competitors, and other stakeholders, as well as the surrounding institutional frameworks, rules, and norms. Marketing knowledge refers to the understanding of how to enter international markets, localise offerings, and run an international business (Fletcher et al., 2013). While the transfer of technological knowledge and related inter-organisational learning processes have been relatively well-studied aspects of the Big Science-supplier collaboration, market and marketing knowledge have received less attention in the context of the effects of Big Science on its suppliers. This is surprising as a lack of market and marketing knowledge has been shown to be the main internal barrier that holds SMEs back in their internationalisation efforts (Paul et al., 2017). Furthermore, surveys of Big Science suppliers have confirmed the importance of learning of market knowledge through the collaboration with Big Science (Autio, 2014; Florio et al., 2018).

The literature provides evidence that Big Science and its wider business network are sources of different types of knowledge that can be assimilated by its suppliers to enhance their capacity to improve and change internal processes related to R&D, internationalisation, or other dimensions of business strategy; however, the effects of Big Science stretch beyond these firm-level effects and involve populations of economic agents.

According to Smits and Kuhlmann (2004), the formulation of innovation policy has reached to a stage where policy instruments need to become systemic in order to support innovation processes. In the Smits and Kuhlmann (2004) approach, systemic instruments provide interfaces for interaction across a sub-system border and help to establish and organise innovation systems, provide a platform for various types of learning, and stimulate demand articulation. Despite being originally weakly theoretically developed (cf. Wieczorek and Hekkert, 2012), the concept of systemic instruments has drawn scholars' attention. Van Lente et al. (2003) combine the idea of systemic instruments with innovation intermediation in order to delineate 'systemic intermediaries' that have three main functions in an innovation system:

- Articulation of demand – establishing a dialogue between actors in the innovation system is the key function of an innovation intermediary (Klerkx and Leeuwis, 2008) and Big Science has specific capabilities to address user-supplier interaction failures (as described in Chicot and Matt, 2018).

- Alignment of actors and possibilities – Big Science has been shown to engage with activities for building and nurturing linkages between actors in the innovation system to make the best use of their complementary capabilities (for ESA, e.g. Fernandez et al., 2014).
- Support for learning processes – which was discussed in the context of Big Science in the previous paragraphs – and entrepreneurial experimentation.

Big Science is engaged with all these activities that characterise systemic intermediaries – connecting actors, facilitating mutual learning, and articulating demand. Systemic intermediaries support innovation at a higher system level (van Lente et al., 2003; Klerkx and Leeuwis, 2009) – a property that differentiates public financing to systemic intermediaries, including the Big Science mode of knowledge generation, from measures targeting primarily individual beneficiaries, such as direct R&D subsidies to companies, which is the most traditional supply-side instrument[9].

The transformative innovation processes are collective experimentation processes involving multiple actors in multiple technology domains. Economic transformation means that many new technologies must become institutionalised and some others must become obsolete (Kivimaa and Kern, 2016), and there is a need for accompanying social, institutional, and behavioural changes to complement technological innovation for actual transformation (Diercks et al., 2019). Robinson and Mazzucato (2019) discuss how ESA responds to global societal challenges, such as climate change, by articulating the demand to drive the growth of services, which apply data generated by the space infrastructure launched by ESA and scientific missions around the core activities of ESA. ESA is the European Commission's partner in developing the Copernicus constellation of Earth Observation satellites equipped with instruments to collect consistent data on bio-geophysical processes at the global scale, which would be unfeasible with any alternative technology at a comparable cost level. The information products based on the satellite's data provide insights about processes on the land surface, in the atmosphere, and in marine environments, thus enabling evidence-based public policies for tackling climate change (Tassa, 2019). Needs that are targeted with such demand articulation activities reside often outside ESA (cf. Eerme and Nummela, 2019a). ESA is the focal element in the actor network that emerges in connection to the dedicated mission-oriented public funding of such field of science and technology (Mazzucato and Robinson, 2017). ESA's network position enables the organisation to deal with diverging interests of the surrounding network of economic agents. For example, ESA shapes the institutional arrangement

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[9] Mapping of innovation policy instruments shows that direct financial support for innovation activities is a dominant policy measure (for Europe, Edler et al., 2012) and governments tend to prefer R&D intensity indicators in policy goal setting (Carvalho, 2018).

to cope with uncertainties that characterise long term transformative change processes (van Lente et al., 2020) and dynamically evolving ecosystems, such as a nascent technological innovation system (cf. Suurs et al., 2009) or emerging markets. This example shows that system level effects of systemic intermediaries, such as Big Science, manifest themselves in the ability to affect the dynamics of multiple emerging and existing agent populations. However, the processes behind such meso-level effects[10] from collaboration with Big Science have not been addressed in the literature.

This chapter consolidated theory-based rationales for financing Big Science and described possible pathways behind micro- and meso-level effects of participation in Big Science missions. Flanagan et al. (2011) note that innovation policy literature tends to treat theory-based rationales as the main driver of innovation policy development. The policy process is usually viewed as consisting of linear discrete stages, and policy instruments emerging through this process should correspond to the theory-backed rationales. Nevertheless, Borrás and Edquist (2013) stress that rationales for policy interventions are certainly not constrained to the intervention logics suggested by the economic theories. Policymakers may follow other rationales to devise, select, and employ a policy instrument or a combination of instruments (Laranja et al., 2008). Often, policy interventions are retrospectively rationalised (cf. Gök and Edler, 2012). Despite these arguments, explaining the rationales that different schools of innovation policy thinking propose for policy intervention is critical for any meaningful evaluation.

1.2. Evaluation of micro- and meso-level effects of Big Science

The design of innovation policy requires a broad knowledge base – starting from theoretical and political rationales and understanding the capabilities of targeted groups of actors, the linkages and interactions between these actors and other stakeholders, the interplay with other existing policy instruments ('policy mix'[11]), the meso- and macro-level framework conditions (context), and the policy effects. Evaluations of policy interventions inform policymakers about the effectiveness, efficiency, appropriateness, and effects of policy instruments. Evaluation refers to "a process that seeks to determine as systematically and objectively as possible the relevance, efficiency and effect of an activity in terms of its objectives, including the analysis of the implementation and administrative management of such activities" (Papaconstantinou and Polt, 1999, p. 10).

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[10] Meso is the analytical domain that deals with populations of agents (Dopfer et al., 2004).

[11] A good literature review on the development of the concept of policy mixes in innovation studies is provided by Kern et al. (2019). The emergence of the term is associated with the contributions by Nauwelaers and Wintjes (2002), Laranja et al. (2008) and Flanagan et al. (2011).

Evaluations are carried out to assess past performance (summative evaluations) to understand if the intervention met its objectives in socio-economic terms and/or to assist policymakers in the design, implementation, and re-adjustment of policies (formative evaluations) (Edler et al., 2008). Evaluations usually combine summative and formative aspects (Edler et al., 2012). Learning processes entailed in formative evaluations, described as "the most positive dimension of evaluations" (Georghiou, 1999, p. 524), are important in addressing the reflexivity failure highlighted by Weber and Rohracher (2012). Transformative policy is selective as it pursues specific socio-technical pathways (Janssen, 2019). Transformative innovation processes are subject to continuous policy adaptations. For reflexivity, policymakers need to develop a policy evaluation system that continuously monitors progress – with respect to the transformation objectives – and provides the analytical and future-looking basis for the development of adaptive policies.

Evaluations seek to identify and quantify the effects induced by a policy instrument. Additionality is a key dimension for measuring the effects of an instrument. A counterfactual approach is applied for additionality, the scenario without a policy instrument is compared to the effects in the presence of the policy instrument (Georghiou, 2002). Additionality is further divided into input additionality – i.e. how many additional (private) resources are dedicated to innovation efforts due to intervention –, output additionality – i.e. the output lost without intervention – and behavioural additionality – the persistent change of an actor's *modus operandi* due to the instrument that leads to superior innovation performance (Georghiou, 2002; Gök and Edler, 2012). Evaluations that consider additionality aspects mostly rely on quantitative methods (Edler et al., 2012). However, evaluations should also provide inputs for understanding processes related to the diffusion of innovations and pertinent inter-organisational learning. Therefore, in evaluation practice, qualitative methods are used in combination with quantitative methods to extract a more holistic picture of the effects of the policy instrument (Edler et al., 2012).

The majority of policy evaluations still apply a single instrument perspective and functional approach (Edler et al., 2016), which treats policy instruments as functional 'technical devices' (cf. Lascoumes and Gales, 2007). Since the emergence of the systems of innovation perspective, the systemic interactions between policy instruments are more stressed. Scholars are increasingly arguing that conventional evaluation methods are not appropriate to investigate the effects of policy mixes, particularly in the context of transformative change (e.g. Magro and Wilson, 2013; Mazzucato, 2016). Nevertheless, empirical evidence shows that system oriented innovation policy evaluations are still rare (Borrás and Laatsit, 2019).

The following chapters discuss the use of input, output, and behavioural additionalities in innovation policy evaluations with a specific emphasis on evaluations of Big Science. Chapter 1.2.1 is dedicated to input additionality and output additionality, while chapter 1.2.2 focuses on behavioural additionality. Contributing to the formation of new markets is one of the key roles of demand-side instruments; therefore, chapter 1.2.3 examines how information on market formation processes is embedded to policy evaluations.

1.2.1. Input and output additionality

Government-funded research, direct R&D subsidies, and tax incentives for providing additional inputs to knowledge generation processes of companies are the dominant supply-side innovation policy instruments. These measures are justified with the market failure argument. Scholarly studies on the effectiveness of direct R&D subsidies to companies have traditionally focused on input additionality, which seeks to capture whether the incremental investments to R&D by treated agents were greater than or equal to the amount of direct R&D subsidies (Georghiou and Roessner, 2000). Researchers are concerned with the possible 'crowding out' effect of R&D subsidies. Crowding out occurs because any firm always has an incentive to apply for the direct R&D subsidy to substitute private research investment with public funding in order to increase the expected private returns from the R&D investment. There is mixed evidence regarding the crowding out or crowding in (input additionality) effects of direct R&D subsidy programs (e.g. Szücs, 2020; Czarnitzki and Hussinger, 2018; Dimos and Pugh, 2016; Zúñiga-Vicente et al., 2014; Cerulli, 2010; David et al., 2000). For example, the meta-regression analysis of 52 micro-level studies published since 2000 performed by Dimos and Pugh (2016) rejected the crowding out of private investment by public subsidies but did not show evidence of a substantial input additionality.

In the context of this thesis, empirical evidence regarding a few specific aspects of the 'crowding in' effects are of interest. First, are direct R&D subsidies associated with input additionality in sectors with an above-average level of R&D intensity, such as aerospace? Second, as in a number of ESA programs R&D activities at lower technological maturity levels are purchased, it is relevant to ask whether the relationship between R&D subsidies and input additionality is affected by the R&D stage at which funding occurs, comparing far from market 'research' to close to market 'development?' With respect to the R&D intensity of sectors, some authors have found that R&D subsidies are more effective in terms of input additionality for companies operating in sectors with below-average levels of R&D intensity (e.g. González and Pazó, 2008; Becker and Hall, 2013). Consistent with a notion of knowledge as semi-public good, studies by Clausen (2009) and Hottenrott et al. (2017) have shown that R&D subsidies to far from market 'research' projects result in input additionality, while subsidies to close to market 'development' projects are less effective or even crowd out private R&D investment (Clausen, 2009). These results imply that ESA's innovation funding to companies could lead to input additionality for projects at lower technology levels, such as PCP projects.

Compared to literature on the input additionality of direct R&D subsidies, scholarly studies about the effect of direct R&D subsidies on R&D output are less frequent. Dimos and Pugh (2016) connect this to several methodological problems. If the R&D subsidy leads to a higher level of R&D output (measured in numbers of patents or sales arising from innovation) than the counterfactual situation, the presence of additionality cannot be determined due to the incommensurable nature of output indicators and the value of subsidies. Also, it is problematic to disentangle the effects of many unobserved factors that might have contributed to the extra output along with the particular R&D project (the project fallacy problem, cf. Georghiou and Clarysse, 2006). Recent studies (e.g. Cin et al., 2017; Vanino et al., 2019) have established the positive effect of R&D subsidies on the business performance of the recipients. Vanino et al. (2019) showed this effect to be stronger in R&D intensive sectors. An interesting approach is to apply the Crépon–Duguet–Mairesse (CDM) framework[12] (Crepon et al., 1998) to estimate input additionality and then analyse whether the public R&D subsidy and induced private R&D investment lead to output additionality, that is – more innovation. Using a modified CDM framework, Czarnitzki and Delanote (2017) found evidence of both input additionality and output additionality, which means that subsidy-induced R&D increases the subsidised companies' sales from new products.

While measuring input additionality is common for supply-side financial instruments, it is problematic to deal with input additionality in evaluations of demand-side policy instruments (Edler et al., 2012). For example, it is often challenging to distinguish the specific intervention from other demand-side instruments and, thus, the specific financial expenditure on the policy in promoting an agency's budget (Uyarra, 2016; Edler et al., 2012). In practice, the borders between supply-side and demand-side instruments are blurred. There are instruments such as PCP that are located on this borderline. The majority of authors (e.g. Edler and Georghiou, 2007; Lember et al., 2014; Rigby, 2016) view PCP as a form of PPI. This view is strongly challenged by Edquist and Zabala-Iturriagagoitia (2015), who consider PCP as a specific type of public R&D funding subsidy.

Empirical studies on the effects of public procurement on the private sector suppliers' innovative behaviour and innovation outcomes are scarce, with a few notable exceptions. Aschhoff and Sofka's (2009) results highlighted that public procurement contracts are associated with the better innovation performance of suppliers expressed as the share of turnover in products new to the market as a whole. Guerzoni and Raiteri (2015) conclude that PPI stimulates private R&D investment. This conclusion holds when this policy instrument is considered in isolation from, as well as in combination with, supply side instruments – direct R&D subsidies and R&D tax credits. The empirical results by Pickernell et al.

[12] The CDM model is structural model that describes the link between (i) R&D expenditure, which depends on the characteristics of a firm and industry, such as size, internationalisation patterns, or institutional environment, (ii) innovation output, which is a function of the R&D input, and (iii) productivity, which is a function of innovation output. The CDM is widely used in the empirical studies on links between innovation and productivity. The CDM been applied to firm-level data of more than 40 countries (Lööf et al., 2017).

(2011) and Slavtchev and Wiederhold (2016) indicate that the sophistication of demand determines the effectiveness of the use of public procurement as an instrument for inducing additional private investments in knowledge production. For example, an econometric analysis of US federal procurement policy showed that each Euro of public spending reallocated to high-tech industries at the expense of low-tech industries was associated with an increase in private R&D expenditures equal to 0.21 Euros (Slavtchev and Wiederhold, 2016).

According to the comprehensive review of methods applied to study the effects of large research infrastructures[13] by Reid et al. (2018)[14], quantitative studies based on rigorous econometric approaches[15] which look into firm-level effects of collaboration with Big Science organisations are rare. The most elaborate study was recently performed by Castelnovo et al. (2018), who used a sample of 365 CERN suppliers. The firm-level data contained detailed information about procurement contracts with CERN and main financial indicators for the period of 1996–2007. Its empirical strategy was based on the CDM framework. The following sequence of events was tested as a system of simultaneous equations using a three-stage least squares procedure for the estimation: (1) if a procurement relation with CERN leads to increase in R&D effort (proxied by the yearly variation of intangible fixed assets per employee in the model), which (2) results in more innovations as measured in a number of patents, which (3) leads to higher productivity (in the model, the yearly change in sales normalised by the number of employees is used as a proxy for labour productivity), and ultimately, (4) change in revenues and profitability (using different financial performance indicators, such as EBIT). For high-tech companies, the estimation results underscored the presence of the direct 'CERN effect' on R&D investments, which propagates along the consequential chain-of-events into additional innovation output, higher productivity, and better economic performance of CERN suppliers. In other words, the study provided evidence of both input additionality and output

[13] Partial overlaps between these two terms – Big Science and research infrastructures – are well addressed in Hallonsten (2020). While "the most physically imposing (and expensive) research infrastructures, accelerators and reactors, are also archetypal examples of Big Science" (p. 7), the roadmap issued by the European Strategy Forum for Research Infrastructures (ESFRI, 2018) contains also distributed data repositories and vessels (icebreaker ships or aircraft) as the research infrastructures of Pan-European importance. Hallonsten (2020) argues that such heterogeneity, due to various political reasons, undermines the analytical value of the construct of large-scale research infrastructures.

[14] Two widely applied types of evaluation methods – socio-economic assessments based on the analytical input-output framework that dates back to the works of Leontief in the 1930s (cf. Miller and Blair, 2009) and cost-benefit analyses appraising the Big Science's full contribution to social welfare by evaluating non-market impacts and using shadow prices that reflect the social opportunity cost of goods and services (e.g. Florio and Sirtori, 2016; Florio et al., 2016) – are not covered in this thesis.

[15] Such studies often apply the knowledge production function approach, based on seminal contributions of Griliches (e.g. Griliches, 1979) that connect the inputs, the outputs, and the rules according to which inputs are transformed into the outputs.

additionality from offering sophisticated products to Big Science. One of the main strengths of the study is usage of accounting data instead of survey-based data; however, the study did not account for the survival of CERN suppliers. Therefore, the estimators of the 'CERN effects' may be upward biased.

The production function-based approaches to study the firm-level input and output additionality of collaboration with Big Science, have a number of merits. The theoretical foundations of such studies are thoroughly elaborated. The methodologies are reproducible in different contexts and, therefore, the results of different studies would be directly comparable. However, such studies fail to capture some of the crucial dimensions of the firm-level effects.

1.2.2. Behavioural additionality

Evaluators' focus on the concepts of input and output additionality has been considered to be emblematic for traditional innovation policy, which is based on the linear model of innovation and uses the neoclassical market failure rationale as a justification for policy intervention. Evaluations that concentrate on input and output additionality treat the firm as a 'black box.' This perspective assumes the existence of an unequivocal connection between inputs and outputs, i.e. more R&D investments means better performance, even though this assumption is debatable (Georghiou and Clarysse, 2006). According to this line of thinking, if a public instrument designed to compensate market failures does not induce more inputs than would have been generated in the absence of this instrument, there is ground to regard this instrument as ineffective (Gök and Edler, 2012).

Buisseret et al. (1995), who introduced the concept of 'behavioural additionality' to the literature, noted that traditional concepts of additionality do not capture the effects of R&D support programs on large firms comprehensively. They argued that the effects on the firms are more nuanced, ranging from changing patterns of their R&D collaborations to strategic and organisational dimensions. Behavioural additionality was conceived to illuminate the internal processes within the 'black box' that converts inputs into outputs. Behavioural additionality is based on evolutionary and structuralist ideas about innovation (Gök, 2010) that stress the centrality of the interactions between agents and different forms of learning, thus being compatible with the systems of innovation perspective on the innovation policy, which builds on a process oriented non-linear model of innovation.

Gök and Edler (2012) divide various definitions and understandings of behavioural additionality into four categories to illustrate the lingering theoretical vagueness of the concept. Two dimensions – functional scope and time considerations – form the basis for the categorisation. A narrow understanding of behavioural additionality as the scale, scope, and acceleration additionalities represents one end of the continuum (Georghiou, 2002; Falk, 2007)[16]. While the functional scope of the narrow understanding of the concept is confined to the R&D activities of firms, and the persistence of the effects is not a central issue, the broadest view of the concept seeks to identify persistent changes in the general conduct of the firm across all dimensions of business strategy (Gök and Edler, 2012). These different definitional categories of the concept of behavioural additionality reflect the different theoretical perspectives of scholars. Approaches that build on the resource-based theory and dynamic capabilities (e.g. Georghiou and Clarysse, 2006), theory of organisational learning (e.g. Clarysse et al., 2009), or evolutionary economics (e.g. Gök, 2010), tend to emphasize the temporal scope of the concept, i.e. the persistence of the changes associated with a policy intervention.

This conceptual heterogeneity is reflected in the diversity of measurement practices in empirical studies on the behavioural additionality of innovation policy instruments. If the focus of a study is on project additionality, then researchers have collected survey-based data in the attempt to create hypothetical, counterfactual situations (for example, by asking questions “Would the project have been conducted without public support without changes or cancelled?” as in Falk (2007, p. 669)). This approach entails a possibility that the respondents over-exaggerate the positive effects of the policy instrument or downplay unanticipated changes in behaviour (Pérez, 2016). The occurrence of scope or scale additionality can be then used as a binary dependent variable to study associations with firm-level characteristics, such as firm size, exporting activity, and R&D intensity (Wanzenböck et al., 2013). Empirical studies on behavioural additionality often study the effects of innovation instruments on a firm’s propensity to cooperate with external partners (e.g. Fier et al., 2006; Busom and Fernández-Ribas, 2008; Afcha Chávez, 2011; Teirlinck and Spithoven, 2012; Chapman et al., 2018; Bianchi et al., 2019). Generally, the results of these studies point in one direction – firms receiving R&D support tend to collaborate with a larger number of external partners, such as publicly funded research organisations and universities.

