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Medical Technology Innovation Ecosystems:

Factors influencing the formation of new companies

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Abstract

This thesis focuses on how the medical technology (MedTech) innovation ecosystems contribute to the formation of start-ups. An innovation ecosystem involves collaboration and the exchange of resources in order to stimulate its own development and change over time. The MedTech innovation ecosystem is characterized by a large number of innovations, which are more concentrated in the pharmaceutical industry, biotech, medical devices, and healthcare information technology fields. Existing ecosystem studies offer a fairly diverse understanding of the formation goals, development parameters, and other parameters, which are often inaccessible to an external observer. Understanding the internal processes typical of successful MedTech innovative ecosystems contributes to the adaptation of best practices for developing innovative ecosystems, reducing the financial, time, and human resources spent, and developing the economy. As a result of the activity of innovative MedTech companies, customers receive new equipment, methods of treatment, and rehabilitation of patients, reducing the costs and workload for medical personnel.

The MedTech innovation ecosystem is explored in four Papers and an extended summary in this thesis. Since the study aimed to increase knowledge about how MedTech innovation ecosystems contribute to an increase in the number of start-ups, qualitative research strategy and content and within, cross-case, and narrative methods of analyzing the collected information were chosen. The studied phenomena were investigated from the point of view of subjectivity, that is, the interpretation of the past events of the participants and their personal view of the actions taken.

The results of the study were the identification of two key parameters that contribute to the formation and successful development of MedTech innovative start-ups, namely the provision of public support and the possibility of cooperation. Public and private support includes financial resources at various stages of company development, including support for basic and applied research, provision of grants at the stage of company formation for marketing research, a grants search, company registration, other loans, and grants for company formation. Non-financial types of support include providing access to the infrastructure of the innovation ecosystem, which includes laboratories, specialized equipment, training courses, entrepreneur support programs, etc. Collaboration involves leveraging the internal connections of the innovation ecosystem and providing access to other innovation ecosystems to work on projects that cross the interests of several areas, as well as MedTech innovation ecosystems in other countries.

This thesis brings more clarity to the process of formation and development of the MedTech innovation ecosystem and proposes a model of a successful ecosystem that could be claimed by policymakers who make decisions about the development of the industry. Moreover, the thesis offers several successful cases that consider the non-obvious benefits that start-ups from innovative ecosystems can receive and use as an additional benefit for their development.

KEYWORDS: innovation ecosystem, medical technologies, start-ups, innovation

Svensk sammanfattning

Denna avhandling fokuserar på hur det innovativa ekosystemet för medicinsk teknik (MedTech) bidrar till bildandet av nystartade företag. Ett innovationsekosystem innefattar samarbete och utbyte av resurser för att stimulera sin egen utveckling och förändring över tiden. MedTechs innovationsekosystem kännetecknas av ett stort antal innovationer, som är mer koncentrerade inom läkemedelsindustrin, bioteknik, medicintekniska produkter och informationsteknik inom hälso- och sjukvården. Befintliga ekosystem studier erbjuder en ganska mångsidig förståelse för formations målen, utvecklings parametrar och andra parametrar, som ofta är otillgängliga för en utomstående observatör. Att förstå de interna processerna som är typiska för framgångsrika MedTech-innovativa ekosystem bidrar till anpassningen av bästa praxis för att utveckla innovativa ekosystem, vilket ökar tids effektiviteten, minskar de ekonomiska och mänskliga resurser som används, samt utvecklar ekonomin. Som ett resultat av aktiviteten hos innovativa MedTech-företag får kunder ny utrustning och metoder för behandling och rehabilitering av patienter, vilket minskar kostnaderna och arbetsbelastningen för medicinsk personal.

MedTechs innovationsekosystem fall utforskas i fyra artiklar och en utökad sammanfattning i denna avhandling. Eftersom syftet med studien var att öka kunskapen om hur MedTechs innovationsekosystem bidrar till en ökning av antalet nystartade företag, valdes kvalitativ forskningsstrategi och innehåll, inom och cross-case, och narrativa metoder för att analysera den insamlade informationen. De studerade fenomenen undersöktes med avseende på subjektivitet, det vill säga tolkningen av deltagarnas tidigare händelser och deras personliga syn på de vidtagna åtgärderna.

Resultaten av studien var identifieringen av två nyckelparametrar som bidrar till bildandet och framgångsrik utveckling av MedTech-innovativa nystartade företag, nämligen tillhandahållandet av statligt stöd och möjligheten till samarbete. Offentligt och privat stöd inkluderar finansiella resurser i olika stadier av företagsutveckling, inklusive stöd för grundläggande och tillämpad forskning, tillhandahållande av bidrag i företagsbildning stadiet för marknadsundersökningar, bidragssökning, företagsregistrering, andra lån och bidrag för företagsbildning. Icke-finansiella typer av stöd inkluderar tillhandahållande av tillgång till infrastrukturen i innovations-ekosystemet, vilket inkluderar laboratorier, specialutrustning, utbildningskurser, entreprenörsstöd program med mera. Samarbete innebär att man utnyttjar innovationsekosystemets interna förbindelser samt ger tillgång till andra innovationsekosystem för att arbeta med projekt som korsar intressen inom flera områden, liksom MedTechs innovationsekosystem i andra länder.

Denna avhandling ger mer tydlighet i processen för bildning och utveckling av MedTechs innovationsekosystem och föreslår en modell för ett framgångsrikt ekosystem som kan krävas av beslutsfattare som fattar beslut om utvecklingen av branschen. Dessutom erbjuder avhandlingen flera framgångsrika fall som tar hänsyn till de icke-uppenbara fördelarna som nystartade företag från innovativa ekosystem kan få och använder dem som en ytterligare fördel för deras utveckling.

NYCKELORD: innovationsekosystem, medicinsk teknik, nystartade företag, innovation

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Contribution of the author

The author's contribution to the preparation of Papers 1–4 consisted of collecting data for research, analyzing, and writing drafts. The modeling of the article and the development of the framework were carried out in cooperation with the co-authors. The selection of analytical methods and their application in practice was carried out under the guidance of supervisors and other senior researchers. The author has participated in empirical work and analysis as follows:

Paper 1. The work was carried out with the direct support of Dr. Magnus Hellström and Prof. Kim Wikström.

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Abbreviations

CEO - Chief Executive Officer
CTO - Chief Technical Officer
IPRs - Intellectual property rights
MedTech - Medical technology
RQ - Research question
R&D - Research and development
TTO- Technology transfer office
USO - University spin-off

1. Introduction

Innovation is a key driver for countries to develop and build knowledge-based economies in the 21st century (Oh et al. 2016, Godin 2015, Verspagen 2005), making it possible to close the welfare gap between developed and developing countries. Countries that strive to develop innovation take a systems approach that includes policies, development tools, innovation ecosystems, and others to successfully overcome market difficulties. The analysis of building successful innovation ecosystems requires accounting for many characteristics that are often invisible to an outside observer. In turn, use of the innovation ecosystem as a tool for business development is an important factor for the formation and development of business (Breschi, Malerba 1997, Autio, Thomas 2014). Innovation is often associated with inventors and entrepreneurs who bring new products to users around the world or apply previously known technologies to create a unique proposition that has not previously existed on the market (Amit, Zott 2012, Massa, Tucci 2013).