The second stream of empirical literature focuses on cognitive capacity additionality as the firm’s management capabilities are positively affected by project management guidelines that are imposed by the R&D subsidy (Buisseret et al., 1995), more elaborated and formalised innovation management processes (Clarysse et al., 2009), inter-organisational learning resulting from extended R&D collaborations and new partnerships (Falk, 2007; Clarysse et al., 2009), ‘systematization’ of R&D activities (Magro et al., 2010), and, at the individual level, changes in senior managers’ innovation-orientated attitudes (Chapman and Hewitt-Dundas, 2018). In the model of Clarysse et al. (2009), the dependent variable was the change in the way the firms operationally manage their innovation

[16] Scale additionality refers to possible economies of scale induced by public intervention leading to R&D projects that are larger than they would otherwise have been. Scope additionality means that new objectives or even new research domains that are beyond the existing competence bases of firms are added to projects.

process. They used the Likert scale to capture the respondents' opinions about the degree to which the R&D subsidy allowed the firm to "formalize the innovation management process within the firm" and "increase the innovation management capabilities" (p. 1521). Measures of the independent variables, such as the number of R&D projects funded by the funding agency, the number of other organisations involved in these projects, and the R&D intensity of the firms, represented different types of organisational learning in the model. The study identified behavioural additionality from R&D subsidies, which was realised simultaneously with input additionality. The empirical studies tend to agree that behavioural additionality is an antecedent of output additionality (e.g. Falk, 2007; Cerulli et al., 2016), and the changes in R&D collaborations and cognitive capacity should ultimately lead to better performance.

Due to ambiguities regarding the concept, Gök and Edler (2012) and Pérez (2016) note there is a tendency to label input additionality as behavioural additionality. There are studies that view the increase in scientific personnel induced by an R&D subsidy as the occurrence of behavioural additionality (Madsen and Brastad, 2006). Meuleman and De Maeseneire (2012) associate behavioural additionality with the SMEs' improved access to external financing thanks to the legitimising effect of R&D subsidies, which results in more inputs to the 'black box.' Such studies indicate the frequent misuse of the concept of behavioural additionality in evaluations (Gök and Edler, 2012).

Gök (2010) concluded that a universally accepted unit of analysis is missing for the concept of behavioural additionality; therefore, the operationalisation of the concept continues to be problematic. Collaboration is the most studied aspect of behavioural additionality; however, the finding that direct R&D subsidies induce a measurable increase in the number of partners involved in R&D collaboration is not really informative about the processes that take place within the 'black box'. Researchers merely open the 'black box' to find a smaller 'black box' inside the company (Amanatidou et al., 2014). The current evaluation practices that rely on survey-based data are unsuitable to unfold the dynamics of the internal processes of the treated firms (Gök and Edler, 2012). According to Gök (2010), the comparative static perspective of these studies basically examines two stationary snapshots of the firm's input or output indicators characterising certain behaviour (i.e. level of R&D cooperation) and considers the difference in indicators to be a measure of behavioural additionality. It is obvious that such an approach does not inform the evaluators about links between the intervention practice and the company's innovation process, nor does the approach grasp the entire spectrum of behavioural and strategic effects.

Within the past ten years, a couple of doctoral theses defended at the University of Manchester (Gök, 2010; Pérez, 2016) have sought to address the limitations related to the concept of behavioural additionality and its evaluation. Inspired by Nelson and Winter's (2004) seminal contribution to evolutionary economics, Gök (2010) proposes organisational routines as a unit of analysis for behavioural additionality. Organisational routines are defined as "repetitive[17], recognizable patterns of interdependent actions, carried out by multiple actors" (Feldman and Pentland, 2003, p. 95), such as adopting new approach to purchases of components, or standard product testing methods for implementing a R&D project.

Gök (2010) also assimilated the evolutionary micro-meso-macro framework of Dopfer and Potts (cf. Dopfer et al., 2004) to his approach. In this perspective, the micro level is concerned with the adoption of new organisational routines within a treated firm in response to the particular policy intervention. The meso level investigates how particular organisational routines diffuse and eventually become institutionalised in agent populations, such as markets and industries. Empirically, both doctoral theses employed a multiple case study approach with the aim to test if the methodology is capable of observing complex organisational processes over time in order to identify behavioural additionality through changes in routines, such as collaborative R&D routines in Gök (2010). However, the studies remained at the firm-level and the approach was not empirically tested at the meso-level.

In evaluations of Big Science, the concept of behavioural additionality has been employed implicitly. The evaluations have dealt with strategic changes within Big Science suppliers without explicitly using the term 'behavioural additionality'. Gök and Edler (2012) argue that this is rather common in evaluations. One of the evaluation methods that shares the same theoretical roots as the concept of behavioural additionality is the BETA method. This approach was originally conceived in the 1970s by the Bureau d'Economie Théorique et Appliquée at the University of Strasbourg to study the socio-economic impacts of two Big Science organisations, namely ESA and CERN (Bach and Matt, 2005; Bach and Wolff, 2017). In their review, Reid et al. (2018) label the BETA method as a 'multi-method approach'[18] as it seeks to capture the multidimensional nature of the socio-economic impacts of Big Science.

The BETA method has been extensively used to study the so-called indirect industrial effects of ESA suppliers' involvement in ESA programs, both at the European level (Cohendet, 1997; Bach et al., 2002) and, in a modified and reduced form, at the national level (e.g. Ramboll Management, 2008; Norsk Romsenter, 2018). The indirect industrial effects are firm-level effects, which go beyond the scope of the objectives of the contract between Big Science and its suppliers. The

[17] In this context, repetitiveness implies persistence.

[18] Another example of multi-method approaches is the SPRU approach developed at the Science Policy Research Unit (SPRU) of the University of Sussex (Martin, 1996; Martin and Tang, 2007). The SPRU approach proposed to measure various categories related to the production of scientific knowledge (scientific activity, production, and progress), but also technological, educational, and cultural contributions of Big Science (for CERN, Irvine and Martin, 1984). The technological dimension of impacts was embodied in new products, processes and services, new or improved instrumentation, and new methodologies applied for purposes not directly linked to of the research agenda of Big Science (Martin, 1996, p. 346).

BETA method emphasises the importance of knowledge creation and diffusion processes associated with the Big Science-supplier collaboration. The indirect industrial effects are defined through the acquisition of new knowledge which, in turn, increases the capacity of the contractor. The incumbent firm exploits this extra capacity for purposes not related to collaboration with Big Science. The indirect industrial effects are quantified *ex post* using standard financial data, such as revenue, added value, or cost savings. The data is collected through interviews with the top management or R&D managers of companies (Bach and Matt, 2005). The interview protocol emphasises the principle of conservative, i.e. minimum, estimates of the effects (Cohendet, 1997).

The BETA methodology disentangles the capacity-enhancing effects into four pathways (Cohendet, 1997):

- Technological effects relate to learning processes and intra-firm knowledge transfers that result in widening scientific and technical knowledge and, ultimately, in product and process innovations.
- Commercial effects, such as the effects of Big Science collaboration on the accumulation of market and marketing knowledge thanks to the new research and business connections of Big Science suppliers.
- Organisation and method effects, such as inter- and intra-organisational learning, that leads to the adoption of novel management procedures and methods and, potentially, to changes in the organisational structure of a firm in order to accommodate for these new ways of conducting business. Organisation and method effects are well aligned with Gök's (2010) evolutionary view of behavioural additionality as the adoption of new organisational routines.
- Work factor effects, such as heightened qualifications and skills acquired by the personnel employed in Big Science projects.

Technological effects in the BETA methodology are a proxy for output additionality. Other types of effects deal with the different dimensions of behavioural additionality and are connected to each other. Similarly to the framework of Clarysse et al. (2009), new connections facilitated by Big Science provide access to different forms of knowledge, such as the business practices and market strategies of other actors. This knowledge is assimilated by Big Science suppliers and leads to persistent changes in the *modus operandi* of the firms.

1.2.3. Evaluating market formation processes

The Gök (2010) approach to the evaluation of behavioural additionality echoes the conceptual focus of the Dopfer and Potts framework, which stresses that evolutionary meso-economics stands at the core of evolutionary economic analysis. The evolution of the economic system, such as the market, is a process driven by the origination, adoption, adaptation, and diffusion of novel ideas in a population of interacting agents (Dopfer et al., 2004). Market formation starts when new technical knowledge – created through the entrepreneurial effort of an economic agent – connects to a cognitive, social, and behavioural context in a specific way which makes this novelty understandable and communicable to other agents (Bleda and del Río, 2013). This is the pre-requisite for further adoption.

In the Dopfer and Potts framework, the processes of origination and adoption at the meso-level are the most essential to capitalism. Evolution at the meso-level is ”evidenced in transformed market and industrial organisational structures” (Dopfer et al., 2004, p. 272) and may involve new markets as “any new product can always be defined as the basis of a new market” (p. 274). Creating new markets through public demand is one of the main tasks of demand-side innovation policy instruments since the emergence of the systems of innovation perspective. Therefore, the evaluation of demand-side policies has to go beyond the firm-level perspective and cover also the meso-level – combining qualitative and quantitative methods (Edler et al., 2012).

If the aim of demand-side instruments is to guide existing markets towards new consumption and investment patterns, which is often the case for the demand-side interventions (particularly in energy markets), then evaluators have to select indicators that appropriately describe changes in core themes addressed within the policies. With that respect, Edler et al. (2012) referred to pioneering market transformation programs, such as the Swedish market transformation program (cf. Neij, 2001; Neij and Åstrand, 2006), as the demand-side policies with the most elaborated evaluation designs. Neij (2001) highlights that such evaluations have both summative and formative roles and should monitor changes in an actors’ behaviour, market development, and technological development. In the long term, the dynamics of various parameters – such as changes in available products and engaged actors, changes in the market share of products and actors, changes in a product’s performance and price, and formal and informal standards – describe the persistence of market transformation. Neij and Åstrand (2006) discuss this bundle of outcome indicators in the context of an impact assessment of transformational policy on a complex socio-economic system, which, in essence, is a combination of multiple technological innovation systems.

Bleda and del Río (2013) emphasize the usefulness of the TIS functional perspective in capturing the dynamics of markets in an innovation system. Both theoretically and empirically, the TIS perspective mostly concerns the emerging technologies that are the important building blocks in the formation of new markets. Early literature on TIS identified two phases of market creation – a formative phase and a growth phase (Bergek et al., 2008). The empirical work on the build-up of a TIS has used a diversity of indicators to characterise the performance of market formation function of a TIS (a few examples are given in Table 3). The indicators can be grouped into several categories that connected to the three key analytical dimensions characterising a TIS. These dimensions are: (1) actors who are involved in the TIS, (2) institutions that affect the actions of these actors, and (3) dynamically evolving technology (Markard, 2020). Indicators, such as sales figures, number of sold units, market size, or market shares, can be derived from the aggregated firm level data of relevant actors. The firm-level data can be gathered through the prevailing subject-centric data collection approach[19]. The build-up of a TIS can be a decades-long process, but even in such a prolonged case market formation may remain insignificant (Suurs et al., 2009; Bento and Wilson, 2016; Davidian, 2020). Therefore, delineating relevant actors may be challenging, in practice, because new markets involve loosely connected, emerging populations of interacting agents, which sales figures are often low or close to zero. Uyarra (2016) notes that problems with defining the target groups of the demand-side interventions is one of the reasons why such instruments, including PPI, have remained under-evaluated.

Table 3. Market formation indicators in empirical studies on the build-up of a TIS

Study	**TIS**	**Market formation indicators**
Gosens and Lu (2013)	Wind power (China)	• Size of markets formed • Drivers of market formation (e.g. support scheme) • Competitiveness of domestic and foreign firms in global markets • Relevance of domestic and international support schemes
Bento and Fontes (2015)	Energy technologies (Portugal)	• Events of tariff stimuli • Installed capacity • Market shares
Bento and Wilson (2016)	Energy technologies	• Sales figures (incl. subjective assessments if sales growth is permanent and represents take-off), • Sold unit numbers • Installed capacity
Chou et al. (2019)	Fuel cells (Taiwan)	• Events of market regulations • Events of tax exemptions
Sawulski et al. (2019)	Offshore wind (Poland)	• Size of markets formed • Subjective assessments of expected future market size
Kushnir et al. (2020)	Hydrogen reduction (Sweden)	• Descriptions of customer groups • Descriptions of application types • Sales information

Source: the author's compilation

[19] The 'subject-based' approach that is in line with the Oslo Manual (OECD, 2005) looks at the innovative behaviour and activities of the firm, while data collection with a focus on specific innovations, embodiments of new technical knowledge ('object-oriented' measurement), could be better suited for tracing the impact of demand-side policies (Appelt and Galindo-Rueda, 2016).

Some of the market formation indicators in Table 3 represent the institutional aspects of the functional performance of a TIS, such as events of tariff stimuli in Bento and Fontes (2015) and events of market regulations in Chou et al. (2019). From the perspective of sociological neo-institutional theory (cf. Scott, 2014), these indicators fall under the regulative institutional pillar. According to sociological neo-institutional theory, regulative institutions, such as laws and rules, make sure that actors behave according to certain regulated standards out of fear of sanctions. The normative pillar consists of norms and values, which allow actors to perceive the social implications of a certain behaviour. It represents assumptions about what is appropriate or expected in social interactions (Scott, 2014). Cognitive institutions refer to „ways, perceptions, and descriptions, theories and models, empirical data about reality and thus, the understanding of a business reality as a basis for operating as a successful business“ (Edvardsson et al., 2014, p. 302). In the Markard's (2020) TIS life cycle model, cognitive institutions have an influential role in the formative phase. Wirth et al. (2013) show that the effects of the regulative pillar on the meso-level dynamics depend on the normative and cognitive institutions that modulate the effects.

Actors are often engaged with the purposive action to create and disrupt institutions. This institutional work (cf. Lawrence and Suddaby, 2006), even by a single market actor (Kukk et al., 2016), is instrumental in market formation. In the absence of other quantifiable indicators that enable scholars to capture weak signals of market formation, tracing institutional change along all institutional pillars, not only in regulative pillar, could be useful to understand if demand-side interventions are sufficiently effective in triggering expected meso-level changes. However, measuring institutional change is challenging because of problems with the theoretically sound operationalisation of the concept – "articulating institutions along three encompassing pillars may encourage the view that everything is an institution“ (Abdelnour et al., 2017, p. 1779). Another problem is how to deal with proto-institutions, which are defined as weakly embedded and less persistent institutions (Lawrence et al., 2002).

Even though demand articulation by Big Science has been linked with the creation of new markets (e.g. Vuola and Hameri, 2006; Mazzucato and Robinson, 2017; Kattel and Mazzucato, 2018), this market-shaping role has been overlooked in evaluations of Big Science until now. This resonates with Mazzucato's (2016) discontent of the mismatch between the tools currently applied in evaluation practice and the nature of dynamic processes of change at the meso and system levels.

1.3. Research questions

This thesis investigates processes behind various firm-level and industry-level effects of collaboration with international Big Science organisations. The theory-based rationales behind any policy instrument are a starting point for the assessment of the instrument's effects. The membership in international Big

Science organisations is a systemic innovation policy instrument that helps to target market, systemic, and transformational failures. The previous chapters discussed the alignment between different approaches of evaluations of participation in Big Science and the three dominant innovation policy paradigms (Schot and Steinmueller, 2018; Diercks et al., 2019*)*. Evaluation methodologies grounded in the knowledge production function are theoretically consistent with the neo-classical market failure 'doctrine' (Smith, 2000) in the science and technology policy paradigm, while the theoretical reasoning behind the BETA methodology is coherent with the systems of innovation perspective.

In addition to the theory-method fit, the usage of different evaluation approaches can be constrained by the limited availability of data. For example, small sample sizes prohibit replicating the CDM approach applied by Castelnovo et al. (2018) to investigate 'ESA effect' on ESA suppliers in small ESA member states, such as Estonia. As of June 2020, there were only 24 ESA suppliers among Estonian companies. Two Estonian companies that were awarded an ESA contract have ceased to exist, and another four did not create any turnover according to the most recent annual reports. The sample size does not allow for applying rigorous large-N econometric methods, even though a dataset compatible with Castelnovo et al. (2018) could be constructed from survey-based data and data available from public registries and the ESA Procurement Department. Under such circumstances, multi-method approaches (e.g. for Denmark, Ramboll Management, 2008) and case based approaches (e.g. for Sweden, Åberg, 2013) have been deployed in academic and grey literature to assess the firm-level effects of participation in Big Science organisations in smaller member states (Reid et al., 2018).

In the case of ESA, various country-level studies have collected primary data through interviews and surveys in order to establish the magnitude of firm-level effects accrued to ESA suppliers thanks to technology transfer and learning benefits from collaboration with the agency (OECD, 2012). Edler et al. (2008) suggests that evaluation results of specific individual policy instruments should be used more systematically to disclose regularities in the evaluations. They propose secondary analyses – systematic reviews and syntheses of evaluations – to ascertain the quality of evaluations and the plausibility of their findings. One of the purposes for conducting a meta-analysis of a set of evaluations is to notify practitioners about the merits of different methods and draw attention to the possible pitfalls undermining the credibility of evaluation. The expected outcome of evaluation syntheses is to reach more generalised conclusions about a policy instrument (Cooksy and Caracelli, 2005). A secondary analysis has a formative element; it carries the potential to enhance policymakers' understanding of a policy instrument. Against this backdrop, Study 1 responds to the call by Edler et al. (2008) and systematically reviews the existing country-level studies of the firm-level effects of collaboration with Big Science, more specifically the ESA. The study asks the following research question – *how methodologically trustworthy are the processes and findings of the available country-level studies on public investments to ESA programs*? Each reviewed study has a specific context shaped by the prevailing evaluation practices (e.g. guidelines of the best practices at the national level), the regularity of evaluations, the industry's structure, or the accessible data sources for data triangulation. The answer to the first research question enables the appraisal of the value of the current evaluation practices, for policymakers at both the national and supranational levels. The results of a systematic review help to determine the reliability of reported indicators for international benchmarking purposes (cf. OECD, 2012).

Extant literature has paid considerable attention to the different learning processes that happen in supplier firms during their collaboration with Big Science organisations. In particular, the focus has been on technological learning taking place in this mutual relationship and between Big Science suppliers and actors in Big Science organisations' wider R&D network (Bach et al., 2002; Nordberg et al., 2003; Autio et al., 2004; Åberg and Bengtson, 2015; Florio et al., 2018). Learning is cumulative; the learning processes are supported by the amount of dyad-specific resources brought into the collaboration. The readiness to build up such resources depends on the congruence between the organisational goals of the parties (Autio et al., 2004). The accumulation of market and marketing knowledge in this learning environment has also been acknowledged by researchers (Cohendet, 1997). In the context of this thesis, a contract with Big Science is a case of direct exports for its suppliers. Exporting entails 'learning by exporting' effects, i.e. exposure to foreign customers enhances the firms' technological, market, and marketing knowledge, which in turn forms the basis for the development of further innovations (cf. Love and Ganotakis, 2013). To add to the learning related effects, both quantitative analysis in academic research (e.g. Florio et al., 2018) and quotes from interviews with Big Science suppliers in grey literature (e.g. Ramboll Management, 2008) have highlighted the importance of collaboration with Big Science as a marketing reference. Being selected for delivery of novel products or services by ESA certifies the quality of the supplier to uninformed third parties (Lerner, 2000) thus, it is a major event in the process of legitimation of an actor. Legitimacy is viewed as a resource, which facilitates the acquisition of other tangible and intangible resources (Zimmerman and Zeitz, 2002). However, in literature, the emphasis has been on measuring the monetary value (Cohendet, 1997) or determinants (Florio et al., 2018) of the reputation effects. There is a research gap concerning the understanding of the processes of market and marketing knowledge acquisition, assimilation, and integration in connection to collaboration with Big Science. Therefore, the second research question of the thesis asks *how do firms capitalise on knowledge from collaboration with Big Science organisations?* More specifically, Study 2 focuses on the internationalisation processes of resource-constrained, knowledge-intensive companies to answer this question.

Contributions by various authors suggest that procuring sophisticated products and services at the highest possible governance level by a competent supranational body, such as an international Big Science organisation, positively affects firm-level innovation outcomes from PPI/PCP compared to procurement conducted at lower levels of governance (Guerzoni, 2010; Georghiou et al., 2014).

A Big Science organisation is an innovation intermediary, in which activities in an innovation system are leveraged by its high-level of technical expertise, procurement skills, reputation, and market power (Leyden and Link, 1999; Landoni, 2017). These properties enable Big Science to identify latent needs and convert them into concrete and explicit users' requirements (Boon and Edler, 2018). Innovations developed to satisfy these requirements form the basis for new markets. The actions of Big Science organisations are guided and constrained by the prevailing institutional order, but given the multitude of roles prescribed to Big Science by its member states (Robinson and Mazzucato, 2019), Big Science organisations also act as change agents that induce institutional development to support market formation processes in nascent ecosystems (Battilana and D'Aunno, 2009). This facet of Big Science has not been discussed in the academic literature. Against such a background, the third research question of the thesis asks: *how PPI/PCP implemented at the supranational level by Big Science organisations leads to the meso-level institutional change?* Study 3 seeks answer to this question from the perspective of ESA contractors involved in the emerging market of Earth Observation applications.