The relationship between innovation and the country's economic development has been confirmed by many studies (Helpman 1998, Sanidas 2004, Godin 2015, Autio, Thomas 2014). Innovation and natural resources can be the basis for the development of the country and the growth of its citizens' well-being (Mavrotas, Murshed & Torres 2011). An added benefit of innovation is the ability to increase production efficiency by reducing costs and increasing efficiency. The country's technological and innovation strategy includes industrial and financial plans, where actions for the development of local industry should be the focus (Roolaht 2012). It acts as a benchmark for development, determining the order and speed of an industry's growth, for example, an industry that already exists or a new type that did not exist before, but there is a desire to invest and develop.

Innovation ecosystems that shape states with the aim of concentrating efforts to develop a particular industry offer new opportunities for participants to develop business. Innovation ecosystems include

- the level of innovation policy, that is, the national policy for the promotion and management of innovation;
- the executive level, that is, national institutions that contribute to the development and implementation of innovations, for example, research programs, government demand for innovations, etc.; and
- the infrastructural level, namely education, training of human capital, legislation, and sources of financing for activities.

In most cases, no more than four to six areas are selected for resource investment and innovation development (Gamidullaeva 2018, Jackson 2011). The innovation ecosystem can offer not only financial support to start-up and advanced entrepreneurs but also other types of non-financial support, for

example, expertise, facilities, networking, etc. The use of the provided opportunities by the business has a beneficial effect on the growth of the industry, the number of jobs, the development of entrepreneurship, etc. In turn, the use of the proposed infrastructure of the innovation ecosystem pushes entrepreneurs to develop their own advantages. First, it is worth noting networking, which has become an important topic for researchers and practitioners. Business model innovation often appears at the intersection of multiple areas of expertise, which is typical of many modern industries. The social capital of entrepreneurs can to some extent replace other resources, such as money or time, contributing to the emergence of competitive advantages in business. Previous successes that an innovation ecosystem can provide motivates other people to become entrepreneurs and try their hand at this area. Nevertheless, an individual approach to the formation and development of the company helps to increase the chances of success. The presence of experienced mentors and advisors within the innovation ecosystem, with experience and an extensive network of acquaintances, builds confidence among new founders. Each company is individual, its own specific products and needs. However, different approaches to the transfer of value and expertise from innovation ecosystems have an impact on their success.

The thesis focuses on the impact of innovation ecosystems on the formation of MedTech start-ups. The goal of this project is to provide recommendations for action for MedTech researchers who would like to commercialize their results by using the opportunities offered by the innovation ecosystems of the countries.

Researchers and nascent entrepreneurs can create and capture value from private and public resources in the innovation ecosystems. Policymakers can use the proposed recommendations to build a new MedTech innovation ecosystem, reduce the required resources for optimal development, increase the attractiveness and accessibility of knowledge-based entrepreneurship among university graduates, increase employment, and keep qualified personnel from relocating. Thus, the main research question of this study is: How do innovation ecosystems contribute to the formation of MedTech start-ups?

1.1 Background and research environment

An innovation ecosystem is a cluster of diverse members and organizations that jointly create value in a specific area that exceeds the capabilities of individual members (Autio, Thomas 2014, Adner 2006). Innovation ecosystems include companies, universities, private and public organizations, investors, business incubators and accelerators, and more (Autio, Thomas 2014). Innovation ecosystems shape entrepreneurial communities with different ideas and visions. As a result, joint value and new ideas for implementation are formed and developed. Innovation ecosystems offer flexible opportunities to create value and encourage innovation. It is expected that companies working together using the prepared infrastructure of the innovation ecosystem could create and capture more value than they could alone, thereby increasing the return on public and private investments (Adner 2006).

Innovations are the basis for the economic development and competitiveness of countries (Helpman 1998, Sanidas 2004). By analyzing the innovation ecosystems of different countries, we can better understand the reasons for success and differences in approaches to business development, and we can identify trends and successful patterns for policy adjustments. By comparing innovation ecosystems, we can identify certain parameters that should be stimulated to improve the competitiveness of companies operating in the market, attract new participants, and, as a result, accelerate the economic development of countries.

MedTech combines various industries where innovations play a critical role in the development of healthcare systems and the maintenance of human health (Wei, Clegg 2014, Maresova et al. 2015). MedTech includes areas such as biotechnology, health information technology, pharmaceutical industry, medical device development, and others. Healthcare innovations start with small medical devices and follow with global disease vaccines, artificial organs and limbs, surgical complexes, etc. (May 2013). Technologies in this area are undoubtedly the driving force in development that can hardly be overestimated. As a result of these innovations, practicing doctors, patients, and the entire healthcare system receive new incentives for development, from the diagnosis of diseases to the postoperative course and recovery of patients. Medical personnel will be able to concentrate more on key medical tasks with fewer distractions during routine and administrative tasks, which in turn will reduce burnout at work. Patients will benefit from more comfortable and convenient treatment, which were, in some cases, previously unavailable for incurable diseases. Simultaneously, insurance companies, policymakers, hospitals, and others can benefit from a reduction in financial costs or time for treating and recovering patients (Abrishami, Boer & Horstman 2014, Heston 2017).

A large number of modern countries are currently considering the MedTech industry as a basis for long-term economic development and, as a result, for positive effects on the lives of residents. Currently, MedTech is an important part of economic development in European countries. Finland has chosen MedTech as one of the priority industries for development. It was assumed that medical products and technologies could become one of the four pillars for the development of an export-oriented Finnish economy (Tulkki et al. 2001, Viljamaa 2003, Pajunen, Järvinen 2018). Finnish MedTech innovations were supported by significant investments in product development and commercialization in the 1990s and 2000s (Lumme, Mason & Suomi 2013, Tulkki et al. 2001). However, despite significant efforts in the past, there is now a gap in product and solution innovation in this area. According to some studies, this is due to the disunity of the participants in the innovation ecosystem, the difficulty with the transition from university research to the commercialization of results, and the lack of sufficient financial infrastructure (Rahkola 2019, Mladenović et al. 2020). Previous failures in formation and development of the Finnish MedTech innovation ecosystem created an infrastructure gap which

reduces the likelihood of success in the commercialization of local medical products.

By contrast, Sweden and Denmark can be considered two of the leaders in the field of MedTech in Europe. These countries have a long and successful history of commercializing medical innovations (Hyde, Paterson 2001, Nadowska 2013, Shane 2004). The innovation ecosystems of these countries consist of several world leaders in the production of medical products and solutions, several dozens of medium and large companies that put innovation at the head of their business, and many small companies with a narrow specialization but great potential for development. At the same time, public and private organizations provide significant support for businesses and stimulate the transfer of ideas and personnel from the university environment to business. Universities, as regional hubs of MedTech ecosystems, are a source of innovation and are significant contributors to business development. Most companies in these countries offer products and solutions not only in the local market but also globally. Companies like AstraZeneca and Nobel Biocare, Sweden offer infrastructure for the formation and implementation of innovations, swift project approvals, and support for initiatives. All this entails the formation and sustainable development of innovation ecosystems in these countries. Export of focal technologies play an important role in export-oriented economies (Sandström-VINNOVA 2014).