Both Study 2 and Study 3 seek to contribute to the understanding of how collaboration with Big Science alters the behaviour of its supplier firms and the institutional environment where the supplier firms operate. Therefore, the Studies deal with different aspects of behavioural additionality at the micro- and meso-levels.

1.4. Data and methods used in the thesis

The research process of this study can be described as a combination of exploratory and explanatory elements, which calls for the use of a mixed-method research strategy (Teddlie and Tashakkori, 2003). The journey started by searching for correlations between various firm-level explanatory variables, such as the size and selected financial indicators of Big Science suppliers, their position in the value chain, and the dependent variable – output additionality from the collaboration with Big Science, specifically ESA, in the new member states of Big Science. Associations between these variables were expected to provide new insights into the determinants of the micro-level effects of the Big Science membership. The first task, in order to realise the plan, was to construct an original dataset consisting of survey-based primary data and financial data from various secondary sources, such as the Estonian Commercial Register.

To elaborate a methodology for collecting firm-level data, the author of the thesis conducted a meta-analysis of the existing country-wide policy evaluations which aimed at measuring firm-level additionalities related to public investments to ESA. A set of studies for the analysis was identified by re-examining earlier reviews (e.g. Hof et al., 2012; Simmonds et al., 2012; OECD, 2014b). An additional search was performed in electronic journal databases (Web of Science, Scopus) and publication repositories of national space agencies and space offices in Europe[20]. The country-wide impact assessments performed in the following five ESA member states dealt with micro-level effects from the collaboration with ESA and were chosen for the next step of the analysis: Belgium, Denmark, Ireland, Norway, and Portugal.

Table 4. Interviews regarding the methodological aspects of the country-wide impact assessments

Interviewee	**Represented organisation**	**Impact assessment**	**Interview date**
Gorm Kofoed Petersen, Per Kolbeck Nielsen	Division for Space, Danish Agency for Science, Technology and Innovation	Ramboll Management (2008)	November 6th, 2013
Brian Landbo	Ramboll Management		November 12th, 2013
Rune Eriksen	Industry Policy Department, Norwegian Space Agency	Annually published, e.g. Norsk Romsenter (2018)	December 19th, 2013
Tony McDonald	Programme Manager Space Industry, Enterprise Ireland	Delve Research (2012)	December 12th, 2013
Jacques Nijskens	Service Spatial, Belgian Science Policy Office	Capron et al. (2010)	January 8th, 2014
Didier Baudewyns	Université Libre de Bruxelles		January 8th, 2014
Luís Serina	Fundação para a Ciência e a Tecnologia	Clama Consulting (2011)	February 19th, 2014

To better understand the methodological nuances of the reviewed studies and the differences between countries, the author conducted seven interviews with representatives of space offices and research teams who implemented the impact assessments (see Table 4). Collecting the additional data from parties involved in the impact assessment process enabled tackling the common problem of limited information in situations when formal reports are the only sources used in meta-evaluations (supported by Cooksy and Caracelli, 2005). The detailed description of each study in the sample contained information about the total population of ESA suppliers in their respective countries, the concentration levels of ESA

[20] For example, the following search terms were combined: „Big Science“, „European Space Agency“, „space programmes“, „impact assessment“, „evaluation“, „socio-economic analysis“, „return on investment“, „firm-level effects“, „output additionality“, „additional turnover“, „additional revenue“ etc.

contracts, the data collection methods, the characteristics of collected quantitative and qualitative data, the data triangulation approaches applied by the study teams, key indicators, theoretical foundations, and political arguments behind the selection of the indicators. The main findings of the meta-analysis are reported in Study 1.

The results of the meta-analysis provided a good basis on which to build on the semi-structured interviews on the firm-level effects from collaboration with ESA in two new ESA member states – the Czech Republic[21] and Estonia. The interview guidelines disentangled firm-level effects into sub-types similarly to the original BETA methodology (see Cohendet, 1997; Ch. 1.2.2). Next, face-to-face interviews with 25 ESA suppliers were conducted by the author of the thesis between February 2015 and April 2015. The companies in the study sample accounted for 91% and 88% of the total financial value of ESA contracts with Czech and Estonian companies, respectively. These interviews revealed that a time lag between the beginning of an ESA assignment and the additional output attributed to this contract by interviewees was five years on average (Eerme et al., 2015). Consequently, most of the Estonian suppliers to ESA were in the development phase during the fieldwork, where ESA-derived products and services were not yet ready for markets. Additionally, the collected estimates of firm-level effects in the Czech Republic were considerably lower in monetary terms than the reviewed reference studies suggested. The latter, seemingly controversial finding, made the author revisit the initial research questions and take a closer look at the processes that are associated with different dimensions of additionality from collaboration with Big Science.

The author made two interesting observations during the primary data collection process in Estonia and the Czech Republic. First, the role of Big Science in the internationalisation process of its suppliers was more far-reaching than was expected from assumptions afforded by the extant literature. The author recognised shifts in ESA suppliers' collaboration patterns with cross-border partners and strategic management. Second, Big Science appeared to have a unique capacity to support the formation of new markets for innovations that were developed in collaboration with Big Science. ESA is linked to entrepreneurial activities aimed at changes in institutional environment that steers the behaviour of actors in the focal firms' business networks. The interviews with the Czech and Estonian companies provided evidence that collaboration with ESA strongly affects the internal processes of ESA contractors as well as interactions between the firms and other actors in their business networks.

All this indicated that a more exploratory qualitative approach was needed. To start with, both phenomena of interest – the internationalisation of knowledge-intensive firms for resource seeking and innovation intermediation for multi-level institutional change – are understudied in the extant literature. Furthermore, there are knowledge gaps regarding how Big Science is connected to these processes of interest that take place within the firms and their external environments. In the

[21] Full member state of ESA since 2008.

case of nascent theories and understudied empirical contexts, qualitative inquiry offers a value for inductively generating new theories or refining the existing theories on the basis of fieldwork – observations, interviews, and archival data (Edmondson and Mcmanus, 2007; Bansal et al., 2018). Qualitative methods facilitate the emergence of rich, context specific, and in-depth description of the phenomenon (Ghauri, 2004). Both Studies 2 and 3 are qualitative multiple-case studies, which provide a good methodological fit with the research tasks of this thesis as case studies can illustrate process logic and establish links between constructs (Siggelkow, 2007).

A similar research design has been applied previously in some benchmark studies related to the collaboration between Big Science and its suppliers. For example, based on the cases of 14 Swedish CERN suppliers, Åberg and Bengtson (2015) investigated the connection between innovation outcomes and the complexity of Big Science-supplier interaction. The cases provided evidence that the level of mutual involvement modulates the innovation outcomes from Big Science-supplier interaction, but the continuity of the relationship does not have a similar effect. On the other hand, Autio et al. (2004) developed a theoretical framework that describes how Big Science organisations operate the learning environment for their industrial suppliers by relying on three in-depth case studies of projects implemented by companies in collaboration with Big Science.

In order to provide in-depth understanding of the phenomenon, both Studies 2 and 3 were based on purposeful sampling procedures to ensure that cases provide rich information on the processes of interest (Patton, 2015). In Study 2, the cases were selected among small knowledge-intensive firms that co-created an innovative technology with Big Science. In Study 3, interactions with ESA staff members enabled a comprehensive initial list of companies in the Central and Eastern Europe that satisfied the most important criterion – the companies had to be involved in the catalytic procurement of ESA in the field of Earth Observation services. Then, additional criteria were applied to narrow down this list in order to manage different variance dimensions relevant for the research question, such as cross-country variance related to the institutional environments and cross-case variance to control for the firm’s size and maturity level. In both studies, an important criterion for the case selection was access to information (Fletcher et al., 2018).

Data collection and analysis were further supported by engaged scholarship. Engaged scholarship (cf. Van de Ven, 2007) provides an opportunity to enrich scientific knowledge with practical knowledge for better sense-making of the empirical context and, consequently, for deeper understanding of phenomena and processes under investigation (Bansal et al., 2018). The author of the thesis worked as a consultant assisting the Estonian Space Office and Estonian SMEs in matters related to ESA industrial policy and the ESA procurement system since 2010. He could closely follow the activities of the ESA suppliers in Estonia without direct involvement in the internationalisation processes of the companies or activities aimed at institutional change and, hence, function as an observer (Piekkari et al., 2013).

Table 5. Major rounds of data gathering in Estonia

Period	**Method**	**Number of ESA suppliers involved**
September 2014	Self-reported survey covering the capabilities of companies and the applications of their space technologies	11 companies
February–March 2015	Semi-structured interviews covering different aspects of how knowledge and technologies acquired through collaboration with ESA are used in business practices	10 companies
December 2016–January 2017	Semi-structured interviews covering the acquisition and exploitation of market and marketing knowledge and other resources through collaboration with ESA, and the impact of these activities on the evolution of business networks of the interviewed companies.	6 companies
June 2017	Self-reported survey covering the characteristics of ESA-derived products and services and their commercialisation routes	11 companies
March 2018	Semi-structured interviews covering different aspects of how knowledge and technologies acquired through collaboration with ESA are used in business practices	6 companies
May 2018	Self-reported survey about the outputs, outcomes, and impacts of all ESA contracts	10 companies
January–March 2019	Semi-structured interviews covering the institutional change in the evolving service ecosystems	4 companies

Source: author's compilation

Data triangulation, i.e. collecting data from diverse sources is considered to enhance the rigor of qualitative research (Gibbert et al., 2008; Hoorani et al., 2019). The author of the thesis was able to build up a database consisting of qualitative data about the Estonian ESA suppliers. This data was collected through several rounds of semi-structured interviews and surveys, conducted for different purposes (Table 5). The nature of the firm-level effects from collaboration with Big Science and the commercialisation pathways of new products and services co-created with Big Science were the central themes that were repeatedly covered over time during these data collection rounds. Furthermore, besides structured data gathering, the author of the thesis was in constant contact with the managers of the ESA suppliers through digital communication channels, such as Skype. Such information exchange sessions were informal, mainly focusing on different aspects of R&D, internationalisation processes, and the reasoning behind managerial decision-making. The described database and the information exchange sessions provided supplementary data to semi-structured interviews in Studies 2 and 3.

The Gioia method (cf. Gioia et al., 2013) was applied in the early phases of data analysis to manage rich information collected during fieldwork and a NVivo software tool was used for data coding to support this analytical phase. The Gioia method helps to create a bridge between informant-centric terms and conceptual interpretations of data by a researcher, i.e. to move "from raw data to first-order codes to second-order theoretical themes and dimensions" (Gehman et al., 2018, p. 286). The structured data emerging through this analytical step was used in the later stages of analysis. First, case narratives were prepared on the basis of the structured data (Eisenhardt, 1989). New themes and concepts began to surface inductively from the case narratives. These concepts were then linked to formulate dynamic relationships between them and, finally, derive descriptions of the processes of interest.

2. EMPIRICAL STUDIES

3. DISCUSSION

3.1. Empirical findings of the thesis

The thesis is concerned with different aspects of firm- and industry-level effects from collaboration with Big Science, more specifically the ESA. In chapter 1.3, three research questions were formulated by identifying knowledge gaps in the literature. The thesis is based on three research papers; each research paper addresses one research question. Therefore, the discussion of the empirical findings pertaining to the formulated research questions is structured along the individual Studies.

Study 1 sought an answer to the question *how methodologically trustworthy are the processes and findings of the available country-level studies on public investments to ESA programs*? Study 1 published the results of the systematic review of the extant academic and grey literature on this topic. In the following paragraphs, four key findings that emerged from Study 1 are highlighted.

First, the low number of ESA partners in smaller ESA member states narrows down the set of available impact assessment approaches in these countries. In small and mid-sized ESA member states, the total number of active ESA suppliers is usually less than 100. Even more importantly, ESA contracts are concentrated in the hands of a few main partners. For example, the 10 largest beneficiaries of ESA contracts in the Danish private sector were awarded 98% of the total value of ESA contracts in the period from 2000 to 2007 (Ramboll Management, 2008). While larger European countries tend to apply quantitative methods with a thoroughly elaborated theoretical foundation to study the impacts of public space investments – such as impact multipliers based on the analytical input-output framework in UK (e.g. London Economics, 2014) or the production-function approach in Italy (Graziola and Cristini, 2013) – smaller ESA member states resort to so-called multi-method approaches (cf. Reid et al., 2018) of measuring aggregated firm-level additionalities of ESA contracts. There were four smaller ESA member states in Europe – Denmark, Norway, Portugal, and Ireland – that had performed country-wide *ex post* evaluations measuring the firm-level effects from collaboration with the ESA. In these studies, firm-level effects were understood similarly to the BETA methodology (Cohendet, 1997; Bach and Matt, 2005).

Second, the reviewed country-level evaluations focused on firm-level effects from the collaboration between ESA contractors and the ESA, but various knowledge transfer and diffusion pathways that drive those effects received very limited attention in these studies. While the original BETA methodology attempts to look inside a 'black box' by studying the effects from participating in ESA programs on different strategic and organisational dimensions of the firms, the reviewed country-level evaluations collected primary information about specific inputs (the quantity and financial value of ESA contracts) and outputs (the additional turnover from technologies and products developed during the implementation of the ESA contracts). The BETA methodology addresses both behavioural and output additionality, but the reviewed country-level evaluations essentially dealt with output additionality. In addition to this fundamental difference, there are a few other major differences between the BETA methodology and the reviewed studies that are summarised in Table 6.

Table 6. Comparison between the BETA methodology and the existing country-wide evaluations of the firm-level impacts from participation in ESA programs

	Original BETA methodology	**Country-level impact assessments**
Identified additionalities	Behavioural additionality Output additionality	Output additionality
Unit of measurement	Effects measured in value-added units	Effects measured in additional sales
Counterfactual	The interview protocol takes into account the counterfactual logic, i.e. *what if* without the participation in the space programs, whenever possible.	The assessments focus on ESA-generated additional turnover. The counterfactual logic is not explicitly addressed.
Data collection	Interviews	Mail and online surveys, interviews

Sources: compiled by the author on the basis of Cohendet (1997), Bach and Wolff (2017), and Eerme (2016)

Third, several methodological issues make it difficult to transform the indicators reported in the reviewed country-wide evaluations of the firm-level impacts from participation in ESA programs into a standardized indicator for a cross-country comparison. These problems are related to the differences in the underlying data collection approaches, such as differences in sampling interval or time series length. There are also certain peculiarities stemming from national contexts, such as the usage of a tax distortion coefficient in the Danish study to correct for allocative inefficiency in the calculations of output additionality. Therefore, any cross-country comparisons on the basis of reported indicators should be treated with due care. This resounds with the concerns voiced by Reid et al. (2018), who consider the indicators of multi-method approaches, such as the BETA method, not as a measure of socio-economic impacts, but rather as markers of periodic change along impact pathways. Therefore, Reid et al. (2018) argue that such approaches tend to be useful for benchmarking progress towards strategic goals from the perspective of decision makers and managers in Big Science. Study 1 provided evidence to support this understanding. Norway is the only country among the reviewed studies measuring indirect effects on a regular basis – annually since 1992 – and the ministry in charge of supervising the ESA membership applies the ratio of firm-level effects to the value of ESA contracts to trace the efficiency of public investments to ESA. If the indicator is above the pre-defined threshold, then this signals to decision-makers that the public investments to ESA lead to a sufficient level of firm-level effects from the ESA contracts. In other countries, the evaluations of the membership in ESA remained an *ad hoc* analysis for summative purposes and its usefulness from policy-making perspective was limited.

Fourth, the published results of the country-wide *ex post* evaluations of output additionality from public investments to ESA programs raise several questions about the quality of data. For example, the weighted average ratio of the additional turnover from ESA-derived products and technologies to the financial value of the ESA contracts (often called 'spin-off multiplier') that ESA contractors self-reported in Norway was above 4, or even higher depending on the length of the time series for calculating the indicator or pre-set time lags between the contracts and derived effects used in the calculations. Moreover, the histogram of the individual output additionalities of the companies in the study sample of the Norwegian impact assessment showed that there were multiple companies with ratios of the additional turnover from new products and technologies to the financial value of the ESA contracts to the respective firms exceeding 20. The result that, on average, each Euro invested in companies' ESA projects results in at least 4 Euros in additional turnover of the companies is in contrast with what is known about the private rates of return to R&D (cf. reviews in Hall et al., 2009; Salter and Martin, 2001). The distribution of private rates of return is skewed (Scherer and Harhoff, 2000), but just a small proportion of investments in R&D yield positive returns while other R&D investments yield very low or even negative rates of return. This implies that the individual output additionalities of the companies in the study sample of the Norwegian study were anomalously high.

If the self-reported data behind the very high values of the individual output additionalities in Norway represented adequately the firm-level effects from participation in ESA programs, then the access to the ESA procurement system granted to companies through ESA membership can be viewed as a distinctive, highly-selective policy instrument that is geared towards high-growth firms. The implementation of such instrument ('picking the winners' initiative) also requires a strong hands-on, capacity-boosting support from ESA to companies (Autio and Rannikko, 2016). However, the results of the studies on high-growth entrepreneurship (e.g. Coad et al., 2014) point to the difficulties in predicting which firms will grow, and the fieldwork of Studies 2 and 3 does not provide evidence of the unique capacity-enhancing support from ESA to its suppliers. A possible explanation for the high level of output additionality in the Norwegian study is the project fallacy problem (cf. Georghiou and Clarysse, 2006). It means that the respondents associate collaboration with ESA with most of the effects of a number of unknown and unobserved factors that might have contributed to the additional output and performance improvements. Another possible explanation is that the respondents deliberately reported inflated data about the firm-level effects (the so-called 'strategic answering' problem). The high concentration level of ESA contracts with companies in all smaller ESA member states indicates that these companies have incentives to provide such answers to evaluation surveys that help to continue and increase funding to ESA. For example, Archibald and Finifter (2003) argued that the high response rate in a survey distributed to the participants in the NASA small business innovation research program was a result of ”a desire to keep the option open to apply for additional support from NASA” (p. 608). Due to the research methodology of Study 1 and the lack of available data, none of the explanations can be rigorously analysed in order to confirm or reject them.

Study 1 concluded that the results of the existing *ex post* national level evaluations of public investments to the programs of the ESA deserve cautious handling. Despite being intuitive and easy to understand in debates on funding allocations to different innovation policy measures, the usefulness of the spin-off multiplier for international benchmarking or policy-making purposes is limited. The indicator is used for summative evaluations to justify public spending to the ESA membership, but its reliability is undermined by likely problems with the quality of survey-based data, such as the project fallacy problem or the respondents' inclination to provide such answers that correlate with a sustained or increased funding level. The latter problem may be amplified if the population of ESA contractors is stable over the years. Analysing the evaluation practice in Europe, Edler et al. (2012) highlights that evaluations using methods based on survey data are perceived to be of higher quality. Study 1 points out that there are pitfalls undermining the usefulness of survey-based methods in the evaluations of membership to the ESA that call for careful data triangulation approaches.

The secondary analysis of the existing assessments of firm-level effects from the participation in ESA programs in Study 1 showed that collaboration with the ESA may play an important role in the internationalisation processes of its suppliers. For example, in the Irish study (Delve Research, 2012), the informants were invited to add open-ended comments concerning the effects of the ESA's engagement in their company. The reported direct quotes brought out new partner and client relationships through this collaboration.

However, the extant literature has focused predominantly on the technological inter-organisational learning and knowledge transfer, overlooking the internationalisation processes of Big Science supplier firms and the role of Big Science as a systemic intermediary in market and marketing knowledge acquisition and integration. Study 2 addressed this research gap and searched for answers to the second research question – *how do firms capitalise on knowledge from collaboration with Big Science organisations*? The main empirical findings of Study 2 are discussed in the following paragraphs.

Two cases in Study 2 scrutinised the internationalisation processes of knowledge-intensive ESA suppliers in Estonia over a three-year period. Study 2 adopted a holistic view of internationalisation by examining both inward cross-border links (Hernández and Nieto, 2016) – understood as the inter-organisational relationships, which feed new resources into the supplier's internal processes – and outward cross-border links, which are established to exploit the resource base of the ESA contractor. The internationalisation process of the case companies was non-linear and irregular. Their activities on foreign markets were often characterised by transient activity bursts, usually confined to inward or outward activities only, and subsequent withdrawal from the market. For the resource-constrained firms investigated in Study 2, the main motive for internationalisation was the need for additional resources to sustain R&D activities in order to seize an entrepreneurial opportunity, similar to Hewerdine et al. (2014). The perception of the nature of this entrepreneurial opportunity, such as the appropriateness of the value proposition of the company, benefits from the possible first-mover advantage – or the general characteristics of the competitive landscape – is founded on the grounds of the existing knowledge base of the company. However, a closer look at the internationalisation process implied that while some elements of the initial knowledge stock were supportive to internationalisation, some elements of existing market and marketing knowledge hindered the firms from adapting to the foreign market environment, thus becoming subject to 'unlearning.'