1.2 Motivations for the study

Motivations for this study originated from the research context and business needs of the industry. First of all, it is necessary to offer solutions for modern MedTech businesses: how to increase the likelihood of success of companies existing in the market, thereby creating more sustainable innovation ecosystems.

The existing private and public systems of MedTech business development do not always coincide with the desires of developing the business. First of all, it is related to small and medium-sized companies. Policymakers may take chaotic steps to support local markets, may have little knowledge of the specifics of this industry, or may believe that programs for other markets can be copied for the needs of MedTech. Such spontaneous programs may not achieve their goals or may have little impact on the state of innovation ecosystems. As a result, public authorities could decrease the priority of the industry and favor others. Universities as medical technology development centers are also taking steps to encourage researchers to commercialize their developments. However, they often do this in a poor way due to a lack of proper experience, a complex bureaucratic structure, and because it is not their core business (Lambert 2003, Neves, Franco 2018). As a result, research results may remain within laboratories and not be of benefit to society. Funding for such research, which can last many years, may not achieve its goal, new products and services do not appear on the market, and patients and doctors suffer from the lack of convenient and practical MedTech solutions.

On the other hand, the traditional MedTech market is occupied by large international companies, where start-ups and university spin-offs (USOs) constantly appear, offering new innovative products and services. As a result, a paradigm shift from traditional products to innovative solutions can occur, leading to a change in the market, as well as the companies operating within it. When it comes to the MedTech business, there is a lack of knowledge about the business models for the companies and the innovation ecosystems associated with them. Ecosystem participants often underestimate the role of business models and fail to understand the value and benefits of harnessing the power of innovation ecosystems. A lack of business expertise hinders potential entrepreneurs to think about changing the academic environment to the industry or may provoke spontaneous decisions that reduce the likelihood of success in the market. Therefore, this study is needed for solving urgent and relevant problems. In addition to its academic interest, this study has influenced the formation of an innovative MedTech innovation ecosystem and the development of several MedTech companies in Turku, Finland.

The number of studies investigating the role of the innovation ecosystem in developing the economy and business (Valkokari 2015, Oh et al. 2016, Adner 2006, Papaioannou, Wield & Chataway 2009) and transfer of academic inventions to the industry (Lowe 1993, Rasmussen, Moen & Gulbrandsen 2006) are great. However, the academic understanding of the specifics of the formation and development of certain industrial innovation ecosystems is still unclear, and our understanding of how innovation ecosystems contribute to the formation of start-ups is limited. In particular, the question of how the MedTech innovation ecosystem pushes academic staff to form start-ups is also not well researched. The preferential logic of researchers suggests considering financial resources as a key factor that plays a decisive role in the success of an innovation ecosystem (Durst, Poutanen 2013, Granstrand, Holgersson 2020). Nevertheless, the industrial specificity brings its own limitations and peculiarities. MedTech innovation ecosystems require a specific approach, which is little considered by existing research (as an exception, see Sharif, Quinn 2021, Silva et al. 2018, Iyawa et al. 2016). Moreover, companies operating in a particular innovation ecosystem are at different stages of development and have different demand for the available resources. The needs of a start-up could differ from those of an established company (Hasche, Linton 2018, Blevins et al. 2018). There is also an opinion that use of the innovation ecosystem's resources is often confused with the results of the action of the innovation ecosystem, thereby introducing additional misunderstandings (McKeever, Anderson & Jack 2014, Gedajlovic et al. 2013).

This thesis aims at increasing knowledge of exactly how the MedTech innovation ecosystem affects the formation and development of start-ups, finding the best ways to support entrepreneurship and stimulate the commercialization of academic research. Additionally, I contribute to the literature by addressing the topic of using the innovative ecosystem's resources

to increase the transit of researchers and the results of their research into the industry.

An additional important motivating factor for the study of the commercialization of MedTech innovations and start-ups was personal participation in several projects. Prior to starting my research, I was involved in frequent discussions about the commercialization of university research, the difficulties in raising capital, and other industrial barriers to commercialization for inexperienced entrepreneurs. Some results of research projects remained within the laboratories; other projects could not achieve any significant results and were closed. However, university personnel did not give up hope of success and permanently made attempts to achieve success in the industry. Entrepreneurs and I as a researcher have challenged ourselves to leverage the opportunities that the innovation ecosystem presents to help companies and projects get started. The success of start-up entrepreneurs depends not only on the team and the quality of the project but also on partners and other participants who are actively operating in the market. Therefore, studying only entrepreneurs for their companies could provide little insight into how start-ups are formed and developed, but the whole innovation ecosystem must be considered. Such success could be a combination of many unique factors that are difficult to replicate. Other potential entrepreneurs will be forced to follow the same path without accounting for previous experience and may doubt the correctness of their actions. The formation of certain guidelines for academic researchers, start-up companies, and other participants in the MedTech innovation ecosystems could be a step toward improving the understanding of the MedTech ecosystems' existence and development, increasing the attractiveness of entrepreneurial activity in society, and developing the knowledge economy.

1.3 Research question

MedTech companies and their partners became the object of this study and the source for data collection, analysis, and application of knowledge gained during the research.

The main research question of the study is as follows:

How do innovation ecosystems contribute to the formation of MedTech start-ups?

Specific research questions that need to be answered to uncover the main question and achieve the necessary research objectives are as follows:

- *How is it possible to change an existing business ecosystem and overcome its barriers by means of a business model design?* (Response in Paper 1) Having a unique business model is a well-researched factor in a company's competitive advantage. However, companies are tackling industry-specific challenges with an individual approach. Understanding the strengths of the company and the opportunities provided by the

innovation ecosystem makes it possible to gain competitive advantages from the early stages of company formation.

- *How does the availability of financial and non-financial support and ownership of international property rights (IPRs) contribute to the business development of the medical device university spin-offs (USOs)?* (Response in Paper 2)
  A comparative analysis of models for building innovative systems gives an advantage in the form of cost reduction and increased results. Successful practices in building innovative ecosystems can be adapted to new circumstances and can serve as an example for decision-makers and new entrepreneurs.
- *How do life science accelerators contribute to changing a business ecosystem?* (Response in Paper 3)
  Life science business accelerators are new participants in the ecosystem; their role and position are not fully defined. A greater understanding of the contribution of business accelerators to the development of innovation ecosystems will increase the chances of companies' success and can lead to the development of the entire innovation ecosystem.
- *Can the social capital of opinion leaders contribute to the market adoption of start-up innovations, and if so, how?* (Response in Paper 4)
  Usually, the social capital of a start-up is not seen as the company's key resource. However, the benefits of its use and application in business are underestimated. Collaboration built on well-used social capital can replace the lack of other resources inherent in start-ups.