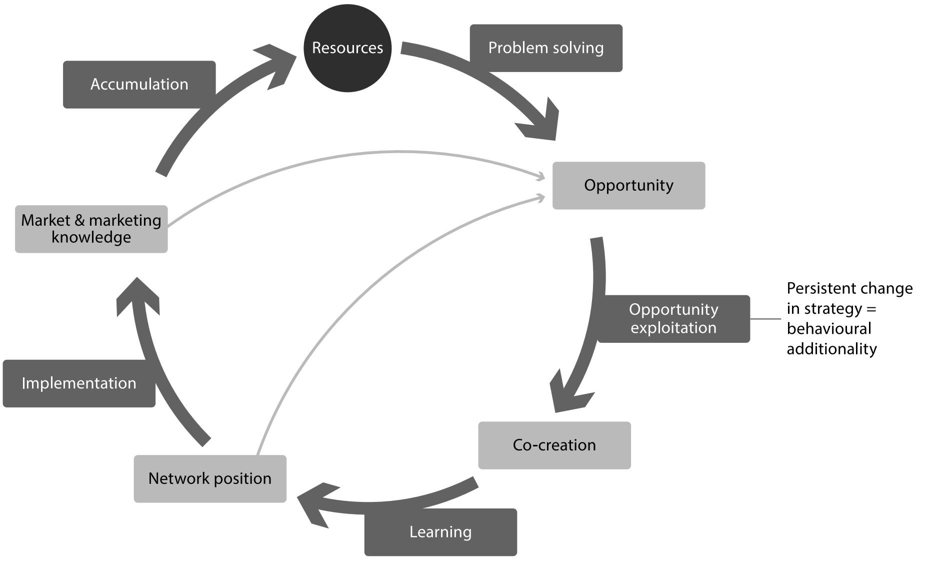

Figure 3. The framework for knowledge acquisition and assimilation from collaboration with Big Science organisations, the author's elaboration on the basis of Eerme and Nummela (2019b)

Study 2 proposed a new theoretical framework to describe the cyclical internationalisation process of knowledge-intensive, resource-constrained firms (see Figure 3). Recursive 'learning loops' are the engines of this process; the firm continuously learns about the technology, market, customers, and competencies required to operate in international markets. Through the knowledge acquisition and assimilation process, new entrepreneurial opportunities are revealed to the companies, which stimulates them to reconfigure their existing resource base and acquire additional resources to pursue new opportunities. There is interplay between the company's resource base, organisational learning, and the timing of internationalisation activities. Collaboration with the ESA connects inward and outward activities of the firm. The role of ESA is essential in the intertwined processes of learning and unlearning market and marketing knowledge that take place simultaneously. The collaboration can be seen as 'a triggering event' (cf. Hedaa and Tornroos, 2008) in this non-linear internationalisation process.

In the framework of the ESA's contract implementation, the purchasing agency and the supplier jointly develop and co-create immature technology into a marketable product. The ESA contractor benefits from temporary access to the cutting-edge technical expertise concentrated at the ESA. On one hand, this knowledge has accumulated at the ESA due to long-term collaboration with a number of companies in its wider partner network that possess technological capabilities similar to the supplier. On the other hand, the ESA is positioned to spin in deep technological knowledge from adjacent competence domains as well as seemingly more distant technology domains.

This co-creation channels not only useful technical knowledge to the ESA supplier, but also manifests rather specific market and marketing knowledge, such as better understanding of the needs and preferences of various end-user groups, or emergent knowledge on elements of viable business strategies. Moreover, the studied companies established contacts with their peers during industry events organised by the ESA, gatherings of incumbent industry actors along the full value chain, and by extracting and using related information from ESA supplier databases. All this resulted in better awareness about the structure of the relevant value chains in Europe and the actors that are involved in the value chains. This knowledge helped to identify potential customers and R&D partners and approach the ESA with the request to act as a broker for new business ties. Study 2 lends support to Hameri's (1997) claim that collaboration with Big Science offers diverse opportunities for its suppliers, even those that are located far from their target markets, to expand and improve business networks and become more engaged with both inward and outward cross-border collaboration.

Big Science contracts have been described as a powerful marketing reference (e.g. Cohendet, 1997; Autio et al., 2003). Study 2 looked at the mechanisms behind this effect. On the basis of the case analysis, it would be more appropriate to label this phenomenon as a 'legitimising signal' as the word 'marketing' implies that Big Science's role is restricted to outward links. In fact, ESA has a strong impact on both the inward and outward internationalisation activities of its suppliers, even without direct involvement in these processes. The cases provided evidence that entering new business networks would not have been feasible to the extent that was experienced without a strong legitimising signal provided by the relationship with a highly esteemed organisation such as the ESA. Without the ESA's supportive role, it would have been unthinkable for the Estonian companies to reach out to leading multinational companies. A heavy reliance on this legitimising signal as a focal point of resource-access strategy is what Rawhouser et al. (2017) called a 'strategy of projective associations.' In this strategy, high-quality relationships indicate the trustworthiness of a company and enable companies to overcome the liability of newness, thus opening up paths to tangible and intangible resources required by the company to implement its strategy. Collaboration with the ESA enables its suppliers to improve their network position, which facilitates inflow of useful market and marketing knowledge. Even though most of the established business ties with large multinationals were short-lived, highly specific knowledge about the market conditions in different countries was channelled to the case companies via these temporary links.

The learning loop that feeds new market and marketing knowledge into a firm's decision processes may also imply the need to discard existing business strategies and adopt new ones. The cases demonstrated how market and marketing knowledge collected from the large number of temporary and enduring cross-border links that were created by virtue of a single contract with the ESA made the companies reassess their business strategy. The firms' business models[22] were continuously refined over the course of the data collection period. Building on the empirical findings of Study 2 and Gök and Edler's (2012) definition of behavioural additionality as the persistent change in a company's strategies, the Freel et al. (2019) position that "exporting may be an important behavioural additionality of innovation policy" (p. 2) can be re-phrased in the context of this thesis: internationalisation is the important behavioural additionality from participation in Big Science programs.

The researched companies' internationalisation processes affected by collaboration with ESA illustrated how impactful rather temporary ties to leading multinational companies and related inter-organisational learning can be in terms of strategy creation and development. The extant literature on the quantitative studies of behavioural additionality, as discussed in Ch. 1.2.2, often relies on the comparative static perspective. Researchers measure the behavioural additionality of a policy instrument by detecting the change in the number of partners at different points of time and attributing the difference to the instrument. The results of Study 2 challenge the usefulness of such approach as it neglects the duration of the linkages and, more importantly, their impact on knowledge acquisition and assimilation processes of companies.

Study 2 demonstrated that the ESA suppliers capitalise on knowledge from collaboration with ESA directly through knowledge acquisition and knowledge transfer during the co-creation of new products and services, the expansion of business networks through involvement in ESA events, the intermediation by ESA staff, and indirectly thanks to the strong legitimising signal provided by collaboration with Big Science – a highly reputable organisation. The collaboration leads to persistent changes in the suppliers' business strategy.

For its member states, the membership in ESA, and involvement in its various programs, means that the procurement of new technologies and innovative products and services is handed over to the supranational level. ESA is engaged with both direct and catalytic procurement. From the economic standpoint, transferring the procurement function to the supranational level implies that the

[22] Understood as a "hypothesis about what customers want, and how an enterprise can best meet those needs, and get paid for doing so" (Teece, 2007, p. 1329).

member state's policymakers expect a higher level of additionalities from such approach compared to the procurement carried out at the national level.

As was discussed in Ch. 1.2.3, in case of innovation policy instruments, which are targeted at infant markets where commonly used indicators often fail to provide reliable input data for evaluators – e.g. sales figures of involved companies are negligible – monitoring institutional change could be an alternative solution for capturing weak signals of market formation. Therefore, Study 3 aimed at answering the third research question: *how PPI/PCP implemented at the supra-national level by Big Science organisations leads to the meso-level institutional change?* In the following paragraphs, the key findings of Study 3 are discussed.

Eight case companies from three Central and Eastern European countries (Estonia, Latvia, and Slovakia) are ESA suppliers, which operate in the nascent market of Earth Observation solutions – developing and offering knowledge-intensive business services that are based on processing satellite imagery. Study 3 showed that without the involvement of ESA as an innovation intermediary, the interaction between the case companies – suppliers – and customers, such as national and regional level public agencies, for mutual value co-creation was impeded by the uneven distribution of knowledge resources.

For creating value, suppliers' knowledge resources – such as accumulated specialist domain knowledge or technological capabilities – must be integrated with customers' knowledge resources that include different types of contextual knowledge. In addition to a high-level of technical expertise, ESA holds deep knowledge about existing markets and emerging market opportunities. By adding ESA as the intermediary in the nascent service ecosystem, a triad emerges which consists of the three dyadic relationship between the ESA, a supplier of Earth Observation applications, and its customers. The empirical findings showed that the emergence of the triad was linked to more intense interaction between the Earth Observation companies and (potential) end-users in the service ecosystem. In line with the theoretical arguments clarifying the role of innovation intermediaries (Howells, 2006), the ESA was found to facilitate a more productive use of complementarities of the knowledge base of the suppliers and the end-users.

Quite surprisingly, the value-generating exchange of knowledge between the ESA and the suppliers was held back by micro-level normative institutions framing the relationships – such as the norms and values that guide the ESA's behaviour in the procurement process. The ESA was engaged with value co-creation, but the intensity of the interaction was below the level expected by the suppliers. Despite this, the influence of the involvement of the ESA in the emerging ecosystem was substantial. The evidence showed that the suppliers also held certain normative expectations about the role of the ESA. Therefore, the suppliers tended to attribute meanings to the actions of the ESA, e.g. the ESA's contract was perceived to validate the company's assumptions about the context in which value is created. The adoption of new mental models about business reality in connection to the interactions with ESA – a process known as the cognitive disposition mechanism (Siltaloppi and Vargo, 2017) – started to steer the behaviour of the suppliers in the dyadic relationships with other actors in the service ecosystem.

It became evident that the reputation of Big Science is not only a source of 'legitimising signals' to uninformed third parties that were observed in Study 2 but the reputation also moderates the emergence of new micro-level cognitive proto-institutions, such as beliefs about the appropriateness of particular mental schemas about how to convert new technologies and other resources into desired market outcomes. Historically, reputation has been an important assessment criterion for the performance of Big Science (Braun, 1993). Through the lens of institutional analysis, Study 3 provides a more fine-grained understanding of the interplay between the firm-level effects and the reputation of Big Science organisations.

The assimilated understandings about their business context, largely shaped by the cognitive disposition mechanism, guided the activities of the researched companies in relation to resource integration with the end-users. It turned out that despite the involvement of the intermediary in the service ecosystem that brought along new configurations of knowledge and competences, disparities in knowledge still persisted hindering the integration of knowledge resources for value co-creation. The case companies gathered new knowledge about the complexities related to the systemic nature of value co-creation through interaction with other actors in the service ecosystem.

The expanding knowledge base made it clear that actors in the service ecosystem differ in their beliefs and values. To create value, the case companies needed to make entrepreneurial efforts aimed at overcoming the identified differences in micro-level normative and cognitive institutional pillars in order to remove obstacles to effective knowledge resource integration in the dyadic relationships. New proto-institutions emerge as a result of this institutional work (cf. Lawrence and Suddaby, 2006). After several 'recursive loops' of deliberate actions by the researched companies to change the prevalent institutional order, these proto-institutions either institutionalised to support value co-creation activities of actors in the service ecosystem or faded away. In the first case, new normative and cognitive institutions shared by a population of actors emerge. For example, in the cognitive institutional pillar, this process is manifested in the evolution of shared understandings of the capabilities of the technology and viable business models (cf. Doganova and Eyquem-Renault, 2009). This contributes to the readiness of the end-users in the triad to purchase Earth Observation applications directly from suppliers without the catalytic intervention by ESA. The Estonian data showed that the described meso-level institutional convergence process took more than seven years in some service ecosystems in which there were no additional public policy interventions to accelerate the process. Some service ecosystems may exhibit even stronger institutional inertia due to deeply rooted assumptions about the roles and ways of working from different actors in the ecosystem.

Study 3 revealed that there are subtle processes of market formation that take place before the nascent market obtains the continuous growth of annual sales of involved actors. The 'recursive loops' of institutional change had a persistent effect on the behaviour of the case companies. Public intervention by integrating ESA as the innovation intermediary to the embryonic service ecosystem did not create immediate output additionality but did generate micro-level behavioural additionality. One example of the latter is institutional work, i.e. entrepreneurial behaviour by the case companies to break the institutional barriers impeding value co-creation. The cross-case comparison revealed that the meso-level institutional convergence process would not have happened without involving the ESA in the ecosystem. Therefore, micro-level behavioural additionality can be, at least partly, attributed to ESA membership as an innovation policy instrument. Study 3 examined the triad and institutional change from the viewpoint of the supplier. Therefore, the study did not provide a sufficient amount of qualitative data to offer a more comprehensive understanding of processes leading to meso-level behavioural additionality – i.e. the emergence of new persistent shared normative and cognitive institutions.

While the role of ESA in institutional change was important, these processes were also affected by other major changes in the macro-level regulative institutional pillar, and the emergence of the European Union's Copernicus program's[23] data policy in particular. The Copernicus program is the most ambitious Earth Observation program worldwide. The Copernicus data policy ensures full, free, and open access to space-based data and information. Also, the ESA and the European Union have jointly invested in terrestrial data dissemination platforms to make the data accessible (Aschbacher, 2017). For the case companies, the Copernicus data policy is a macro-level regulative institution that gives access to resources that enable them to offer new value propositions to multiple other actors without paying for the usage of satellite data with global coverage. Any attempts to isolate the effects of these two major regulative institutional disruptions – accession to the ESA and the establishment of the Copernicus program's data policy – on actors involved in the service ecosystem in policy evaluations inevitably result in the attribution problem and biased estimates of the effects. In practice, the micro-level effects of these two policies are so closely connected that it renders a single instrument perspective in policy evaluation inadequate.

The three papers offered new insights on how the collaboration with an internationally reputable Big Science organisation, such as the ESA, activates various impact channels that are associated with persistent changes in the behaviour of Big Science suppliers. The firm-level behavioural additionality is linked to inter-organisational learning between the ESA supplier and ESA, which possesses a high-level of technical knowledge in multiple technological domains and up-to-date market and marketing information. It also comes from the supplier's access to new, but sometimes temporary, business networks enabled by the legitimising strategy of projective associations (Study 2). The behavioural changes also relate to the cognitive disposition mechanism by deeply affecting the micro-level

[23] The Copernicus program's space component features the constellation of Sentinel satellites, which were specifically developed and commissioned for the operational needs of the Copernicus program.

institutional foundations that shape the conduct of the ESA supplier (Study 3). Participation in ESA programs may trigger micro- and meso-level changes that are important from the perspective of long-term development of innovation systems. If policy evaluations rely only on more traditional concepts, such as *ex post* output additionality derived from survey-based quantitative data (reviewed in Study 1), such changes that take place in early market formation phases may remain unnoticed.

3.2. Theoretical contributions

This chapter summarizes the main theoretical contributions of the thesis. The discussion is aligned with the approach of Corley and Gioia (2011), who proposed two dimensions of what constitutes a theoretical contribution – originality and utility. According to this approach, the theoretical contribution of research has to provide new, sometimes revelatory and even surprising, connections among (previously known) concepts and, also, explore the practical implications of these connections.

This thesis is motivated by the real-life needs of smaller European countries, mostly from Central and Eastern Europe, which have established formalized ties with European Big Science organisations over the past 20 years. The author of the thesis was the prime investigator in a series of impact assessments related to collaboration with one of the Big Science organisations, namely the ESA, commissioned by Estonian and Latvian governmental agencies, and the ESA itself. These assessments combined both summative (*ex post*) and formative (*ex ante*) aspects of evaluations. Given the role of the author, the thesis is an example of problem-driven research (Ployhart and Bartunek, 2019), and the main results of the study have imminent practical utility. The new and would-be member states of international Big Science organisations need to understand the mechanisms and pathways behind different micro- and meso-level effects from collaboration with Big Science. An improved knowledge base helps manage national contributions to Big Science programs as effectively and efficiently as possible to transform public funding into different types of additionality.

Study 1 – the meta-analysis of the existing country-wide policy evaluations dealing with the firm-level additionalities of public investments to ESA programs – enabled the identification of various methodological caveats related to measuring firm-level effects in such studies. The current evaluation practice in smaller European countries tends to employ the so-called multi-method approach (cf. Reid et al., 2018), which focuses on firm-level effects that extend beyond the scope of the objectives of the contracts between Big Science, such as the ESA, and its suppliers. The usefulness of this approach is dependent on the regularity of assessments, which enables policymakers to benchmark progress towards predefined strategic goals. However, in practice, this approach is often used as a one-off exercise for summative purposes, which does not allow for capturing the inherently dynamic nature of inter-organisational learning effects. Also, survey-based studies were found to be susceptible to project fallacy and strategic answering problems. In order to mitigate these problems, this thesis suggests that survey-based data should be combined with case-based methods. The conclusions of Study 1 can be directly applied by policymakers responsible for supervising membership in Big Science organisations, enabling them to conceive and implement more informative and forward-looking methodologies for policy evaluations.

Study 1 consolidated information about possible pathways for realising different types of effects from collaboration with one particular Big Science organisation – the ESA. However, the originality of the thesis is mostly associated with Studies 2 and 3, which extend and refine the current understanding on how collaboration with Big Science affects the internal processes and behavioural patterns of the collaborating firms and wider ecosystems in which they are embedded (see Table 7).

Table 7. The theoretical contributions of the thesis

Study	**Dimension of theoretical contribution**	**Description of the contribution**
Study 1	Utility (practical)	The meta-analysis identified the methodological variance of the extant studies and potential problems by using only output additionality in survey-based evaluations. Data triangulation and the explicit focus on behavioural additionality is recommended.
Study 2	Originality (refinement of theory)	The study proposed a framework for knowledge acquisition and the assimilation of knowledge-intensive, resource-constrained firms to refine the theory of the internationalisation process of the firm. In this framework, internationalisation is a cyclical, non-linear process to acquire resources supported by collaboration with Big Science to co-create products and services, and the related acquisition and exploitation of emergent market and marketing knowledge.
Study 3	Originality (refinement of theory)	The study proposed an innovation intermediation driven model of multi-level institutional change. Innovation intermediation by Big Science triggers institutional entrepreneurship that brings along multi-level institutional change towards a stable institutional order that is supportive to value co-creation in the emergent ecosystem, such as the nascent market.
Studies combined	Originality	The studies highlighted the role of normative institutions as the mediator of micro- and meso-level effects from collaboration with Big Science.

Source: compiled by the author on the basis of Corley and Gioia (2011)

Study 2 advanced theoretical thinking on the role of the ESA as a procuring agency and the systemic innovation intermediary in the internationalisation processes of its suppliers. The study proposed a new theoretical framework reflecting the cyclical nature of the internationalisation process of knowledge-intensive, resource-constrained firms. The suggestive model connects to the emerging theoretical thinking of internationalisation as a non-linear and irregular process (Hewerdine et al., 2014; Kriz and Welch, 2018). The entrepreneurial activities of such firms are driven by constant need for financial and knowledge resources for R&D. Involvement with Big Science plays a crucial role in the acquisition and integration of new market and marketing knowledge by suppliers. Due to changes in the knowledge base of the Big Science suppliers, new entrepreneurial opportunities are revealed. The firms are committed to acquire additional resources and adjust their strategies to go after these new opportunities. There is an interplay between the continuous 'learning loop,' and the resource base and internationalisation pattern of the Big Science supplier.

Study 3 provided new insights about the role of Big Science as a systemic intermediary in the formation of new markets for technologies and innovative products. Study 3 proposed a model of multi-level institutional change towards a stable institutional order at the meso-level. This process, which involves an emerging population of connected actors, is endogenous and driven by activities of ESA suppliers. The suppliers become institutional entrepreneurs in a bid to alter the existing institutional order that is perceived to suppress interactions between actors for co-creating value in the emerging service ecosystem. Big Science has a multi-faceted role in the institutional change. On one hand, Big Science, as the innovation intermediary, facilitates more intense interaction between the suppliers and (potential) end-users in the nascent market. On the other hand, Study 3 showed that the ESA suppliers adopted new mental models about business realities as a result of interactions with the ESA, because the companies held certain expectations about the Big Science organisation's *modus operandi*. This micro-level institutional adjustment process is labelled as the cognitive disposition mechanism (cf. Siltaloppi and Vargo, 2017).

The institutional origins of the legitimising signal effect in Study 2 and the cognitive disposition mechanism in Study 3 both lie in the normative pillar. Actors rely on normative institutions as a guide to how to behave appropriately in the market. There are social expectations that Big Science, an umbrella term for reputable organisations that purchase cutting-edge innovations to advance scientific research, manages the relationships with its suppliers in a particular way. Therefore, a contract with Big Science signals the trustworthiness of its supplier in the eyes of third parties, and that legitimising signal enables the extension of Big Science suppliers' business networks and grants suppliers access to new market and marketing knowledge. Because of normative institutions, adding Big Science as an innovation intermediary to an emerging population of reciprocally engaged economic actors may have a strong effect on the dynamics of this ecosystem, even when Big Science's direct interaction with the actors belonging to the ecosystem remains limited.

The thesis sought to add to the current understanding of the nature of various micro- and meso-level effects that are induced by collaboration with Big Science, and how these effects unfold in an economy. The thesis showed that the behavioural additionality of an innovation policy instrument is manifested at different levels of aggregation. Therefore, the concept deserves more attention in evaluation practice. The cyclical internationalisation process model in Study 2 illustrated the emergence of persistent changes in the ESA suppliers' general conduct, e.g. adoption of a new business model. These changes are embodiments of firm-level behavioural additionality by definition (Gök and Edler, 2012). At the firm-level, the cognitive disposition mechanism and other institutional change mechanisms are origins of behavioural additionality.

The model of the multi-level institutional change in Study 3 indicates that the change does not occur merely at the firm-level, but also at the agent population level. The appearance of new institutions along all institutional pillars – such as the emergence of shared understandings of the capabilities of a new technology and viable business models exploiting the technology – is the source of meso-level behavioural additionality. The formation of new markets and industries is the hallmark of the meso-level behavioural additionality. From the perspective of the ongoing 'normative turn' in innovation policy thinking (Kattel and Mazzucato, 2018), meso-level behavioural additionality may be the most desired effect of an innovation policy instrument. This study insinuates that achieving meso-level behavioural additionality requires meticulously planned and implemented multi-level policy-mixes that pay special attention on how to bring along changes in the normative institutional pillar.

3.3. Managerial and policy implications

This thesis has assigned considerable importance to the practical utility of the research results. Membership to Big Science organisations is a relatively new innovation policy instrument in the overall policy-mix of smaller European countries, mostly located in Central and Eastern Europe. The distinctive features of the ESA – complex industrial policy creating opportunities for firms in its member states with relatively lower levels of industrial capabilities to win orders from a reputable international customers, the procurement of beyond state of the art solutions, and the possibilities to interact with the organisation in the possession of a unique set of knowledge resources – are expectedly leading to knowledge spillovers inductive to industrial innovation. The empirical findings and theoretical contribution of the thesis offer several significant public policy and managerial implications by delineating theoretical rationales for the innovation policy instrument, describing current approaches to evaluating the impacts of Big Science and the approaches' applicability in the context of smaller countries, and offering novel insights into effect pathways from the collaboration with Big Science. These implications are described in this chapter.

Several prominent publications by the OECD on the public investments to Big Science (e.g. OECD, 2012; OECD, 2014a; OECD, 2014b) have consolidated the findings of the existing evaluations and reported strong firm-level effects from collaboration with Big Science. These publications constitute a point of reference for policymakers in the countries that have recently acceded major Big Science organisations, such as the ESA and CERN, or established formalized ties with them with an ambition to join the organisations in the discernible future.

The meta-analysis of the existing body of country-wide policy evaluations that deal with firm-level additionalities from public investments to ESA programs in Study 1 enabled the identification of strengths and weaknesses of the current evaluation practice and the discussion of the usefulness of country-wide assessments for international benchmarking. The smaller ESA member states applied the so-called multi-method approaches (Reid et al., 2018) by making use of survey-based data as small study samples in these countries would not allow for applying large-N econometric methods. This thesis argues that the output indicators of multi-method approaches should be viewed merely as markers of periodic change along impact pathways in a given country. To capture the dynamics of firm-level effects over time, such evaluations should be conducted regularly. However, most of the existing country-wide studies were one-off exercises claiming that each Euro invested in ESA programs may result in up to 4.75 Euros in additional turnover for ESA suppliers (OECD, 2014b). Due to a lack of information about the assumptions regarding time dimension in these studies, or whether the results of the evaluation were compared to the counterfactual situation, such studies deserve cautious handling by policymakers for benchmarking purposes.

The case studies in Study 2 provided novel insights into mutual interactions between complex processes of innovation, internationalisation, and knowledge acquisition and exploitation. While the systematic analysis of evaluation practice in national innovation policy across Europe by Edler et al. (2012) showed that assessments based on primary data gathered through surveys are considered by policymakers to be a hallmark of good evaluation practice, this thesis suggests that survey-based data should be combined with case studies to study the effects induced by ESA contracts. The existing country-wide studies revealed that the population of ESA contractors in smaller ESA member states is rather stable over time. The high concentration level of ESA contracts expectedly correlates to the risk and severity of a strategic answering problem. The steady group of beneficiaries is motivated to report higher level of additional output directly induced by the implementation of ESA procurement contracts, downplaying the importance of other private and public funding sources and presenting the collaboration with ESA as the main contributor to the growth of the company. The combination of two different data collection approaches is a data triangulation strategy, enabling the reduction of respondent bias. If the rationale behind ESA membership as a policy intervention is linked to ideas of systems of innovation or transformational policy paradigms, emphasising demand articulation and market creation functions of public procurement, then case studies are more suitable for detecting 'weak signals of market formation.'

When the catalytic effect of involving Big Science, a systemic innovation intermediary, unfolds according to the expectations of policymakers and nascent markets pass the formative phase of development, then it becomes relevant for policymakers to re-consider the benefits and costs of continuing with the public procurement of innovation at the supranational level. Outsourcing entails agency and transaction costs from using this particular procurement approach, as Big Science, and its member states and cooperating states, may have conflicting policy goals and interests. These costs have to be weighed against input, output, and behavioural additionalities of this governance mode of national R&D investments, and finally compared to other available alternatives.

The majority of policy evaluations still apply a single instrument perspective (Edler et al., 2016). Study 3 provided evidence to argue against such approach. For example, the micro-level effects of two policies – the accession to the ESA and the European Union Copernicus program's data policy – are closely intertwined and assessing these policies separately would result in biased estimates because of the attribution problem. Similarly, the thesis pointed at opportunities to leverage firm-level effects from the collaboration with the ESA by introducing supportive policy instruments. For example, the concurrent implementation of national-level policies aimed at overcoming the institutional inertia that exerts counterforce to the process of market formation could accelerate institutional change towards a stable institutional order that affects the interactions of actors involved in the emergent market. In other words, the interplay of policy instruments implemented at different levels of multi-level governance would lead to acceleration additionality, a sub-type of behavioural additionality (Georghiou, 2002), as value-adding activities of the target group of the policies would be significantly brought forward in time. Even though such interacting policies are context specific (Flanagan et al., 2011), the similarities in institutional dynamics in three different countries captured in Study 3 hints at a possibility that there are policy instruments which are inherently complementary to ESA membership.

The thesis has also managerial implications. Earlier contributions have demonstrated that the inter-organisational learning effects from Big Science increase the potential of innovation creation by Big Science suppliers (e.g. Autio et al., 2004). This thesis throws light on the processes in which firms from geographically remote areas, such as Estonia, are able to capitalise on the 'strategy of projective associations' (Rawhouser et al., 2017) in order to close the distance between other actors in international business networks (cf. Coviello, 2006). The strategy of projective associations is a tool to extend to new markets and new business directions. Therefore, Big Science membership can be viewed as a deliberate policy instrument enabling a target group to reach out to leading multinational companies. A better network position achieved with the help of the legitimising signal from collaboration with Big Science correlates to the intensity of inflows of highly specific market and marketing knowledge, even if the new network ties facilitated by the Big Science affiliation are often short-lived. Learning new knowledge, and the simultaneous process of unlearning some existing knowledge that hinders Big Science suppliers from adapting to foreign market environments, may boost business development of the suppliers.

This study indicated that the Big Science suppliers have a tendency of being over-reverent about the collaboration with Big Science and adjust their perceptions about the business realities on target markets as a result of interactions with Big Science. The direction of the effects of the cognitive disposition mechanism (cf. Siltaloppi and Vargo, 2017) on a Big Science supplier is ambiguous. Service-dominant logic argues that knowledge about context guides the firm's sense-making about the value of resources and, consequently, resource integration activities (Koskela-Huotari and Vargo, 2016). A commonly used word by the case companies in Study 3 to describe the mental models that were embraced through cognitive disposition was 'naïve.' Through interaction with other actors in the evolving business networks, the nuances and complexities related to pursuing a chosen business model are learned. The case histories provided evidence that some elements of the initial understanding of the context of value co-creation were reinstated as a result of organisational learning processes. If experiential learning steers an actor back to their initial business strategy, then it may imply a negative acceleration additionality from the cognitive disposition mechanism. Firms aspiring to become a Big Science supplier should be aware of this possibility and concentrate on the development and constant improvement of internal processes that enable the absorption of new technical, market, and marketing knowledge accessible due to collaboration with Big Science.

3.4. Limitations of the thesis and suggestions for future research

The original studies that form the backbone of this thesis contributed to the literature with two suggestive process models emerging from multiple case studies. This approach to theorising has its merits. It enables the delineation of sequences of events and activities that represent the underlying pattern of a studied process (Van de Ven, 1992). It also captures the nuances of the economic and institutional dimensions where the process of interest unravels. These merits are more pronounced in the case of processes that play out over time and call for longitudinal research, such as internationalisation processes of knowledge-intensive firms in Study 2. This approach is also appropriate for novel research questions when little is known about the relevant constructs and associations between them, such as the role of innovation intermediation in multi-level institutional change in Study 3 (Siggelkow, 2007; Edmondson and Mcmanus, 2007). However, studies adopting a multiple case study approach and the narrative style of theorising (Cornelissen, 2017) are also exposed to the risk that the suggested process models may be too descriptive or tightly connected to the peculiarities of the specific context. These issues ultimately may show themselves in idiosyncratic labels for constructs and processes, which undermine the generalisability of the findings of research.

To illustrate this concern, it is appropriate to raise a question if the important role of normative institutions in the processes behind both micro- and meso-level behavioural additionality is unique to a certain type of companies – knowledge-intensive firms in nascent industries – in the remote corners of the European economic area (i.e. in Estonia and other smaller Central and Eastern European countries)? Future research could provide an answer to this question. Inquiries into the subject could experiment with different strategies of purposeful sampling – such as criterion-based case selection with a wider geographical scope, or maximum variation sampling to deal with the context-specificity issue – in order to increase the external validity of case study research (Gibbert et al., 2008; Patton, 2015). Such follow-up studies would enable propositions – possible cause-effect relationships between constructs inferred from the field data – that are testable with quantitative research methods. However, the methodological shift would require close access to ESA (or any other Big Science organisation's) suppliers in multiple countries. Also, to conduct a qualitative study on a considerably larger sample, a larger research team must be engaged.

Similarly, a dedicated data collection effort must be undertaken in close cooperation with the ESA Procurement Department to replicate the approach of Castelnovo et al. (2018) to estimate the 'ESA effect' on the innovation output and financial performance of its suppliers. The study of Castelnovo et al. (2018) on the CERN suppliers serves as the current best practice in the production-function based quantitative studies of the firm-level effects from collaboration with Big Science. It is important to note, the dataset of this study was heavily unbalanced towards companies from a few larger countries. The suppliers from France, Italy, the United Kingdom, Spain, and Germany constituted nearly 90% of the total sample. It would be illuminating to estimate the 'ESA effect' separately for the new ESA member states (the Czech Republic, Poland, Romania, Hungary, and Estonia) and for the 'old' ESA member states and compare the estimated coefficients of impact. Possible differences in the estimators, such as different signs of coefficients, could be then linked to the institutional aspects that differentiate the 'old' from the 'new' member states.

Several directions for future research could be based upon the existing case study database consisting of a large number of transcribed interviews with ESA supplier firms from Estonia dating back to the early 2010s, pertinent internal documents, and publicly available information (see Ch. 1.4). In the context of collaboration with Big Science, the time span of the associated effects is long (Florio and Sirtori, 2016) and, respectively, any study of change affected by the collaboration should take the time dimension duly into consideration. Regarding an ESA supplier company as a unit of analysis, extending the case study database with interviews conducted over regular intervals,[24] and miscellaneous archival

[24] For example, Ployhart and Vandenberg (2010) suggest at minimum three repeated observations in longitudinal studies.

data, would enable capturing within-unit change (e.g. dynamic relationship between inward cross-border links and outward cross-border links) across time in high fidelity. However, follow-up studies face their own methodological pitfalls, which could result in mismatch between theorising efforts and the fieldwork. For example, Edmondson and Mcmanus (2007, p. 1158) warn against the "opportunistic aspect of field research" in longitudinal studies, an obvious temptation to reanalyse earlier interview data by focusing on novel constructs emerging from fieldwork, which basically means using data collected for one purpose for another reason.

There is abundant room for further progress regarding the concept of meso-level behavioural additionality. Two major avenues for future research deserve a mention in this concluding chapter. The first direction is to address the main limitation of Study 3. The study took a single-sided look at multi-level institutional change and settled on the perspective offered by ESA suppliers. For a more comprehensive picture, and therefore theoretically more rigorous understanding of the processes related to the phenomenon, informants representing other actors in the nascent service ecosystem have to be included in the study sample in follow-up studies. Also, the inherently dynamic nature of the process of institutional change that involves the emergence of transient proto-institutions and their disappearance or maturation into new institutions (e.g. Kleinaltenkamp et al., 2018) calls for a longitudinal research design. The existing case study database is a valuable starting point for future research endeavours in this direction.

The second direction for future research on meso-level behavioural additionality is to blend in the ideas from the literature stream on market shaping and market change. Instead of viewing markets as given structures exogenous to firms, this emerging strand considers markets as malleable socio-technical-material systems (Storbacka and Nenonen, 2015; Vargo and Lusch, 2016). Study 3 provided evidence that firms – which benefit from Big Science procurement and develop new-to-the-world technologies – are engaged with a specific kind of institutional work, also labelled 'market work', defined as purposeful efforts by a focal actor to transform markets (Harrison and Kjellberg, 2016). Market work encompasses market-shaping activities in pursuit of a sustainable competitive advantage. Recent advances in this theoretical field have offered new insights about the institutional work mechanisms that public actors are using to shape markets (e.g. Kaartemo et al., 2020). Scholars are exploring links between the market-shaping actions of agents and the dynamics of market systems at multiple analytical levels (micro, meso, macro). Study 3 can be viewed as the first contribution to this literature stream. Possible longitudinal follow-up studies of this thesis could offer a more fine-grained understanding of the roles that different systemic intermediaries, such as supranational organisations, play in market formation process.

Enriching the multiple case study approach with quantitative empirical data to study meso-level behavioural additionality opens up another promising research direction. For example, Eerme et al. (2020) propose to operationalise market work processes related to the systemic intermediation role of public space agencies by using market change indicators identified by Nenonen et al. (2019), which cover the main elements of market change – including norms and representations. Advancing these novel theoretical perspectives would provide a new angle from which to look at the phenomena of multi-level institutional change and market formation. Mazzucato (2016) has called for new dynamic indicators and evaluation tools for the proper evaluation of public investments and their effects consistent with the contemporary theoretical thinking on innovation policy. The use of mixed methods to study meso-level behavioural additionality holds a potential to contribute to the development of new policy evaluation methodologies that pay attention to market formation processes, which are overlooked by the current evaluation practice.

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APPENDICES

Appendix 1. Cooperation between the European Space Agency and Estonia

All thirteen European countries that have joined the European Union since 2004 (EU-13) have also established formalized ties with ESA (Klock and Aliberti, 2014; Sagath et al., 2018). There are five full member states and two associate member states among the EU-13. The cooperation between the remaining six EU-13 countries is governed by international agreements that ESA concludes with its external partners: four countries have signed the European Cooperating State agreement, while two countries have concluded Cooperation Agreements. The summary of ESA and EU-13 cooperation is provided in Table 8. There are currently twenty-two full member states of ESA (ESA, 2020b); Estonia is the 21st ESA member state.

Table 8. ESA cooperation with the new European Union member states (EU13)

Country	Cooperation Agreement	European Cooperating State	Associate Member	Full Member
The Czech Republic	1996	2003		**2008**
Hungary	1991	2003		**2015**
Romania	1992	2006		**2011**
Poland	1994	2007		**2012**
Estonia	2007	2009		**2015**
Slovenia	2008	2010	**2016**	
Latvia	2009	2013	**2020**	
Lithuania	2010	2014		
Slovakia	2010	2016		
Bulgaria		2015		
Cyprus	2009	2016		
Malta	2012			
Croatia	2018			

Sources: Sagath et al. (2018); Klock and Aliberti (2014)

Astrophysics research has a rich history in Estonia, which dates back to the 19th century. Since the 1960s, Estonian researchers also designed scientific instruments for the Soviet space program. In the early 1970s, the first Soviet Salyut-type space station was equipped with the Estonian built Mikron, a device to measure the brightness of distant objects in the near-infrared spectral region. Later, in the 1980s, a series of teleradiometers FAZA were designed and built in Estonia for experiments on the Soviet orbital space stations Salyut 7 and Mir (Viik, 2014). In mid-2000s, Enterprise Estonia, the Estonian public foundation that promotes foreign trade, investments, entrepreneurship, and innovation, took the leading role in the process towards the full integration of Estonia to the European space community. The cooperation between the ESA and Estonia evolved quickly since the first contacts were established in 2005. In June 2007, Estonia signed a five-year cooperation agreement with the ESA (Mathieu, 2007). The purpose of the cooperation agreement was to establish a legal framework for initial cooperation and for the exchange of information and people. Estonia adopted its first Green Paper on national space policy „*Towards Estonian space policy and strategy*" in 2008, which was prepared by a special working group convened by the Estonian Ministry of Education and Research in 2006 (Kolk and Võõras, 2009).

In March 2001, the ESA created a new European Cooperating State (ECS) status which opened up opportunities for the Central and Eastern European (CEE) countries to participate more closely in ESA programs. ECS countries also subscribe to the PECS Charter, describing the projects that will be undertaken and their funding, usually around one year after the signature of the ECS agreement (Klock and Aliberti, 2014). In September 2008, ESA conducted a technology audit in Estonia to assess the technological capabilities of Estonian firms and research establishments. As an outcome of this exercise, Estonia was proposed to enter into an ECS agreement with ESA. The agreement came into effect in November 2009, and Estonia signed the PECS Charter in September 2010. In 2011-2012, the first „*Strategy for Estonian space affairs 2011–2013*" was developed and adopted. The vision of this strategy stated that by year 2020 „*Estonia is a respected full member of ESA with positive industrial return*." In this strategy, ESA membership was seen as a measure for supporting enterprises in entering chains of supply with high added value (MKM, 2012).

The total contribution of Estonia to the PECS program for 5 years was nearly 6.4 million Euros and, altogether, 27 R&D projects at a relatively low technological maturity level, corresponding to pre-commercial procurement in the context of this thesis, were successfully completed by early 2017. The positive results of the Estonian PECS program pushed Estonia rapidly towards full membership. The agreement between the ESA and Estonia regarding the accession to the ESA Convention was signed in February 2015. Estonia became the 21st ESA member state from September 2015. The period between the Cooperation Framework Agreement and full ESA membership was the shortest among the CEE countries (Eerme and Lillestik, 2019).

In Estonia, the Ministry of Economic Affairs and Communications is responsible for developing Estonian space policy and supervising its implementation. The Space Affairs Council (SAC), an inter-ministerial body established in 2010, offers high-level guidance for policymaking. The main tasks of the SAC are initiation and governance of space related activities at the national and international (regional) level and the coordination of resource allocations to space technology R&D. The SAC is supported by a secretariat, comprised of representatives of Enterprise Estonia and Estonian Research Council. The Estonian Space

Office, a dedicated unit within the Enterprise Estonia, is engaged with the daily management of the implementation of the Estonian space policy. The Estonian Space Office stimulates the uptake of space technologies by the public sector and acts as an intermediary between Estonian companies and the ESA (European Space Agency, 2018).

The main strategic goals related to the full ESA membership were defined in the Estonian National Space Action Plan for the period 2016-2020, which was ratified by the Government of Estonia in 2015. This action plan defined a set of measures and key performance indicators regarding the competitiveness of firms in the field of space and development of entrepreneurship related to space affairs. The two key performance indicators of the plan were (HTM, 2015):

- Estonia's overall geographical return coefficient in the ESA, an indicator of a country's historical performance in the ESA procurement system (Eerme, 2016), with a threshold value 0.85 to be achieved by 2019 and
- the so-called spin-off multiplier associated with the ESA investments that was expected to be at least 1.5 by 2019.

The Estonian Space Action Plan for the period 2016-2020 defined the spin-off multiplier similarly to the BETA methodology (cf. Cohendet, 1997) as the ratio of indirect industrial effects arising from the public contracts of ESA with private sector enterprises to the total value of contracts during a particular period. The indirect industrial effects include all benefits arising from technology, know-how, enterprise image, and business contacts, which are obtained through contractual relationships with the ESA and result in increased sales and/or added value when applied to other activities of an enterprise. As of October 2020, the impact assessment to measure the value of the spin-off multiplier has not yet been conducted in Estonia. In order to achieve such a level of output additionality from ESA full membership, several supportive policy measures were foreseen by the strategy, such as (HTM, 2015):

- Supporting enterprises in entering the international value chains of the space industry through Estonia's participation in the optional programs of the ESA.
- Systematic efforts to raise the awareness of entrepreneurs regarding developments and opportunities in the space industry.
- Facilitating the utilisation of applications based on space technologies in the terrestrial economy.
- Facilitating cooperation between enterprises and research institutions in developing, utilising, and exporting solutions based on space technologies.