Each paper included in the dissertation is a step toward achieving the goal of the research and answering the main question. The study begins by examining the business model for a Finnish biomedical company that offers a new approach to overcoming industrial barriers and creating value for the customer. The study of an innovation ecosystem using the example of an orthopedic veterinary practice gives us an understanding of its functionality, the main participants, and the process of shaping development trends. The existing competition and the peculiarities of the development of the innovation ecosystem give few chances for a significant market share of the company that does not offer innovation, including the business model innovation. Therefore, capturing value using new technologies becomes an opportunity for the company to take its place in the market and create the preconditions for the formation of its own ecosystem (RQ1).

Next, we explore how the financial support and intellectual property rights (IPRs) of university spin-offs impact the development of MedTech innovations in Finland and Sweden. The role of the state in financial and non-financial support of start-up entrepreneurs is the most important in the MedTech industry. Policymakers have different perspectives of the possibilities of using state and university resources for the development of innovation ecosystems, which

affects the commercialization of innovations, business development, and the attractiveness of entrepreneurship for university staff. The prioritization of the approach to support innovation ecosystems rather than the interests of an individual participant provides additional incentives for the development of the entire market (RQ2).

In the third paper, we explore new participants in MedTech, biotech, pharma, and other industries – life science business accelerators. An analysis of their activities provides an understanding of how the focal accelerators contribute to the development of innovation ecosystems in Finland, Sweden, Denmark, Germany, and Holland, what benefits the program participants gain, and how they differ from other industries. We also demonstrate how participants respond to being part of the business accelerator program and how business accelerators contribute to the development of their business. We are talking about an important place in the innovation ecosystem that a life science business accelerator can take with proper positioning and promotion of its program (RQ3).

In the fourth paper, we explore what other non-financial opportunities new companies can receive from the innovation ecosystem to get their place in the market. In this case, opinion leaders – leaders of professional associations – influence the development of the business of a particular company and the entire industry as a whole. We demonstrate that other participants may be interested in cooperating with new companies and projects not only by accepting money or company shares in payment. For example, opinion leaders may be driven by a desire to change the industry and address important issues for their patients. The social capital of opinion leaders could become a value that will allow a company to first assess the chances of a project for success, participate in product development and testing, and then support and develop sales (RQ4).

The increase in knowledge during the research occurred gradually; new ideas for research appeared during the work on the project. The idea for Paper 1 was inspired by the ongoing collaboration of the research team with the studied company. Moreover, further research and papers included the path traveled by the focal company and its development and relationship with the innovation ecosystem. The study for Paper 2 was conducted after identifying the opportunity gap for MedTech start-ups in Finland and Sweden. The research idea for Paper 3 was proposed after the business accelerator program was completed by a company that participated in the Paper 1 research. In turn, Paper 4 is a continuation of the research started in Paper 1, where we identified the collaboration between opinion leaders and the company that contributed to the formation and development of the start-up. Therefore, the presented papers will allow the reader to gain a more structured understanding of the MedTech innovation ecosystems, gradually increasing knowledge in this area.

1.4 Structure of the thesis

In the Introduction chapter, I include a background, motivation for research, and the formulation of a research question of the study. Next, I turn to the Literature

review, where I give definitions of the key terms used in the thesis, as well as the current state of research in the field of innovations, innovation ecosystems, and the MedTech industry. After that, I propose a qualitative methodology that is used in my papers, including research strategy, data collection, and analysis. I continue with the Results section, where I demonstrate how the proposed papers contribute to answering the research question. In the Discussion section, I offer my contribution to the literature and specify exactly how my research increases knowledge in the field of MedTech innovation ecosystems.

The next part consists of four research papers that are mentioned in the thesis as Papers 1–4.

Paper 1. Kulkov, I., Hellström, M. and Wikström, K. (2021), "Struggling with conservatism: entrepreneurships' challenges in business model design," *International Journal of Value Chain Management*, Vol. 12, No. 1, pp. 45–61. https://dx.doi.org/10.1504/IJVCM.2021.112844 (Kulkov, Hellström & Wikström 2021)

Paper 2. Kulkov, I., Berggren, B., Eriksson, K., Hellström, M. and Wikstrom, K. (2020), "The importance of financial resources and ownership of intellectual property rights for university spin-offs: the cases of Finland and Sweden," *Journal of Small Business and Enterprise Development*, Vol. 27, No. 7, pp. 1125–1147. https://doi.org/10.1108/JSBED-09-2019-0308 (Kulkov, Berggren et al. 2020)

Paper 3. Kulkov, I., Hellström, M. and Wikström, K. (2020), "Identifying the role of business accelerators in the developing business ecosystem: the life science sector," *European Journal of Innovation Management*, Vol. 24 No. 4, pp. 1459-1479. https://doi.org/10.1108/EJIM-04-2020-0139 (Kulkov, Hellström & Wikström 2020)

Paper 4. Kulkov, I., Barner-Rasmussen, W., Ivanova-Gongne, M., Tsvetkova, A., Hellström, M. and Wikström, K. (2020), "Innovations in veterinary markets: opinion leaders' social capital," *Journal of Business & Industrial Marketing,* Vol. 36, No. 13, pp. 40–53. https://doi.org/10.1108/JBIM-02-2020-0098 (Kulkov, Barner-Rasmussen et al. 2020)

More detailed information on papers is presented in Table 1.

Table 1. Detailed information about objectives, research design, main data sources, study cohorts, and analysis methods in Papers 1–4

	Paper 1	**Paper 2**	**Paper 3**	**Paper 4**
Title	Struggling with conservatism: entrepreneurships' challenges in business model design	The importance of financial resources and ownership of intellectual property rights for university spin-offs: the cases of Finland and Sweden	Identifying the role of business accelerators in the developing business ecosystem: the life science sector	Innovations in veterinary markets: opinion leaders' social capital
Objectives	To analyze the veterinary ecosystem and business processes that might help provide leadership for the existing ecosystems or develop a new system	To study medical device university spin-offs, accounting for the peculiarities of direct and indirect financial support and intellectual property rights	1. To determine the position of life science accelerators in the business ecosystem and the attributes of support for start-ups 2. To identify key features of the life science accelerators that contribute to the change in business ecosystems	To identify how the personal social capital of opinion leaders contributes to the market adoption of start-up innovations
Research design	Single case study	Multiple case study	Multiple case study	Single case study with three subcases

	Paper 1	Paper 2	Paper 3	Paper 4
Main data source	Finnish start-up with a specialization in the veterinary industry	Four Finnish and four Swedish spin-offs	Five European life science business accelerators	Three projects of the Finnish start-up
Study cohort	CEO, CTO, investor, opinion leaders	Founders of the companies	Managers and advisors of accelerators, participants and alumni of the programs	CEO, CTO, private investor, project managers of TraceRay, opinion leaders
Analysis method	Context analysis and CIMO logic	Within-case and cross-case analysis	Within-case and cross-case analysis	Action research

2. Literature review

2.1. Basic definitions

Before starting to analyze the literature on innovation ecosystems, I propose some definitions of the innovation ecosystem concept components, such as innovation, system, ecosystem, and innovation system.

There are many definitions for the term *innovation*, which is generally defined as a result of a process with some novelty of change and usefulness of application for the user (society, country, company, etc.) (Granstrand, Holgersson 2020). Modern use of the innovation concept was proposed by Schumpeter (1934) in the course of analyzing events for the development of economic systems. Innovation can also be presented as the transformation of an intelligent solution into a new product or knowledge that did not exist before, followed by the implementation and creation of new value for the user or customer (Kline, Rosenberg 2010).

A *system* is a collection of elements and relationships between them. In turn, systems analysis is a way to characterize elements and their relationships (Ackoff 1971). An open system transforms inputs into outputs by means of participants who interact with each other and their environment (Von Bertalanffy 1968).

The term *ecosystem* was originally used in biology in reference to the exchange of energy and material. Shaw and Allen (2018, p. 90) describe an ecosystem as follows: "recycling flows of nutrients along pathways made up of living subsystems which are organized into process-orientated roles; connects living and non-living subsystems; energy gradients power recycling of scarce nutrients, e.g., a rainforest." However, not all researchers agree with the interpretation of "eco-" in the word "ecosystem." Papaioannou et al. (2009) declare a mistaken approach when comparing artificial and biological systems. Artificial systems use and recognize control rules, and there is also an intent to form and use artificial ecosystems in contrast to biological ones.

In turn, the *innovation system* is a systematic approach to the analysis of innovation research (Granstrand, Holgersson 2020). The study of an innovation system must be approached from different angles. The system is inextricably linked with such components as universities, government support for the industry, all types of investment companies, public and private enterprises, and much more. The literature also contains the concept of a regional innovation ecosystem – it is an infrastructure to support innovation in the production structure of the region (Asheim, Gertler 2005). Gamidullaeva (2018) emphasizes the role of open innovation and a more specific distribution of the roles of participants in the formation of a regional innovation ecosystem. Hwang (2013) describes the "external" participants in the corporate innovation ecosystem and their role in functioning. City-based innovation ecosystems and innovation districts are aimed at developing the formation of new and small companies in a particular region, most often planned by the city municipality in cooperation

with universities (Yan et al. 2018). However, they are primarily engaged in real estate development, and then business development. University initiatives to shape an ecosystem can be interpreted as an entrepreneurial ecosystem. The focus on entrepreneurs is described in Fetters and colleagues (2010) and Morris and colleagues (2017). The sectoral innovation system is another related concept, which refers to a set of companies engaged in developing products and technologies (Breschi, Malerba 1997). A corporate innovation system is a set of participants and connections between them, which are important for the innovative activities of a corporation or groups of companies (Granstrand 2000).

2.2. Differences between innovation, entrepreneurial, and business ecosystems

The concepts of the business ecosystem and innovation ecosystem are often substituted for each other in the literature. In the classic work of Moore (1993), cooperation and competition in business ecosystems are considered simultaneously. Business ecosystems are considered as a number of companies working together to develop innovations and offer them to the market on a competitive basis. The integration of these innovations creates a trend and a need that leads to the next round of innovations. In turn, an innovation ecosystem is formed through the collaboration of companies working together to develop innovations (for example, Gomes et al. 2018). However, the development of the innovation ecosystem concept has led to the formation of many definitions, which also included competition between companies (Mantovani, Ruiz-Aliseda 2016, Hannah, Eisenhardt 2018), technology competition (Arthur 1989), and competition and the importance of products (Nambisan, Baron 2013).

The concept of an innovation and entrepreneurial ecosystem emerged as a reaction to the development of a particular region or an entire country. On the one hand, the terms differ from each other, as one ecosystem is focused on the creation and development of entrepreneurs, and the other - innovation. The entrepreneurial ecosystem is aimed at people, and the innovation ecosystem is aimed at shaping and developing innovation and knowledge. On the other hand, innovation is the center of entrepreneurial activity, transforming from inventions to innovation through the use of entrepreneurial activity (Xu and Maas, 2019).

Entrepreneurial and innovation ecosystems aim to allocate resources to form and replicate high-growth, innovation-driven enterprises. In turn, business ecosystems aim to foster innovation and linkages between companies. Entrepreneurial and innovation ecosystems have local impact, while business ecosystems bring companies online and offline. Entrepreneurial and innovation ecosystems develop by increasing internal connections and trust between stakeholders, business ecosystems are improving through the use of new technology platforms (Thomas et al., 2019). Researchers often confuse readers

by using the concepts of innovation, entrepreneurial, business, and other ecosystems interchangeably.

It is also worth noting that in the course of the research, the terms *business ecosystem* and *life science business* were used, while in the thesis, I use *innovation ecosystem* and *MedTech*. This is mainly due to the fact that the terms *business ecosystem* and *life science business* were offered by interviewees and business partners. However, while writing the thesis and through in-depth study of the topic, it was found that the innovation ecosystem is more suitable for research, since we consider cooperation between participants more than their competition. Moreover, the articles have a regional emphasis, which is unusual for business ecosystems. In turn, the life science industry includes a lot of areas that were not considered in the course of the study. MedTech includes fewer areas that more accurately define the business of the studied companies.

2.3. Innovation

The classic definition of innovation proposed by Schumpeter (1934) is "the introduction of new or significantly improved products (goods or services), processes, organizational methods, and marketing methods in internal business practices or the marketplace." The majority of countries consider innovation as a source of economic growth and human well-being (Verspagen 2005). The technology sector is rightfully considered a source of high growth potential (Scherer 2011). One of the best ways to stimulate the formation of new companies and jobs is to support the transfer of innovation from research laboratories to industry. The unstable economic situation at the present time – caused by the pandemic, lockdown, reduction in consumption and the number of jobs – creates a need for new ways of developing the economy and stabilizing society. The growth potential of tech industries is pushing decision-makers to take a closer look at the needs of innovation ecosystems and accelerate the transfer of knowledge from universities to industry.

The development of humanity is inextricably linked with the creative abilities of individuals as a source of transformations in culture, society, and technology. The terms *invention* and *novelty* characterize the essence of innovation. They include such factors of innovation as actions, participants, resources, output, value, conditions, specifics, and much more (Antonelli, Crespi & Scellato 2013). These characteristics evolve over time, and the importance of some factors decreases or increases under the influence of certain factors or players. Currently, the rate of change of factors is maximum and contributes to the growth of competition, and as a result, there is an increase in the number of products and services that can change the usual state and consumption. Innovation researchers propose different types of classification and typology of innovation (Garcia, Calantone 2002, Linton 2009, Oke 2007). However, innovation in general includes open, eco, technological, user-driven, social, cultural, transformative, institutional, inclusive, green, lean, grassroots, low-cost, public, and other types of innovations (Edwards-Schachter 2018). The definition of innovation continues to undergo constant change and development under the

influence of new emerging conditions (Fagerberg, Verspagen 2009, Godin 2015, Gupta et al. 2003). Nevertheless, there is a trend in the literature on the future of innovation (Fagerberg, Martin & Andersen 2013, Lundvall 2013, Martin 2016, Fagerberg 2018). Much of this discussion focuses on the role of non-technological factors that drive innovation and product innovation in the market. These factors include all sorts of social aspects of value formation, the type of created value, the conditions for the formation, and dissemination of successful innovation.