In November 2017, an ESA business incubator was launched in Estonia to support entrepreneurship based on space technologies.

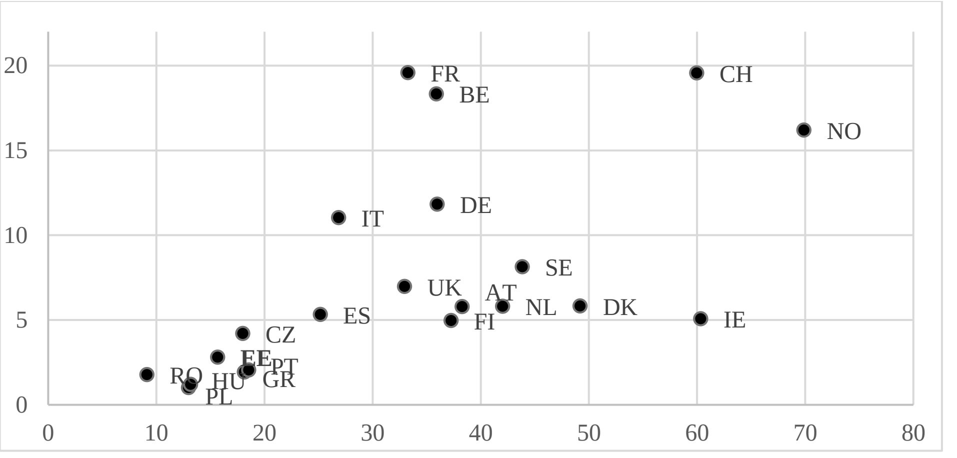

Figure 4. The ESA member states' national contributions to ESA per capita (in Euros) in comparison to the countries' Gross Domestic Product per capita (in thousands of Euros) in 2019, the author's calculations

Each ESA member state's mandatory annual contribution to the ESA budget is calculated on the basis of the national income (Cogen, 2012). Estonia's share in the total annual budget of ESA is below 0.1 per cent (ESA, 2020a). While the Estonia's annual contribution to the ESA budget is the lowest among the member states in absolute terms, the contribution per capita is the second highest among the recently acceded CEE countries (Figure 4). Between 2015 and 2018, Estonia participated in the mandatory programs of ESA and in two optional programs in total amount of 2.6 million Euros annually (Eerme, 2018):

- Earth Observation Envelope Programme (EOEP), which is a key program of the ESA. Among its multiple objectives, two objectives were the most relevant for Estonia. The program is committed to:
  - maximise scientific impact of ESA, European missions, and national missions and;
  - engage the users and pioneer new Earth Observation applications, including via the use of Earth Observation exploitation platforms.
- The General Support Technology Programme (GSTP), which has five major objectives – enable missions of ESA and national programs by developing technology, fostering innovation by creating new products, strengthening the competitiveness of European industry, improving European technological non-dependence and the availability of European sources for critical technologies, and facilitating spin-in from outside the space sector. Estonia contributed to GSTP in a bid to activate the so-called 'Earth-Space-Earth' technology transfer pathway (Petroni et al., 2010), i.e. ESA suppliers adopt terrestrial innovations for space purposes and the upgraded technologies are later commercialized on the main target markets of the suppliers.

Estonia, as a new ESA Member State, is undergoing its transitional arrangement with ESA, which entails specific objectives, measures, and conditions for overall geographical return statistics, such as the implementation of a dedicated Industry Incentive Scheme.

In April 2020, the new Estonian Space Policy and Programme for 2020–2027 was adopted. According to this strategic document, Estonia implements its space policy through ESA optional programs and the European Union Space Programme. The strategic vision of the policy document is: "Estonia is a strong partner in European space programmes by helping to strengthen Europe's leading role in developing space systems in an autonomous, safe and secure manner, and operating in outer space and managing decision-making processes on the ground." In the ESA Ministerial Council – Space19+ – which took place in Seville, Spain in November 2019, Estonia decided to continue to subscribe to the GSTP program, but substituted the EOEP program with two new ESA optional programs: ARTES Business Applications and Space Solutions and InCubed+. In these programs, ESA acts as the lead-user for close to market products and services, involving satellite telecommunications and Earth Observation technologies (MKM, 2020). While in 2020, Estonia's contribution to the ESA programs is still 2.6 million Euros, the new programme aims at increasing this funding to 10 million Euros annually by 2027.

The Estonian Space Policy Programme for 2020–2027 has introduced a more comprehensive assortment of the programme's performance indicators. While the Estonian National Space Action Plan for the period 2016-2020 focused on the output additionality, the new Programme has set ambitious target values for (MKM, 2020):

- The spin-off multiplier – the indicator for output additionality will be measured annually and its target value is 2.8 in 2027.
- Private investments to space-related R&D; the new programme expects substantial input additionality as ESA suppliers' additional financing to their space-related R&D should be at least equal to the monetary value of ESA contracts by 2027.

The programme also expects behavioural additionality from implementing the Estonian space policy through the ESA. Firms winning ESA contracts are expected to reach out to the so-called large system integrators that dominate the European space sector and win at least one contract from these multinational companies a year. ESA suppliers are also expected to change patterns of their R&D collaborations and establish linkages with publicly funded research organisations and universities.

SUMMARY IN ESTONIAN – KOKKUVÕTE

Suured rahvusvahelised teaduskeskused innovatsioonivõimendajatena – mikro- ja mesotasandi efektid Euroopa Kosmoseagentuuri näitel

Töö aktuaalsus ja motivatsioon

Alates 20. sajandi teisest poolest, on rahvusvahelisel koostööl teaduses üha suurem tähtsus tänapäevase teadustaristu loomisel ja haldamisel ning eri riikide teaduspotentsiaali koondamisel (Galison, 1992; OECD, 1995). Suured rahvusvahelised teaduskeskused (ingl nimetus *Big Science*, tekstis edaspidi STK) on käsitletavad teadmuse loomise erivormina (Weinberg, 1967), mis eristub selgelt uurijakeskseest teadustegevusest, mida tihti seostatakse näiteks ülikoolidega (Esparza ja Yamada, 2007). STK uuringuprogrammid on ellu kutsutud riikideülese laiapõhjalise toetusega teadusliku eesmärgi saavutamiseks, milleks on kõige uuemate teadmiste ja tehnoloogia kombineerimise kõrval vajalikud investeeringud unikaalsete teadusinstrumentide arendamiseks (Jacob ja Hallonsten, 2012). STK-d paistavad silma erakordsete mastaapide, uurimisülesannete keerukuse ja eksperimentide kestuse poolest, eeldades rahvusvahelist koostööd ja STK-ga seotud riikide valitsuste pikaajalist toetust (Elzinga, 2012). Euroopa tuntuimad ja teaduskirjanduses enim uuritud STK-d on Euroopa Tuumauuringute Organisatsioon (CERN) ja Euroopa Kosmoseagentuur (tekstis edaspidi ESA). Siiski on STK-d levinud osakeste füüsika ja astronoomia kõrval ka teistes teadusharudes (Meyer, 2009; Autio, 2014).

STK-d on aja jooksul välja arendanud keerukad hankesüsteemid, et soetada teadmusmahukatelt ettevõtetelt oma teaduslike missioonide saavutamiseks vajalikke tooteid ja tehnoloogiat (ESA kohta vt Petrou, 2008; CERN-i kohta vt Åberg ja Bengtson, 2015). STK-d hangivad teaduseksperimentide läbiviimiseks sobilike parameetritega tooteid tavaliselt väikeseeriates või ainueksemplarina ja üldjuhul ettevõtetelt, mis asuvad STK liikmesriikides. Sellised hanked vastavad innovatsiooni edendavate hangete (ingl *public procurement of innovation*, PPI) laialt levinud definitsioonile: „*… sellise toote või süsteemi hankimine, millist pole valmiskujul saada ning mille kavandamine ja tootmine eeldab täiendavaid või algupäraseid teadus- ja arendustegevusi"* (Edquist ja Hommen, 2000, lk 5).

Teaduslike eesmärkide saavutamiseks hangitud uuenduslike toodete ja tehnoloogia arendamisega kaasneb uue teadmuse loomine ning ülekandumine teistesse majandustegevuse valdkondadesse, mille tulemusena suureneb majanduse kui terviku innovatsioonipotentsiaal (Chiang, 1991). STK-de liikmesriikide seisukohalt on liikmelisusest tulenevad teadmuse ülekandeefektid (ingl *knowledge spillovers*) oluliseks liikmelisust toetavaks argumendiks. Üha uute riikide soov ühineda ESA või CERN-i liikmeskonnaga on osaliselt selgitatav valitsuste oodatavate ülekandeefektidega. Viimasel paaril aastakümnel on STK-dega liitunud või liitumisprotsessi algatanud suur osa Kesk- ja Ida-Euroopa riikidest (Klock ja Aliberti, 2014; OECD, 2014a). STK-de uute liikmesriikide ees seisab väljakutse mõõta liikmelisuse efekte innovatsioonipoliitika paremaks planeerimiseks ja elluviimiseks. Seetõttu ongi käesolev uurimus suunatud STK hangetest tulenevate ettevõtte- ehk mikro- ning tööstusharu- ja turu- ehk mesotasandi efektide erinevate toimemehhanismide paremale mõistmisele STK-de uute liikmesriikide, antud juhul Kesk- ja Ida-Euroopa riikide eristuvas empiirilises kontekstis.

Töö eesmärk ja uurimisülesanded

Doktoritöö eesmärk on senisest paremini mõista STK hangetest tulenevaid erinevaid mikro- ja mesotasandi efekte ning nende edasikandumise mehhanisme majanduses. Töö empiiriline kontekst on ESA liikmelisus, mis annab liikmesriigis asuvatele ettevõtetele ligipääsu selle STK alamprogrammidele ning hankesüsteemile.

Eesmärgi täitmiseks püstitati järgmised uurimisülesanded.

- Teoreetilise raamistiku puhul:
  - süstematiseerida teooriast lähtuvad põhjendused STK kui eripärase teadmuse loomise režiimi kasutamiseks innovatsioonipoliitika põhiliste paradigmade perspektiivist vaadatuna (ptk 1.1);
  - anda ülevaade lisanduvuse (ingl *additionality*) kontseptsioonide rakendamisest innovatsioonipoliitika efektide hindamisel ning luua hindamispraktika ja majanduspoliitilise sekkumise teoreetiliste põhjenduste vahelised seosed STK kontekstis (ptk 1.2).
- Empiiriliste uurimuste puhul:
  - viia läbi olemasolevate ESA liikmelisusest tulenevate ettevõttetasandi efektide riigipõhiste uuringute metaanalüüs (ptk 2, 1. uurimus);
  - täiendada senist käsitlust teadmusmahukate, kuid piiratud ressurssidega ettevõtete rahvusvahelistumise protsessist ESA tarnijate näitel, selgitades ESA kui STK rolli turu- ja turundusliku teadmuse hankimisel ja kasutamisel rahvusvahelistumise protsessis (ptk 2, 2. uurimus);
  - selgitada innovatsioonivõimendaja (ingl *innovation intermediary*) rolli institutsiooniliste muutuste suunamisel tärkaval turul, Maa kaugseire rakenduste turu ja ESA läbi viidud katalüütiliste innovatsiooni edendavate hangete näitel (ptk 2, 3. uurimus).

Töö teoreetiline uudsus

Väitekiri põhineb kolmel rahvusvahelistes teadusajakirjades publitseeritud originaaluuringul, mis käsitlevad STK hangetest tulenevate mikro- ja mesotasandi efektide erinevaid aspekte.

- 1. uurimus: **Eerme, T.,** 2016. Indirect industrial effects from space investments. *Space Policy* 38, 12–21.
- 2. uurimus: **Eerme, T.**, Nummela, N., 2019b. Capitalising on knowledge from big-science centres for internationalisation. *International Marketing Review* 36 (1), 108–130.
- 3. uurimus: **Eerme, T.**, Nummela, N., 2019a. Value generation through public procurement of innovative earth observation applications: Service-dominant logic perspective, in: *Proceedings of the International Astronautical Congress, IAC*. International Astronautical Federation, IAF, Washington, D.C.

Kolme artiklit ühendavaks spetsiifiliseks empiiriliseks kontekstiks on ettevõtete lepinguline koostöö ESA-ga, mis on üks laialdasemalt tuntud ja kirjanduses käsitletud STK-sid.

Väitekirja aluseks olevad empiirilised uuringud on võrdlemisi eripalgelised, seda nii vaatluse alla võetud uurimisvajakutelt, rakendatud teoreetilistelt raamistikelt kui ka uurimismeetoditelt. Esimene uurimus täiendab innovatsioonipoliitiliste instrumentide efektide hindamise alast kirjandust, keskendudes just STK hangetest tulenevate efektide hindamisele. Teine uurimus annab panuse teadmusbaasi laiendamiseks rahvusvahelise ettevõtluse valdkonnas. Kolmas uurimus rakendab viimastel aastatel kiiresti arenenud teoreetilise lähenemise – teenusekeskse loogika (ingl *service-dominant logic*) – kontseptsioone (vt lähemalt: Vargo ja Lusch, 2004; Vargo ja Lusch, 2008), et uurida endogeenseid institutsioonilisi muutusi tärkavas teenuste ökosüsteemis (ingl *service ecosystem*).

Esimese uurimuse lähtepunktiks oli puudulik teadmine seni läbi viidud mõju-uuringute, eeskätt just ESA liikmelisusest tulenevate firmatasandi efektide riigipõhiste uuringute (vt ka OECD, 2011; OECD, 2012) metodoloogilistest alustest. Uurimus on suunatud selle uurimisvajaku ületamisele, selgitades välja varasemate mõju-uuringute metodoloogilised lähtepunktid ja eripära, tuvastades võimalikud probleemid mikrotasandi efektide mõõtmisel ning käsitledes erinevate uuringute omavahelise võrreldavuse küsimusi.

Teine uurimus seab kahtluse alla kahe peamise ettevõtete rahvusvahelistumise teooria – Uppsala mudeli (Johanson ja Vahlne, 1977) ning rahvusvaheliseks sündinud ettevõtete – (Oviatt ja McDougall, 1994; Knight ja Cavusgil, 2004) – eeldused. Uurimuses käsitletakse teadmuse rolli piiratud ressurssidega ettevõtete mittelineaarse ja ebaregulaarse rahvusvahelistumise protsessis (vt ka Hewerdine et al., 2014; Kriz ja Welch, 2018). Samuti seda, kuidas STK-ga koostöö tulemusena hangitud ja liidetud uus teadmus aitab kaasa uute ärivõimaluste leidmisel ja ärakasutamisel välisturgudel.

Kuigi teenusekeskne loogika rõhutab institutsiooniliste muutuste endogeensust mingis majandusagentide populatsioonis, on vähe empiirilisi uuringuid selle kohta, kuidas majandusagent saab oma teadlike sammudega majandustegevuse institutsioonilist keskkonda muuta väärtusloomet toetavamaks (v.a Kleinaltenkamp et al., 2018). Kolmas uurimus panustab selle uurimisvajaku ületamisse, pakkudes uusi teadmisi, kuidas endogeenne institutsiooniline muutus mikro-tasandil võib kaasa tuua institutsioonilised muutused kõrgematel analüütilistel tasanditel (meso- ja makrotasanditel) ehk teisisõnu mitmetasandilises öko-süsteemis.

Tabel 9. Doktoritöö teoreetiline uudsus.

Uurimus	**Seotud laiem uurimisvaldkond**	**Uurimuse lühikirjeldus**	**Spetsiifiline uurimisvajak**
1. uurimus	Innovatsiooni-poliitika instru-mentide mõju-uuringud.	Seni läbi viidud uuringute metaanalüüs ja süntees.	Teadmiste nappus seni läbi viidud STK-ga koostööst tulenevate mõju-uuringute metodoloogilistest alustest.
2. uurimus	Väikeste, teadmus-mahukate ettevõtete rahvus-vahelistumine.	Uusi tehnoloogiaid arendavate ettevõtete rahvusvahelistumise protsessi longituuduuring.	Teadmiste nappus STK rollist väikeste, teadmusmahukate ettevõtete turu- ja turundusliku tead-muse hankimisest ja kasutamisest rahvusvahelistumise protsessis.
3. uurimus	Innovatsiooni edendavate hangete institutsioonilised aspektid; teenusekeskne loogika.	Mitmene juhtumianalüüs mitmetasandilise institutsioonilise muutuse uurimiseks.	Teadmiste nappus STK kui innovatsioonivõimendaja rollist mitmetasandilise institutsioonilise muutuse suunamisel.

Allikas: autori koostatud.

Kolme originaaluuringu uuenduslikud aspektid on kokkuvõtlikult esitatud tabelis 9. Kolm uuringut kokku annavad uusi teadmisi STK hangetest tulenevate mikro- ja mesotasandi mõjudest.

Töö teoreetiline taust

Teoreetilised põhjendused innovatsioonideks STK vahendusel

Töös süstematiseeriti teoreetilised põhjendused STK kui teadmuse loomise eri-pärase režiimi kasutamiseks kolme peamise innovatsioonipoliitika laine perspek-tiivist vaadelduna. Kirjanduses eristatakse kolme paradigmat, võttes aluseks selgelt eristuvad arusaamad innovatsiooniprotsessi loogikast, innovatsiooni-poliitika eesmärkidest ja sekkumise alustest (vt nt Schot ja Steinmueller, 2018; Diercks et al., 2019). Need kolm innovatsioonipoliitika lainet on:

- teadus- ja tehnoloogiapoliitika, milles majandusse sekkumise aluseks on vajadus korrigeerida turutõrkeid. Turutõrgete kontseptsioon põhineb suuresti Nelsoni (1959) ja Arrow' (1962) teedrajavatel töödel.
- rahvuslike ja tehnoloogiliste innovatsioonisüsteemide perspektiiv, mis kerkis esile 1980. aastate lõpus ja 1990. aastate algul (Freeman, 1987; Lundvall, 1992) ning milles riigi sekkumise vajadus tuletatakse mitmesugustest süsteemitõrgetest (Klein Woolthuis et al., 2005).
- viimase kümnendi jooksul levinud siirdepoliitika (ingl *transformative innovation policy*) kontseptsioon (Foray et al., 2012; Edler ja Boon, 2018; Kuhlmann ja Rip, 2018), mille puhul rõhutatakse poliitikakujundajate keskse ülesandena siirdetõrgete ettevaatavat lahendamist. Weber ja Rohracher (2012) tõid enda käsitluses välja neli peamist siirdetõrgete tüüpi: arengusuuna tõrge (ingl *directionality failure*), juhtimise kooskõla tõrge (ingl *policy coordination failure*) poliitika elluviimisel, tagasisidestustõrge (ingl *reflexivity failure*) ja nõudluse kujundamise tõrge (ingl *demand articulation failure*).

Tabel 10 võtab kokku STK rollid erinevate turu-, süsteemi- ja siirdetõrgete ületamisel, põhinedes Weberi ja Rohracheri (2012, lk 1045) välja pakutud raamistikul.

Tabel 10. STK roll innovatsioonipoliitikas turu-, süsteemi- ja siirdetõrgete ületamisel[25].

<table>
<tr><th colspan="2">Tõrketüüp</th><th>STK roll tõrke ületamisel</th></tr>
<tr><td rowspan="2">Tututõrked</td><td>Info asümmeetria</td><td rowspan="2">Uue teadmuse loomine STK teadusliku eesmärgiga seotud valdkondades, panustamaks sotsiaalselt optimaalse teadmusloome taseme saavutamisse. Turuosaliste vahel info liikumise suunamine info asümmeetriast tingitud probleemide ületamiseks.</td></tr>
<tr><td>Ülekandeefektid</td></tr>
<tr><td rowspan="2">Süsteemitõrked</td><td>(Nõrk) võrgustikutõrge</td><td>STK vahendab süsteemse innovatsioonivõimendajana majandusagentide vahelist koostööd ja soodustab organisatsioonilist õppimist.</td></tr>
<tr><td>Infrastruktuuri tõrge</td><td>STK kui vahend füüsiliste ja teadmusressursside koondamiseks ja mehhanism teadmusülekande toetamiseks.</td></tr>
<tr><td rowspan="2">Siirdetõrked</td><td>Arengusuuna tõrge</td><td>STK kui mehhanism uute, sotsiaal-majanduslikke siirdeid toetava tehnoloogia arendamiseks ja valideerimiseks.</td></tr>
<tr><td>Nõudluse kujundamise tõrge</td><td>STK kui tipptasemel tehnoloogilise teadmuse, turuteadmuse ja hangete alase oskusteabe koondaja aitab väljendada lõppkasutajate varjatud vajadusi nõudluse kujundamiseks.</td></tr>
</table>

Allikas: autori koostatud, tuginedes Weberi ja Rohracheri (2012), Foray (2004), Clò ja Florio (2019), Howellsi (2006), van Lente et al. (2020), Robinsoni ja Mazzucato (2019) töödele.