Innovation today is everywhere around people and companies. Companies that use the concept of innovation in their business pay attention to it at all levels, including the vision and mission (Kahn 2018). Centers for support and development of innovations appear everywhere, and universities are becoming the center of attraction for the innovation process and companies based on innovations (Feller, Ailes & Roessner 2002). Nevertheless, some companies consider innovation as something unattainable and accessible only to large companies with significant resources (Wagner, Hansen 2005). This is largely due to the fact that management perceives innovation as something completely new and radical in relation to existing analogues; small changes are not perceived as something sufficient and falling under the definition of innovation. Indeed, radical innovation is risky and requires significant company resources, but there are small or gradual innovations that allow companies to succeed in their industry or their own niche.

In this thesis, I use the definitions of innovation proposed by Merriam-Webster (2017) and Edwards-Schachter (2018) as a combination of something new and a new idea, method, or device. This combination defines innovation as a result of activity and, at the same time, a process. Results-based innovation is associated with new products or services, processes, marketing changes, business model innovation, and changes in organizational structure. There are several main types of innovation: product innovation (Cooper 2005), product improvements (Sivakumar, Feng 2019), increase of assortment, entering new markets (Johnsen, Johnsen 1999), an old product for new purposes, and a new product or service that has never been offered in the world before.

The governance of innovative projects is related to the marketing strategy of the company, that is, how the innovation will be developed, tested, and introduced to the market. Most MedTech start-ups choose to enter the market with a new product or service (that is, innovation) or to enter a certain market with the help of an innovation that has previously been tested in another market. The key difference between these strategies is the level of innovativeness of the new technology. A market penetration strategy uses a technology known to the market, and a product development strategy uses a new technology. Market penetration is characterized by an increase in market share and increased use of a new product or service. The existing market does not undergo significant changes; new consumers do not appear. The most frequent manifestations of this technology are a decrease in price for the consumer or a change in the characteristics of a product or service, making it more attractive for use; the

frequency of use of a novelty may increase. Start-ups are less likely to use a product development strategy, that is, increase sales through the use of products already on the market. Increasing the assortment or applying a product in a new niche provides more variety for a potential customer, thereby helping to increase the company's income. The trend of current product innovation is primarily aimed at the customer (Von Hippel 2006). The essence of this trend is that innovation processes should be customer-oriented and should take place under the leadership of the customer, whereas previously, this process mainly aimed to solve the needs of the manufacturer. Customer orientation refers to the exchange of developments and innovations of most novelties and inventions, while manufacturer orientation offers a "defensive" type of interaction, including patenting and research information closure. However, user involvement in the development process is nothing new in management and business practice (Von Hippel 2006). The benefits of being involved in the evaluation of an idea, the development of a product or service, and promotion of a company in the market are well known. Nevertheless, companies still have a wide field of action on how to involve other participants in a new project, especially if the initiative comes from a new and unknown company on the market. How exactly can a start-up capture the interest of potential customers without attracting significant resources, and how can it accelerate the validation of ideas and products and offer a product that will be interesting to the mass market?

Business model innovation is often a disruptive way of changing a market or industry (Aminoff et al. 2017). Business model innovation is classified as innovation in a specific industry, innovation in the way of generating income, and innovation in the model of the company (Massa, Tucci 2013). Industry innovation includes moving into new industries that were previously unavailable to the company, transforming old industries and offering consumers a new vision and opening up new markets. Innovation in how a company generates revenue implies a new concept that incorporates company values. The business innovation model is based on the role that the company receives in the new value chain, together with its employees, suppliers, manufacturers, consumers, and other stakeholders. Amit and Zott (2012) believe that business model innovation is the next step in understanding product and process innovation. Business model innovation is the next most important innovation parameter after processes, products, and organization. The business model innovation differs from the usual ways of creating and capturing the value inherent in a product on a particular market. Information technology is considered by many researchers to be an accelerator of many business model innovations (for example, Amit, Zott 2001, 2012).

Innovation is the foundation for the development of MedTech innovation ecosystems. Nevertheless, in this thesis, I focus more on the business model innovation (Papers 1, 2, and 4) than on other types, as well as how the innovation ecosystem influences the formation and development of MedTech innovation.

It is necessary to form and maintain a business environment that will focus on the emergence of innovations in the company. Reducing costs, identifying new

channels of interaction with the customer, and entering new markets should be part of the company's culture and supported by all employees. Employees must see the benefits of the company's innovation, thereby improving not only the goods and services it produces but also the lives of consumers. In the modern world, there are many approaches to making innovations. "Mixed modes of innovation" (OECD 2017, p. 154) based on cross-sectoral collaboration is an important mode of invention that leads to innovation. Such hybrid innovations are changing markets and societies, lowering barriers, and changing culture.

There is a lot of discussion about the reasons for the success and failure of technology start-ups (Cantamessa et al. 2018, Santisteban, Mauricio 2017). In turn, MedTech start-ups have some peculiarities, but in general, they are subject to general principles. Of course, most researchers and practitioners see the team as the most important success factor for the MedTech project (Hasche, Linton 2018). A great team of the company with a poor product is preferred to a poor team with a great product. A strong team is more likely to succeed as it can refine the idea to a result and, if necessary, change priorities, while a poor team is more likely to ruin a good project. Despite the fact that Chief Executive Officers (CEOs) of companies are mostly represented in the media and we associate the success of a company with a specific person to a greater extent, entrepreneurship is not an individual sport. On the one hand, research shows that the success of a project increases dramatically if the founders are a team of four to five members (Graham 2012, Kollmann et al. 2016). Moreover, the success of the project is increased if the skills of the team members can complement each other; the similarity of the experience and skills of the team founders adds less chance of success. In addition to complementarity, each team member must have expertise that is not questioned by either the other team members or the project partners. On the other hand, a start-up can face financial difficulties due to a large start-up staff and, possibly, the inability to work in multitasking mode. Successful technology start-ups, including MedTech, often include (1) a technical manager or engineer who is responsible for the hardware and becomes the Chief Technical Officer (CTO) of the project, and (2) a marketing and sales specialist who is a CEO that is responsible for negotiations with partners, the formation of a vision of the project, and other things. It is they who become the key basis of the project. Some researchers also add a member to a successful team who has access to funding and partly deals with the internal processes of the company; however, most start-ups cannot boast of such opportunities (Rompho 2018). The second most important component of a successful technology project is invention (Chen, Yin & Mei 2018, Kline, Rosenberg 2010). Investors considering projects for cooperation expect the existence or potential for innovation. To interest an investor, a start-up must offer an innovation or even several to potential customers. According to some expectations, the unique value proposition of a start-up should be ten times higher than its counterparts in order for a company with streamlined business processes to switch to a new start-up solution (Metrick, Yasuda 2021).

One of the frequent challenges young innovative companies face is overcoming the Valley of Death (Corallo et al. 2019, Wessner 2005). On the one hand, there are significant financial resources offered by states to support basic academic research. On the other hand, the industry can afford investments in product development. In the interval between these stages, there is a significant gap for projects that must go through the stages of demonstration and the development of technology and proceed to commercialization. It is at this stage that many innovations die due to a lack of resources before reaching the market when investors or industry can identify and support the potential of a new product or solution. In turn, the MedTech market is further complicated by the need for lengthy research and subsequent approvals with regulatory authorities to enter the market (Heiss 2017, Vlckova, Thakur-Weigold 2019). Combining the need to conduct long-term and resource-intensive research reduces the attractiveness for non-core investors, which in turn reduces the desire of potential entrepreneurs to move to the commercialization of research. Public investment can be one solution to overcoming the Valley of Death (Laplane, Mazzucato 2020). Innovation ecosystems are just being formed in order to focus efforts and resources in a specific area and to provide an opportunity for the development of the direction and more competently allocate resources invested in education and regional development. Attempts to unlimited public investment in a certain area may not give the expected result (Jackson 2011). The resources of the innovation ecosystem may support many non-viable projects, the results of which will be unclaimed by the market and will not find their niche in the local and global markets. The combination of investments with other factors influencing the transition of innovation from the laboratory to the industry, for example, training in entrepreneurial skills, networking, expertise, etc., contributes to building sustainable innovation ecosystems that can produce competitive products and increase their attractiveness to new participants.

However, getting out of the Valley of Death is not just about a lack of investment. The project may not survive this period for other reasons that may not be related to funding. First, this may be due to the part-time employment of the project's founders. Insufficient time may be devoted to the project initially, perhaps due to the search for investment or to the need for personal funds in the project. However, even with the initial investment, not all founders are ready to switch completely to a new project because it is not yet generating income (Oe, Mitsuhashi 2013). Second, a project developed alone requires increased motivation to continue working on it in the face of a lack of time and energy. Most successful projects are well-coordinated teamwork, where there is mutual assistance of the project participants. If the founder cannot bring along several partners and convince them of the need for the product, then it can also be difficult to attract customers. The combination of the skills and expertise of several people will have a positive impact on the scale of the project and the likelihood of success (Cantamessa et al. 2018). Third, the diversity of a company's board of directors also has a positive impact on its development. MedTech innovation is impossible without competent engineers and

researchers. However, business competencies are equally important for the successful development of a company (Wrobel 2018). The ability to continue working with internal resources and motivation despite the absence or negative results is a frequent challenge for an entrepreneur. Some of the projects were probably closed a few steps before success due to the burnout of entrepreneurs. An entrepreneur with an innovation must have unlimited patience, faith in the result, constant ideas, and stimulation to continue, despite the fact that it will feel more like running on the spot (Stewart, Roth 2007, Shane, Scott, Locke & Collins 2003).

Therefore, innovation is an opportunity for a company to differentiate itself from other market participants in order to reduce the likelihood of failure and increase the likelihood of success. The term *company* should be understood not only for commercial organizations but also non-commercial, government, social, and other forms. Innovation is associated with human evolution, changes in society, and the introduction of new ideas, referring not only to the product but also to the methods by which changes occur. Changes can be planned and spontaneous, with the need for global change and small and imperceptible improvement.

2.4. Innovation ecosystem

The number of publications devoted to innovation ecosystems has been constantly growing over the past 15 years (Granstrand, Holgersson 2020). The growth in the use of this concept in the literature and in practice happened after the publication of Adner (2006), in which the author proposes a definition of the innovation ecosystem as "the collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution" (Adner 2006, p. 2). Using the concept of an ecosystem, researchers identify a problem and further study a variety of companies and their interrelationships, the formation of value within an individual company and the entire ecosystem, and the exchange of information and resources (Peltoniemi, Vuori 2004). Jackson (2011) defines an innovation ecosystem as follows: "the complex relationships that are formed between actors or entities whose functional goal is to enable technology development and innovation." Among the participants in the innovation ecosystem, the author notes "material resources (funds, equipment, facilities, etc.) and the human capital (students, faculty, staff, industry researchers, industry representatives, etc.) that make up the institutional entities participating in the ecosystem (e.g., the universities, colleges of engineering, business schools, business firms, venture capitalists, industry-university research institutes, federal or industrial supported centers of excellence, and state and/or local economic development and business assistance organizations, agencies funding, policymakers, etc.)." Therefore, the concept of an innovation ecosystem includes many participants and their relationships, which together contribute to the value creation and its further capture (Ketonen-Oksi, Valkokari, 2019). However, it is worth noting that the innovation ecosystem is not heterogeneous. An innovation ecosystem consists of

two large but separate components, namely the research component or research economy, which is responsible for fundamental research, and the commercial component or commercial economy, which is responsible for commercializing the results of theoretical research (Oh et al. 2016). Jackson (2011) notes that the goal of any innovation ecosystem is to create innovation. To achieve this goal, all the resources of the innovation ecosystem are directed, as well as the participants and their relationships. Moreover, Jackson (2011) does not limit the innovation ecosystem to geographic boundaries and explores the interactions between participants in the innovation ecosystem without location binding. However, the term innovation ecosystem can often be replaced with similar terms as "innovation support systems" (Chen 2014), "innovation support platforms" (Seo 2014), or others. Therefore, the number of variations of the term "innovation ecosystem" and its definitions is large. Researchers emphasize one of the parameters of the innovation ecosystem and interpret it based on research needs.

Business ecosystems go beyond one industry, while innovation or entrepreneurial ecosystems are more focused on a particular industry and are located within one city, region, or country (Côté, Cohen-Rosenthal 1998, Jackson 2011). The degree of development of an ecosystem is also determined by its sustainability in new breakthrough innovations, the number of these innovations, the possibility of the emergence of new companies, cooperation with other ecosystems, etc. (Adner 2006). In general, an ecosystem is an interconnection of suppliers, consumers, manufacturers, and other participants that create and capture shared value (Granstrand, Holgersson 2020, Iyawa, Herselman & Botha 2016). Xu et al. (2007) and Carayannis and Campbell (2009) offer a new perspective on the innovation ecosystem by looking at non-technological dimensions and highlighting the importance of non-technological components such as institutions, culture, strategy, and others.

However, the term *innovation ecosystem* has several differences from the proposed concepts of technology parks, regional innovation systems, clusters developing specific areas, and others. First, it is a more systematic approach to developing a specific area. Multiple connections within an innovation ecosystem foster innovation (Oh et al. 2016). Relationships and methods of communication between the cooperating participants determines their diversity and can subsequently lead to the emergence of new outcomes. Second, these are information technologies, which play an important role in the formation and development of new products and services and also unite the participants in innovative activities (Ghobakhloo et al. 2012). Third, innovation ecosystems imply the presence of open innovation, including alliances, licensing, and open access to information, which combine to form new ideas and solutions (Chesbrough, Kim & Agogino 2014). A new value is being formed that was not previously available due to the limitations associated with the dissemination of information and collaboration. Fourth, an innovation ecosystem always has its own niche or specialization, in which companies from different fields or industries can cooperate, but they aim to create value in a certain way

(Jucevičius, Grumadaitė, 2014). The fifth point refers to the role of the state in the development of the innovation ecosystem. On the one hand, some researchers emphasize a decrease in the role of public influence on the innovation ecosystem. Previous forms of innovation development as technopolises were much more dependent on the action of the state and could be characterized as a public-private partnership (Oh et al. 2016). On the other hand, due respect and attention is paid to the state form of support for innovation ecosystems as a framework that regulates activities and state educational programs influencing the formation of industries and innovation ecosystems (Jugend et al. 2020).