[25] Tabelisse lülitati need tõrketüübid, mille puhul on kirjanduses kirjeldatud STK võimalikku rolli tõrgete ületamisel.

Nõrk võrgustikutõrge tähistab olukorda, kus majandusagentide vahelised suhted on välja arenemata ega toeta sellisena õpiprotsesse ning seega teadmuse levikut innovatsioonisüsteemis. Innovatsiooni võimendus (ingl *innovation intermediation*) on üks võimalusi nõrga võrgustikutõrke ületamiseks. Innovatsiooni võimendajad loovad ja vahendavad koostöösuhteid üksteist täiendavate teadmusressurssidega majandusagentide vahel teadmuse loomiseks ja levitamiseks (Howells, 2006; Edler ja Yeow, 2016). STK rolli innovatsiooni võimendajana märkis juba Braun (1993). STK toob kokku ettevõtted enda ärivõrgustikust, et need liidaksid oma võimekuse STK ees seisvate keeruliste tehnoloogiliste ülesannete lahendamiseks. Innovatsioonivõimenduse funktsiooni täitmist STK poolt soodustavad tipptasemel tehnoloogilise teadmuse valdamine ja tugev turupositsioon (Fernandez et al., 2014; Landoni, 2017), samuti STK maine (Leyden ja Link, 1999).

Infrastruktuuri tõrge tähistab teatud elementide, näiteks füüsilise teadustaristu või ka teadmussiiret toetavate meetmete puudust innovatsioonisüsteemis (Klein Woolthuis et al., 2005). STK peamiseks eripäraks ongi unikaalse ja tehnoloogiliselt nõudliku füüsilise infrastruktuuri välja arendamine ja haldamine teaduseksperimentide läbiviimiseks. Samuti on kirjanduses kajastatud mitmesuguseid STK meetmeid teadmuse ülekande toetamiseks, enda teadus- ja arendusvõimekuse täiel määral ära kasutamiseks (nt Autio et al., 2004; Lauto ja Valentin, 2013; Venturini ja Verbano, 2014; Nilsen ja Anelli, 2016).

Nõudluse kujundamise tõrge toob esile vajakajäämise ühiskonna liikmete (varjatud) vajaduste mõistmisel, millel on pärssiv mõju süsteemisiiret toetavate uuenduste juurdumisele (Weber ja Rohracher, 2012). Innovatsiooni edendavate hangete üheks eesmärgiks on nõudluse kujundamise tõrke ületamine. Chicot ja Matt (2018) räägivad selles kontekstis pakkuja ja lõppkasutaja lävimistõrgetest (ingl *interaction failure*) kui põhjendusest innovatsiooni edendavate hangete kasutamisele. Pakkujate teadmised majandusagentide vajadustest on ebapiisavad ning samuti puuduvad asjakohased teadmusvahetuskeskkonnad (ingl *interactive learning spaces*), kus majandusagendid saaksid oma vajadustest märku anda. Sellisteks teadmusvahetuskeskkondadeks on näiteks turud, kuid siirdepoliitika alane kirjandus rõhutab, et paljude süsteemisiirete seisukohalt oluliste toodete ja teenuste turud on veel välja kujunemata (Frenken, 2017; Grillitsch et al., 2019). STK hankesüsteemil on roll puuduvate teadmusvahetuskeskkondade loomisel erinevaid tehnoloogiaid lõimivate innovatsioonide tekke toetamiseks (Castaldi et al., 2015; Edler, 2016; Frenken, 2017), et toetada pikaajalist majanduskasvu.

Tabelis 10 kirjeldatud rolle täites mõjutab STK oma tarnijate ressursside ja võimekuste dünaamikat ning seeläbi nende sooritust turgudel. Autio et al. (2004) on kirjeldanud koostööd STK-ga kui omalaadset õpikeskkonda tema tarnijate vaates, mis soodustab uute innovatsioonide turuletoomist. Fletcher ja Harris (2012) tõid välja teadmuse kolm tüüpi, mis on olulised rahvusvahelistumise protsessis: tehnoloogiline-, turu- ja turundusteadmus. Ehkki STK hangetest lähtuvad tehnoloogilise teadmuse ülekandemehhanismid STK ja tema tarnijate vahelises koostöösuhtes on leidnud kirjanduses küllaldast käsitlemist (Bach et al., 2002; Nordberg et al., 2003; Autio et al., 2004; Åberg ja Bengtson, 2015; Florio et al., 2018), siis ei ole STK roll turu- ja turundusteadmuse hankimisel ja kasutamisel veel kirjanduses piisavat tähelepanu pälvinud. See on mõneti üllatav, arvestades teadmuse olulisust ettevõtete rahvusvahelistumise protsessis (Åkerman, 2015) ning üldist konsensust, et turu- ja turundusteadmuse nappus on üks peamisi väike- ja keskmise suurusega ettevõtete rahvusvahelistumise takistusi (Paul et al., 2017).

Eelnevat kokku võttes aitab STK luua ja korrastada innovatsioonisüsteemi, toimib oma tarnijate seisukohalt omalaadse õpiplatvormina teadmuse hankimiseks ning panustab tulevikku suunatud nõudluse kujundamisse. Teisisõnu, STK toimib süsteemse innovatsioonivõimendusmeetmena Smitsi ja Kuhlmanni (2004) mõistes. Süsteemsed innovatsioonivõimendajad toetavad innovaatilist tegevust kõrgemal tasandil (van Lente et al., 2003; Klerkx ja Leeuwis, 2009), mitte üksnes üksikute kasusaajate ehk mikrotasandil.

ESA puhul on seda rolli näitlikustanud Robinson ja Mazzucato (2019), kirjeldades ESA panust tänapäeva ühiskonna ees seisvate suurte arenguväljakutsete (esmajoones kliimamuutus) lahendamisse nõudluse kujundamise kaudu uute satelliitkaugseirel põhinevate teenuste järele. Need teenused kasutavad ESA enda hangitud orbitaaltaristut ja varasemate teadusmissioonide andmekogusid ning loovad tõenduspõhist teadmust kliimamuutusega seotud geofüüsikaliste protsesside kohta sisendiks poliitikaloomesse. ESA-l on keskne asend nõudluse kujundamise tulemusena tekkivas majandusagentide võrgustikus (Mazzucato ja Robinson, 2017). See võimaldab tal lepitada eri osapoolte vastandlikke huvisid ning seeläbi kujundada institutsioonilist keskkonda, tulemaks toime määramatuse ja ebakindlusega, mis on seotud pikaajaliste süsteemisiirde protsesside (van Lente et al., 2020) ning samuti tärkavate ökosüsteemide arenguprotsessidega (vt nt Suurs et al., 2009).

STK hangetest tulenevate mikro- ja mesotasandi efektide hindamine

Poliitikainstrumentide hindamise eesmärgiks on tuvastada ja arvuliselt mõõta instrumendi rakendamisest tulenevaid efekte. Poliitikate hindamisel on üks keskseid kontseptsioone lisanduvus (ingl *additionality*). Lisanduvuse mõõtmine põhineb võrdlusstsenaariumitel – poliitilise instrumendi rakendamise tulemusena kujunenud olukorda võrreldakse (hüpoteetilise) stsenaariumiga ehk olukorraga, mis võinuks kujuneda poliitilise instrumendi rakendamata jätmisel (Georghiou, 2002). Lisanduvuse kontseptsiooni puhul eristatakse kolme mõõdet (Georghiou, 2002; Gök ja Edler, 2012):

- sisendite lisanduvus (ingl *input additionality*), mis innovatsioonipoliitika puhul uurib, kui palju täiendavaid ressursse panustasid majandusagendid teadus- ja arendustegevusse tänu riigi sekkumisele;
- väljundite lisanduvus (ingl *output additionality*), mis vaatleb, kui palju täiendavaid väljundeid suutsid majandusagendid luua tänu riigi sekkumisele;
- käitumuslik lisanduvus (ingl *behavioural additionality*), mis kõige laiema määratluse kohaselt tegeleb poliitikainstrumendi tulemusena avaldunud majandusagentide käitumuslike muutuste tuvastamisega, olgu selleks ettevõtte valdkondlike (teadus- ja arendustegevuse, rahvusvahelistumise) strateegiate või kogu ettevõtte ärimudeli püsiv muutus majanduspoliitilise instrumendi toimel.

Sisendite ja väljundite lisanduvuse ökonomeetrilisele hindamisele suunatud teaduskirjandus avalike hangete, eeskätt just innovatsiooni edendavate hangete kontekstis on napp. Eranditena saab välja tuua Aschhoffi ja Sofka (2009), kes tuvastasid avalike hangete ja hanked võitnud ettevõtete väljundnäitajate vahelise positiivse seose. Guerzoni ja Raiteri (2015) näitasid, et innovatsiooni edendavate avalike hangetega kaasneb sisendite lisanduvus, st et hanked võitnud ettevõtted suunavad täiendavaid ressursse teadus- ja arendustegevusse, seda nii innovatsiooni edendavate hangete rakendamisel eraldiseisva poliitikainstrumendina kui ka kogumis teiste poliitikameetmega. Pickernell et al. (2011) ning Slavtchev ja Wiederhold (2016) näitasid ära sisendite lisanduvuse seose avaliku nõudluse iseloomuga. Mida tehnoloogiliselt keerukamad on avalikud hanked, seda suurem on oodatav sisendite lisanduvus.

Reid et al. (2018) põhjalikus STK mõjude hindamise metoodikate ülevaates nenditakse, et tavapäraselt Cobb-Douglas tüüpi tootmisfunktsiooni baasilt tuletatud kvantitatiivseid lähenemisi STK majanduslike efektide hindamiseks mikrotasandil kohtab harva. Üheks erandiks on Castelnovo et al. (2018) uurimus CERN-i hangete mikrotasandi efektide kohta. Castelnovo et al. (2018) kasutasid efektide hindamiseks Crépon–Duguet–Mairesse (CDM) mudelit ning leidsid, et CERN-i hangetel on otsene mõju hankeid täitnud ettevõtete täiendavatele teadus- ja arendusinvesteeringutele, mille tulemusena suurenevad innovaatilise tegevuse väljundid mõõdetuna patentide arvus, paranevad ettevõtete tootlikkus ning peamised finantssuhtarvud. Teisisõnu, Castelnovo et al. (2018) tulemused näitavad, et CERN-i hangetega kaasneb nii sisendite- kui ka väljundite lisanduvus.

Sisendite ja väljundite lisanduvuse kontseptsiooni kriitikud osutavad sellele, et need käsitlevad ettevõtet nn musta kastina, millel on pelgalt sisendeid väljunditeks teisendav roll. Selline nägemus eeldab vaikimisi, et sisendite lisamisega kaasnevad täiendavad väljundid. Selle seose ühene paikapidavus on kaheldav (Georghiou ja Clarysse, 2006). Buisseret et al. (1995) asusid seisukohale, et sisendite ja väljundite lisanduvuse mõisted ei ole piisavad, kirjeldamaks innovatsioonipoliitika instrumentide mikrotasandi efekte, ning tõid teaduskirjandusse uue kontseptsioonina käitumusliku lisanduvuse. Selles kontseptsioonis nähti võimalust asetada arutelude keskmesse nn mustas kastis toimuvad ettevõttesisesed protsessid. Göki (2010) hinnangul põhineb käitumusliku lisanduvuse kontseptsioon evolutsioonilise majandusteooria ideedel, mis rõhutavad majandusagentide vaheliste vastastikmõjude olulisust ning sellega kaasnevaid õpiprotsesse. Sellest johtuvalt on käitumusliku lisanduvuse kontseptsioonil oluline ühisosa innovatsioonisüsteemide paradigmaga, mis samuti näeb kesksena innovatsioonisüsteemi struktuursete elementide omavahelist vastastikmõju teadmuse ülekandumiseks süsteemis.

STK mõju-uuringutes ei ole käitumusliku lisanduvuse kontseptsiooni ilmutatud kujul kasutatud. Erinevates uuringutes on mikrotasandi efekte käsitledes küll tegeletud ettevõtete üldiste ja valdkondlike strateegiate püsiva muutuse küsimusega, aga seejuures selgesõnaliselt käitumusliku lisanduvuse terminit mainimata. Üheks mikrotasandi efektide mõõtmise metoodikaks, mis STK hangete tulemusena hangitava ja liidetava uue teadmuse ning ettevõtete võimekuse omavahelisi seoseid käsitleb, on nn BETA lähenemine. Selle töötas välja Strasbourgi Ülikool 1970. aastatel STK (eeskätt CERN ja ESA) sotsiaal-majanduslike mõjude selgitamisel (Bach ja Matt, 2005; Bach ja Wolff, 2017). BETA metoodika jaotab STK hangetest tulenevad mikrotasandi efektid ülekandemehhanismide alusel neljaks alatüübiks: 1) tehnoloogilised efektid ehk ettevõttesisene teadmusülekanne teistesse ärivaldkondadesse; 2) ärilised efektid ehk turu- ja turundusteadmuse lisandumine; 3) organisatsioonilised efektid ehk ettevõtte erinevates tegevusvaldkondades uute rutiinide teke tänu organisatsioonilisele õppimisele koostöös STK-ga; 4) inimressursi efektid ehk uute oskuste ja võimekuse loomine ettevõtetes (Cohendet, 1997).

Nõudluspoolsete poliitikameetmete, sealhulgas STK innovatsiooni edendavate hangete üheks peamiseks eesmärgiks on suunata majandusagente muutma oma tarbimisharjumusi või investeerimismustreid, millega kaasuvalt võivad välja kujuneda uued turud (vt Vuola ja Hameri, 2006; Mazzucato ja Robinson, 2017; Kattel ja Mazzucato, 2018). Poliitika hindamisel tuleks seega käsitleda süsteemisiirde protsesse ning mingites majandusagentide populatsioonides ehk mesotasandil (vt ka Dopfer et al., 2004) ilmnevaid efekte. Süsteemisiirde alases kirjanduses on avaldatud arvamust, et häid lahendusi mesotasandi efektide (nt uute turgude teke tänu teadmuse ülekandumisele või teatud organisatsiooniliste rutiinide kinnistumisele mingis majandusagentide populatsioonis) hindamiseks ei ole (Mazzucato, 2016). Juba väljakujunenud turgude puhul sobivad süsteemisiirde toetamisele suunatud meetmete hindamiseks (nt Neij, 2001; Neij ja Åstrand, 2006) ja tehnoloogiliste innovatsioonisüsteemide evolutsiooni jälgimiseks (nt Suurs et al., 2009; Bento ja Wilson, 2016) standardsed agregeeritud mikrotasandi indikaatorid (käibed uute toodete müügist, turuosad jms). Alles kujunemisjärgus turgude puhul on perspektiivikas lähenemine mesotasandi efektide hindamiseks muutuste tuvastamine majandusagentide populatsiooni omavahelisi suhteid kujundavas institutsioonilises keskkonnas. Sotsioloogiline uusinstitutsionalism, mis eristab nii regulatiivseid, normatiivseid kui ka kognitiivseid institutsioone (Scott, 2014), pakub selleks teoreetilise aluse.

Töös püstitatud uurimisküsimused

Edler et al. (2008) peavad otstarbekaks poliitikameetmete hindamiste teiseste analüüside ehk süstemaatiliste ülevaadete läbiviimist, et aidata sellega kaasa hindamise kvaliteedi ja hindamistulemuste usaldusväärsuse paranemisele. Üheks metaanalüüside teostamise eesmärgiks on teavitada poliitikainstrumentide hindamisega tegelevaid praktikuid erinevate hindamismeetodite tugevusest, kuid ka võimalikest ohtudest, mis võivad avaldada negatiivset mõju uuringutulemuste usaldusväärsusele. Samuti on varasema hindamispraktika sünteesimisel võimalik jõuda uute teadmisteni poliitikameetme olemuse kohta (Cooksy ja Caracelli, 2005). Eelnevat arvestades püstitati doktoritöös eesmärk läbi töötada senised ESA kui ühe konkreetse STK liikmelisusest tulenevate firmatasandi efektide riigipõhised uuringud, et vastata uurimisküsimusele: *kui usaldusväärsed on senistes riigipõhistes ESA-sse tehtud investeeringutest tulenevate efektide uuringutes kasutatud meetodid ning uuringute tulemused*?

Varasemas teaduskirjanduses on pööratud palju tähelepanu STK tarnijate õppimisprotsessidele, mis on seotud nende ettevõtete koostööga STK-ga. Siiski on üldjuhul tegeletud tehnoloogilise teadmuse ja seotud õppimisprotsessidega, vaadeldes nii STK tarnija ja STK vahelist koostööd kui ka STK tarnija ja teiste STK partnervõrgustikku kuuluvate ettevõtete vahelist koostööd (Bach et al., 2002; Nordberg et al., 2003; Autio et al., 2004; Åberg ja Bengtson, 2015; Florio et al., 2018). Samas ei ole kirjanduses käsitletud turu- ja turundusteadmusega seotud protsesse – STK-ga koostöösuhtest tuleneva teadmuse kogumist ja selle rakendamist STK tarnija äritegevuses. Selle uurimislõtku ületamiseks püstitati teine uurimisküsimus: *kuidas ettevõtted rakendavad STK-ga koostööst saadavat teadmust*? Teises uurimuses keskenduti piiratud ressurssidega teadmusmahukate ettevõtete rahvusvahelistumise protsessidele.

Nii nagu mitmetasandiline institutsiooniline keskkond kujundab ja piirab STK käitumist, mõjutab STK ka ise oma liikmesriikide poolt delegeeritud ülesandeid täites (Robinson ja Mazzucato, 2019) institutsioonilise keskkonna dünaamikat. STK toimib muutuste suunajana (Battilana ja D'Aunno, 2009), toetades muu hulgas uute turgude tekkeprotsesse. Seni oli see STK roll jäänud kirjanduses käsitlemata ja seetõttu sõnastati kolmanda uurimisküsimusena: *kuidas mõjutavad supranatsionaalsel tasandil STK poolt läbi viidavad innovatsiooni edendavad hanked institutsioonilisi muutusi mesotasandil?* Kolmandas uurimuses otsitakse sellele küsimusele vastust tärkaval satelliitkaugseire rakenduste turul tegutsevate ESA tarnijate vaatenurgast.

Töö uurimismetoodika ja andmed

Esimese uurimuse raames viis töö autor läbi seniste STK liikmelisusest tulenevate mikrotasandi efektide ja lisanduvuste riigipõhiste uuringute metaanalüüsi, keskendudes ühele konkreetsele STK-le ehk ESA-le. Uuringute valim metaanalüüsiks moodustati varasemate ülevaateuuringute (nt Hof et al., 2012; Simmonds et al., 2012; OECD, 2014b), elektrooniliste teaduskirjanduse andmebaaside (Web of Science, Scopus) ning erinevate ESA liikmesriikide rahvuslike kosmoseagentuuride ja -büroode publikatsioonide kogumite läbitöötamisel. ESA väiksemates liikmesriikides tehtud uuringute eeskujuks oli üldjuhul BETA metoodika (Cohendet, 1997; Bach ja Matt, 2005). Metaanalüüsi raames töötati põhjalikumalt läbi Taani, Norra, Portugali ja Iirimaa ettevõtete andmete põhjal koostatud hindamisraportid. Mõistmaks paremini eri uuringute aluseks olnud metoodikate nüansse, viis autor läbi 7 intervjuud uuringutega seotud isikutega, nii tellijate esindajate kui ka uuringute teostajatega. Intervjuude eesmärgiks oli koguda täiendavaid andmeid, vältimaks metaanalüüside tavalist probleemi, st asjakohase info vähesust ja ühekülgsust uuringuraportite kasutamisel ainsa andmeallikana (vt ka Cooksy ja Caracelli, 2005).

Teine ja kolmas uurimus põhinesid mitmesel juhtumiuuringul. Kvalitatiivne uurimisviis oli metodoloogiliselt kõige sobivam, arvestades uuritavate nähtuste olemust avavate tööde nappust. Sellest tulenevalt on teadmised puudulikud nii sellest, milline on STK roll väikeste, teadmusmahukate ettevõtete poolt turu- ja turundusliku teadmuse hankimisel ja kasutamisel rahvusvahelistumise protsessis kui ka sellest, milline on STK kui innovatsioonivõimendaja roll mitmetasandilise institutsioonilise muutuse suunamisel majandusagentide populatsioonis.

Teise ja kolmanda uurimuse valimi moodustamisel rakendati sihipärast meetodit (ingl *purposeful sampling*, vt ka Patton, 2015). Teise uurimuse valimisse lülitati teadmusmahukatest väikeettevõtetest ESA tarnijad, kes arendasid ESA-ga koostöös globaalselt uut tehnoloogiat. Kolmanda uurimuse valimisse võeti ESA uutes liikmesriikides ja ESA-ga liitumisprotsessi algatanud riikides asuvad satelliitkaugseire rakenduste arendajad, kellega ESA oli sõlminud hankelepingu rakenduse prototüübi arendamiseks ESA-väliste kasutajate vajaduste rahuldamiseks. Algsete valimite kitsendamiseks rakendati lisakriteeriume, pidades sealhulgas väga oluliseks head andmetele ligipääsu (Fletcher et al., 2018). Teise uurimuse raames viidi läbi longituuduuring, st et andmed juhtumianalüüside läbiviimiseks koguti kolme aasta vältel. Kolmanda uurimuse raames intervjueeriti kaheksat ettevõtet Eestist, Lätist ja Slovakkiast.

Andmete esmaseks analüüsimiseks rakendati Gioia meetodit (vt Gioia et al., 2013) ja andmete mugavaks kodeerimiseks NVivo tarkvara. Gioia meetodi abil struktureeriti intervjuude käigus kogutud andmed, et algandmetest eristada huvipakkuvad teoreetilised kontseptsioonid ja nendevahelised seosed (Gehman et al., 2018). Struktureeritud andmete alusel koostati juhtuminarratiivid, mille põhjal täpsustati teoreetiliste kontseptsioonide vahelised dünaamilised seosed, et avada uuritavate protsesside loogika.

Töö tulemused

Esimese uurimuse raames viidi läbi olemasolevate ESA hangetest tulenevate mikrotasandi efektide riigipõhiste uuringute metaanalüüs. Kui suuremates ESA liikmesriikides rakendatakse mikrotasandi efektide hindamisel põhjalikult läbitöötatud teooriatel põhinevaid kvantitatiivuuringuid, näiteks sisend-väljundanalüüs (nt London Economics, 2014) või Cobb-Douglas tüüpi tootmisfunktsiooni baasilt tuletatud ettevõtete tootlikkuse analüüs (nt Graziola ja Cristini, 2013), siis vaadeldud uuringute aluseks olevad väikesed valimid kitsendavad oluliselt praktikas rakendatavate metoodikate valikut. Kuigi Taani, Norra, Portugali ja Iirimaa ettevõtete andmetel tehtud uuringutes tegeleti sarnaselt BETA lähenemisega mikrotasandi efektide uurimisega, jäid erinevad teadmuse ülekandemehhanismid neis uuringutes sisuliselt käsitlemata. Vaadeldud uuringutes keskenduti peamiselt ESA hangetest tõukunud täiendava käibe kui väljundite lisanduvuse indikaatori mõõtmisele, jättes tähelepanuta käitumusliku lisanduvuse aspektid, mis BETA lähenemises on kesksel kohal. BETA lähenemise ja ESA hangetest tulenevate mikrotasandi efektide riigipõhiste uuringute metodoloogilised erinevused on kokku võetud tabelis 11.

Esimeses uurimuses jõuti järeldusele, et ESA hangetest tulenevate mikrotasandi efektide olemasolevate riigipõhiste uuringute usaldusväärsus on madal. Väljundite lisanduvusele keskendumine neis uuringutes on seletatav antud kontseptsiooni näilise lihtsusega, mis soodustab kontseptsioonil põhinevate indikaatorite kasutamist poliitika kujundamise aruteludes. Samas on vaadeldud uuringute raportites esitatud väljundite lisanduvust väljendavate indikaatorite arvulised väärtused oluliselt suuremad, kui võiks eeldada seniste teadmiste alusel ettevõtete tasuvusnäitajate statistilise jaotuse asümmeetrilisusest (nt Scherer ja Harhoff, 2000). Kuna metaanalüüsist nähtus, et ESA hangetest kasu saavate ettevõtete kogum majanduses on aastate lõikes püsiv, siis on nende ettevõtete seisukohalt küsimustikele vastates ratsionaalne näidata ESA hangetest tulenevaid mikrotasandi efekte tegelikkusest suuremana. Nn strateegiline vastamine (ingl *strategic answering*) on võimalus tagada liikmesriigi poolt STK-sse panustatud finantsvahendite püsimine etteantud tasemel või nende suurenemine. Koguefektide erinevate mõjurite panuse eristamise keerukus (ingl *project fallacy*) on teine probleem, mis võib tingida väljundite lisanduvuse nihkega hinnangu. Esimese uurimuse tulemused viitavad andmete triangluatsiooni vajadusele STK hangetest tulenevate mikrotasandi efektide riigipõhistes uuringutes, näiteks täiendades hindamismetoodikat juhtumianalüüsidega.

Tabel 11. BETA lähenemise ja ESA hangetest tulenevate mikrotasandi efektide riigipõhiste uuringute metoodikate võrdlus.

	Algne BETA lähenemine	**Analüüsitud riigipõhised uuringud**
Käsitletud lisanduvuse tüübid	Käitumuslik lisanduvus. Väljundite lisanduvus.	Väljundite lisanduvus.
Efektide mõõtmise alus	Lisandväärtus.	Lisanduv müügikäive.
Võrdlusstsenaariumite kasutamine	Jah, kajastub intervjuu protokollis.	Võimalikke võrdlusstsenaariume ei käsitleta ilmutatud kujul.
Andmete kogumise viis	Intervjuud.	Ankeedid, intervjuud.

Allikas: autori koostatud; põhineb Cohendet’ (1997), Bachi ja Wolffi (2017) ja Eerme (2016) töödel.

Teises uurimuses vaadeldi piiratud ressurssidega teadmusmahukate ettevõtete rahvusvahelistumise protsessi. Rahvusvahelistumise protsessi käsitlus uurimuses oli holistiline (Hernández ja Nieto, 2016) ning vaatles samaaegselt ettevõtete piiriüleseid sisend- ja väljundseoseid (ingl *inward-outward links*). Sisendseosed täiendavad ettevõtete põhiprotsessideks (nt arendustegevuseks) vajalikku ressursibaasi ja väljundseosed on suunatud ettevõtte ressursside ärilisele rakendamisele.

Uurimuses vaadeldud ettevõtete rahvusvahelistumise protsess oli mittelineaarne ja ebaregulaarne. Ettevõtete tegutsemist välisturgudel iseloomustasid intensiivsed, kuid lühiajalised majandusliku aktiivsuse puhangud, mis enamasti piirdusid kas sisend- või väljundseostega ning päädisid välisturult taandumisega. Uuringusse kaasatud ettevõtete peamine rahvusvahelistumise motiiv oli sarnaselt Hewerdine et al. (2014) tööle ettevõtte põhiprotsesside (nt teadus- ja arendustegevuse) kestlikuks läbiviimiseks vajalike ressursside kaasamine avastatud ärivõimaluste kasutamiseks.

Teise uurimuse tulemusena pakuti välja uus teoreetiline raamistik piiratud ressurssidega teadmusmahukate ettevõtete tsüklilise rahvusvahelistumise protsessi kirjeldamiseks. Selles mudelis suunab rahvusvahelistumist tagasisideline õppimisprotsess. Ettevõte kogub pidevalt uut tehnoloogilist, turu- ja turundusteadmust edukaks tegutsemiseks välisturgudel. Teadmuse hankimise ja liitmise tulemusena avastatakse uusi ärivõimalusi, mille mõjul kujundatakse ümber ettevõtte ressursibaas ning asutakse otsima täiendavaid ressursse uute ärivõimaluste kasutamiseks. Kirjeldatud tagasisidelist protsessi iseloomustab rahvusvahelistumise ja õppimisprotsesside ning ressursibaasi dünaamiline vastastikmõju. ESA-l on selles protsessis unikaalne roll õppimisprotsesside mõjutamise ning sisend- ja väljundseoste vaheliste ühenduste loomisel.

Juhtumianalüüs näitas, et ESA-l on oluline roll tarnija rahvusvahelise ärisuhete võrgustiku laienemisel. Uuringus vaadeldud ettevõtete seisukohalt oli leping ESA-ga legitimeeriv märguanne (ingl *legitimising signal*) teistele turuosalistele, mille toel oli võimalik läheneda ärivaldkonna juhtivatele ettevõtetele koostööettepanekutega. Koostöö ESA-ga aitas ellu viia projektiivsete assotsiatsioonide strateegiat (vrd Rawhouser et al., 2017) ressursside kaasamiseks, mille puhul ettevõtte usaldusväärsust turusuhetes kujundavad tema lähedased kontaktid kõrge mainega organisatsioonidega ja see loob paremad eeldused ressurssidele ligipääsuks. Legitimeeriva märguande mõjul paraneb piiratud ressurssidega väikeettevõtete positsioon rahvusvahelistes ärivõrgustikes, mis võimaldab ka ligipääsu uutele turu- ja turundusteadmuse allikatele. Uurimus näitas, et legitimeeriva signaali abil loodud kontaktid ärivaldkonna juhtivate ettevõtetega olid pigem lühiajalised. Siiski kaasnes nendega valdkonnaspetsiifilise turu- ja turundusteadmuse hankimine.

Sellel uuel teadmusel oli suur mõju ettevõtete äriotsuste kujundamisele. Lisandunud turu- ja turundusteadmus võis olla vastuolus senise arusaamaga välisturgudest, mistõttu uuritud ettevõtted kujundasid korduvalt ümber oma äristrateegiad. Uurimus näitas, et ühel hankelepingul STK-ga võib olla väga suur mõju ettevõtte turu- ja turundusteadmusele ning seeläbi ka kogu ettevõtte toimimise loogikale. Püsiv muutus ettevõtete strateegias on definitsiooni kohaselt käitumuslik lisanduvus (Gök ja Edler, 2012). Seega andis teine uurimus uusi teadmisi selle kohta, milliste protsesside tulemusena võib avalduda STK hangetest tulenev käitumuslik lisanduvus.

Kolmas uurimus võttis vaatluse alla majandusagentide käitumise dünaamika tärkavas teenuste ökosüsteemis. Ilma innovatsioonivõimendaja sekkumiseta teenuste ökosüsteemi ei kombineerinud majandusagendid vastastikku täiendavaid ressursse väärtuse koosloomeks (ingl *value co-creation*). Koosloomet pärssis asjakohase teadmusressursi ebaühtlane jaotus ökosüsteemis agentide vahel. Teenusepakkujad, antud juhul satelliitkaugseire rakenduste arendajad, panustavad väärtuse koosloomesse tehnoloogilise ekspertteadmusega ning potentsiaalsed lõppkasutajad, antud juhul erinevad riigisektori organisatsioonid ning ettevõtted, väärtusloome spetsiifilise konteksti teadmusega. ESA innovatsioonivõimendajana toob ökosüsteemi nii tehnoloogilise teadmuse kui ka spetsiifilise turu- ja turundusteadmuse, mis on akumuleerunud tänu pikaajalisele koostööle arvukate teadmusmahukate tarnijatega.

Uurimus näitas, et ESA lisandumisel ökosüsteemi on oluline mõju ökosüsteemi kujunemisele. ESA lisandumine soodustab majandusagentide koostööd väärtuse koosloomeks. Seega täidab ESA innovatsioonivõimendaja rolli selles ökosüsteemis (Howells, 2006). Kvalitatiivuuring tõi ühe ootamatu mõjuna välja kognitiivse dispositsiooni (ingl *cognitive disposition*) mehhanismi (Siltaloppi ja Vargo, 2017). Sotsioloogilise uusinstitutsionalismi ideede kohaselt juhinduvad majandusagendid oma tegevuses mitmesugustest eri tasandite normatiivsetest ja kognitiivsetest institutsioonidest. Uurimus selgitas, et ESA lepingulistel teenusepakkujatel olid teatud normatiivset laadi arusaamad ESA toimimisviisidest, mistõttu oli ESA-ga hankelepingu sõlmimisel äriotsuste aluseks olevaid eeldusi valideeriv mõju. Kognitiivse dispositsiooni mehhanism väljendub institutsiooniliste muutuste esiletoomises mikrotasandil, mis avalduvad näiteks ökosüsteemi osaliste muutunud arusaamades arendatava tehnoloogia võimalustest või lõppkasutajatele kasu loovast väärtuspakkumusest (nt Doganova ja Eyquem-Renault, 2009).

Vaatamata ESA lisandumisele ökosüsteemi, püsis teadmusressursi jaotus ökosüsteemis ebaühtlasena ning sellel oli jätkuvalt väärtuse koosloomet pärssiv mõju. Teenusepakkujatele sai teadmuse akumuleerudes selgeks, et väärtusloome toetamiseks tuleb astuda samme ökosüsteemi institutsioonilise keskkonna muutmiseks, mille tulemusena kindlad arusaamad ja sotsiaalsed normid leviksid ja ühtlustuksid üle majandusagentide populatsiooni. Teenusepakkujate sellesuunalise tegutsemise ehk institutsioonide vormimise (ingl *institutional work,* vt Lawrence ja Suddaby, 2006) tulemusena kerkivad ökosüsteemis esile uued protoinstitutsioonid, mis teatud eeldustel fikseeruvad uute mängureeglitena ja hakkavad kujundama ökosüsteemi osaliste vastastikmõjusid. Institutsioonide vormimine teenusepakkujatest institutsiooniliste ettevõtjate (ingl *institutional entrepreneur*) poolt on tagasisidestatud tsükliline protsess, mille tulemusena kujuneb ökosüsteemis ajapikku välja väärtuse koosloomet toetav uus institutsiooniline keskkond. Empiiriline uuring näitas, et selline konvergentsi protsess võttis ühel juhul aega enam kui 7 aastat, olles sõltuv ökosüsteemi institutsioonilisest inertsist.

Kolmas uurimus näitas, millised vaevumärgatavad protsessid leiavad aset kujunemisjärgus turgudel makrotasandilt vaadates. Turud hakkavad formeeruma oluliselt varem, kui turu areng muutub kirjeldatavaks laialt levinud standardsete agregeeritud mikrotasandi indikaatorite abil. Kolmandas uurimuses analüüsitud mitmetasandiline institutsiooniline muutus, mille käivitavaks jõuks on STK innovatsioonivõimendus, kujutabki endast käitumuslikku lisanduvust mesotasandil.

Tabel 12. Doktoritöö teoreetiline panus.

Uurimus	Teoreetilise panuse mõõde	Teoreetilise panuse lühikirjeldus
1. uurimus	Kasulikkus (praktiline).	Metaanalüüsi tulemusena tehti kindlaks seniste STK hangetest tulenevate mikrotasandi efektide hindamise uuringute metodoloogiline piiratud võrreldavus. Samuti toodi välja üksnes väljundite lisanduvuse uurimise probleemid. Töö tulemusena pakuti välja ideed andmete triangulatsiooniks efektide hindamisel.
2. uurimus	Originaalsus (teooria täiendamine).	Töös pakuti välja uus teoreetiline raamistik piiratud ressurssidega teadmusmahukate ettevõtete rahvusvahelistumise protsessi kirjeldamiseks. Rahvusvahelistumine on tsükliline, mittelineaarne protsess ressursside kaasamiseks, mida toetab koostöö STK-ga toodete ja tehnoloogiate koosloomeks ning turu- ja turundusteadmuse hankimiseks ja kasutamiseks.
3. uurimus	Originaalsus (teooria täiendamine).	Töös pakuti välja mudel innovatsioonivõimendaja rolli kirjeldamiseks mitmetasandilise institutsioonilise muutuse algatajana. STK kui innovatsioonivõimendaja lisandumine teenuste ökosüsteemi käivitab institutsioonilise muutuse mikrotasandil ning institutsioonide vormimise protsessi kõrgematel analüütilistel tasanditel. Nende protsesside tulemusena kujuneb välja selline institutsiooniline keskkond, mis soodustab majandusagentide koostööd väärtuse koosloomel tärkavatel turgudel.
Uurimused koos	Originaalsus	Uuringud tõid esile institutsioonide olulisuse STK hangetest tulenevates mikro- ja mesotasandi protsessides, mis on seotud käitumusliku lisanduvusega.

Allikas: autori koostatud Corley ja Gioia (2011) alusel.

Tabelis 12 on esitatud töö aluseks oleva kolme uurimuse teoreetiline panus eraldiseisvalt ja kogumina. Teoreetilise panuse väljatoomisel lähtutakse Corley ja Gioia (2011) lähenemisest, mis eristab kahte peamist mõõdet teadustööde teoreetilise panuse hindamisel – töö teaduslikku originaalsust ning töö praktilist ja teaduslikku kasulikkust.

Töö praktiline tähtsus

Töö on tõukunud praktilisest vajadusest täiustada STK hangetest tulenevate mikro- ja mesotasandi efektide uurimise metoodikaid, mida saaksid STK uued liikmesriigid kasutada selle eripärase poliitikameetme mõjude hindamisel. Töö rõhutas mikro- ja mesotasandi käitumusliku lisanduvuse kontseptsioonide asjakohasust STK hangetest tulenevate efektide hindamisel. Seni on hindamised liialt keskendunud väljundite lisanduvuse dimensioonile.

Kui senini on ankeetküsitlusi peetud Euroopas poliitikameetmete hindamisel parimaks praktikaks (Edler et al., 2012), siis selle töö järelduste taustal tuleks ankeetküsitlusega paralleelselt kasutada teisi uuringuviise, näiteks juhtumianalüüse. Andmete trianguleerimine võimaldab ohjata strateegilise vastamise probleemist tingitud nihkega hinnanguid efektide mastaabile.

Innovatsioonisüsteemide ja süsteemisiirete kontseptsioonid rõhutavad riigi innovatsioonipoliitika ettevaatavat rolli nõudluse kujundamisel ja seeläbi uute turgude tekkele kaasaaitamisel. Neil juhtudel on vaja leida uusi lähenemisi mesotasandi käitumusliku lisanduvuse mõõtmiseks olukorras, kus standardsete agregeeritud mikrotasandi indikaatorite kasutamine ei ole (veel) põhjendatud, nt seotud ettevõtetel puudub käive. Töös vaadeldi mitmetasandilist institutsioonilist muutust tärkaval turul. Institutsiooniliste muutuste tuvastamine ja jälgimine kvalitatiivseid uurimismeetodeid rakendades on üheks paljulubavaks võimaluseks mesotasandi käitumusliku lisanduvuse (nt turgude tekkeprotsessi) hindamiseks.

Soovitused edasisteks uuringuteks

Selle töö edasiarendamiseks on mitmeid võimalusi. Üks paljutõotavamaid suundi on seotud mesotasandi käitumusliku lisanduvuse kontseptsiooni jätku-uuringutega. Töö aluseks olevas kolmandas uurimuses on piirdutud ühe teenuste ökosüsteemi osapoole – teenusepakkuja kui institutsioonilise ettevõtja – perspektiiviga. Uuringumetoodika kohandamine, viies uuringu läbi longituudsena ning kaasates kvalitatiivuuringusse ka teised ökosüsteemi osapooled, sealjuures STK kui innovatsioonivõimendaja ja lõppkasutajad, võimaldab saavutada mitmekülgsema ja usaldusväärsema pildi mitmetasandilisest institutsioonilisest muutusest ning ökosüsteemi erinevate osaliste rollidest selles.

Samuti on võimalik mesotasandi käitumusliku lisanduvuse kontseptsiooni uurimiseks lõimida uusi ideid kiiresti arenevast turgude vormimise (ing *market shaping*) alasest teaduskirjandusest (Storbacka ja Nenonen, 2015; Harrison ja Kjellberg, 2016). Kuigi selles teoreetilises suunas on juba leidnud käsitlemist avaliku sektori organisatsioonide tegevus institutsioonide vormimiseks erinevatel analüütilistel tasanditel (nt Kaartemo et al., 2020), on uurimislõtk innovatsioonivõimendajate rolli mõistmisel. Töös on tehtud esimesed sammud selle uurimisvajaku ületamiseks.

Turgude vormimise protsesside mõõtmiseks on kvalitatiivsete meetodite abil tuletatud ja uuringutes valideeritud indikaatorite komplektid (Nenonen et al., 2019). Töö esimeses jätku-uuringus leidsid Eerme et al. (2020), et Nenonen et al. (2019) välja pakutud indikaatorid on kasutatavad institutsioonilise keskkonna normatiivsete ja kognitiivsete komponentide muutuste mõõtmiseks. Edasised uuringud selles suunas panustaksid mesotasandi käitumusliku lisanduvuse kontseptsiooni mõõdetavuse probleemi lahendamisse.

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Peamised uurimisvaldkonnad: kosmosemajandus, innovatsioonipoliitika, innovatsiooni edendavad riigihanked, innovatsioonipoliitika instrumentide hindamine, turgude kujunemine ja vormimine, institutsioonilised muutused turgudel

Osalemine teadusprojektides:
01.01.16–31.12.19 Ekspordimustrite holistiline protsessiperspektiiv: teooria arendus ja empiirilised tulemused

Juhendatud magistritööd:
1. Triin Teppo, magistrikraad, 2019, (juh) Eneli Kindsiko; Tõnis Eerme, Factors Encouraging the Creation of Spin-Offs from Student Satellite Projects (Tudengisatelliidi projektidest lähtuvate spin-off ettevõtete levikut soodustavad tegurid), Tartu Ülikool, Sotsiaalteaduste valdkond, majandusteaduskond.

Ühiskondlik tegevus:
2015– Eesti delegatsioon Euroopa Kosmoseagentuuri juures, nõunik, tööstussuhted
2016– Euroopa Kosmoseagentuur, Space Economy Steering Group, liige
2017– Euroopa Kosmoseagentuur, Technology Harmonisation Advisory Group, liige

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