The geographic localization of the innovation ecosystem makes it possible to concentrate on the development of a specific technology and to form a strategy for its development at the local level. Silicon Valley in the U.S. could be an example of a successful innovation ecosystem (Jackson 2011). Innovation ecosystems can be formed on almost any topic, for example, energy (Surie 2017), car manufacturing (Ding, Ye & Wu 2019), or maritime (Garcia, Wigger & Hermann 2019). Innovation ecosystems are considered healthy and successful if the private and public money invested in scientific development is subsequently replenished and multiplied by the formation of value in the industry caused by these innovations. When the funds received exceed the amount of funds invested in R&D, this situation is called the growth of the innovation ecosystem.

A sustainable innovation ecosystem could be considered a situation when it has sufficient income to cover all the costs and failures associated with research and doing business (Jackson 2011). The high risks of investing in start-ups and technology projects form requirements that investors place on projects. The most important is that successful projects in the innovation ecosystem must cover the costs of its development. Since the vast majority of projects that emerge in the innovation ecosystem will fail, the system must be able to stop investments from potentially losing projects and must also be able to reuse resources to create new value. The reuse of human capital plays an important role in the development of an innovation ecosystem (Jackson 2011). An experienced entrepreneur will move faster toward a new goal, time, and financial investments in its own development, and the network will be used more optimally.

The success parameters of an innovation ecosystem may also be the number of companies, entrepreneurs, and research in the particular industry or territory, the number of world-class projects, a culture aimed at developing entrepreneurship, access to investment, or a developed administrative and legal environment (Phillips 2006). An innovation ecosystem is not just a combination of costs and revenues (Valkokari 2015). A direct approach to comparing income and expenses may lead to incorrect results. For example, different actors in an innovation ecosystem may strive for different results. Companies seek to increase income and market share, policymakers can seek to increase employment and reduce social tension in society, or people may want to increase their quality of life and well-being (Oh et al. 2016). The sustainability and

development of an innovation ecosystem also depends on the ability to identify bottlenecks and fill them as quickly as possible. Moreover, the success of an innovation ecosystem can also be measured by the ability to support human capital development and tolerance for failure (Hutchison-Krupat, Chao 2014).

A sustainable innovation ecosystem offers its participants not only material benefits but also mechanisms for building relationships and exchanging intangible assets. Intangible assets contribute to business development and attract, for example, tangible assets, if necessary. For MedTech innovation ecosystems, this can be networking, access to laboratories, expertise, patient data, and so on. The identification of other important intangible assets and the possibility of their use is of particular interest from the side of the business, which is often in a difficult financial condition at the initial stages of development. Timely and correct use of intangible assets can lead to accelerated business development and reduce the likelihood of failure.

Despite its popularity, researchers are ambivalent about this concept, and opinions diverge to diametrically opposite ones. There is a lot of criticism of the concept of an innovation ecosystem, its usefulness, and its similarity to a biological analogue (Oh et al. 2016, Basis, Armellini 2018). Other authors who agree with the criticism, however, argue that this concept is appropriate and complementary to research in the field of innovation management (Ritala, Almpanopoulou 2017). The third group of researchers pays increased attention to the focal concept, highlights various methods and approaches, and explores the features of construction depending on the industry (Baiyere, Salmela & Tapanainen 2020). However, there is a lack of coherence among researchers about what an innovation ecosystem is, despite its many definitions.

For this study, I will adhere to the terminology proposed by Autio et al. (2018). An innovation ecosystem is a structure for the co-production of value to a defined audience. Companies cooperate with each other more than they compete, the roles of the participants are predetermined, and the business model innovation is an important factor for achieving success in the market. The MedTech innovation ecosystem is focused on producing value for the healthcare industry, which includes physicians, patients, hospitals, and other actors. Value is mainly generated on the basis of scientific knowledge, special attention is paid to the development and certification of products and services, and significant resources are often required to bring a product to market.

2.5. MedTech industry

MedTech can be one area that brings a lot of innovation. This industry offers equipment, technologies, and medicines for healthcare. There is a constant solvent demand for improving the quality of medical services and technologies that can reduce treatment costs or provide new solutions that were previously unavailable (Fuchs, Sox Jr. 2001).

The MedTech industry is developing rapidly thanks to the introduction of new technologies. MedTech includes the pharmaceutical industry, biotech, medical devices, and healthcare information technology, which are characterized by

innovation and continuous excellence (Lee 2018). MedTech includes all types of products that are used to treat medical diseases (Hasche, Linton 2018). The goal of MedTech products and solutions is to improve the quality of medical care by reducing time and financial costs of treatment, reducing invasive activities, and accelerating patient rehabilitation (Lee 2018). Many MedTech innovations have served as the basis for the formation of technology products, as well as for the companies that promote them. Over the past decades, the MedTech industry has undergone significant growth due to its importance to society and to solving the necessary problems people face.

Professional investments in MedTech are mainly made by serial entrepreneurs in the field, angel investors, and venture capitalists (Jackson 2011). However, this industry is not very different from others. Only one in ten professional investments can qualify for success (Metrick, Yasuda 2021). Working with professional investors and using standard due diligence procedures does not significantly reduce the risk of failure. Professional investors cannot guarantee the success of a project, as there are many uncontrollable factors in the market that cause companies to fail. In MedTech areas, this includes factors specific to this industry, for example, complex approval procedures by state certification bodies as well as common reasons, such as a lack of market for a product, poor management and incorrect company strategy, and strong competition, etc. (Vlckova, Thakur-Weigold 2019, Heiss 2017).

MedTech is a fairly broad concept that includes a large number of products and solutions in the field of healthcare. For example, there are about two million different medical devices on the market, which are combined into seven hundred groups (Chatterji 2009). A medical device can be an instrument, implant, device, software, etc. that can be used for medical purposes (Kucklick 2012). Another popular MedTech solution is electronic medical records, which are an electronic storage of patient information. With the help of such solutions, the transfer of patient information between doctors and clinics is greatly facilitated. It stores information about tests, used drugs, diagnoses, and more. The reliability of storage and the provision of remote access favorably distinguish electronic medical records from paper ones. In turn, Internet portals connect patients and their electronic health records to interact with selected doctors and hospitals. The use of such solutions reduces the likelihood of information loss or its inaccurate interpretation, the need for repeated tests when moving to a new clinic or changing doctors, etc. The world leaders in MedTech innovation are Johnson & Johnson and GE Healthcare (Donzé, Imer 2020, Vlckova, Thakur-Weigold 2019).

Innovation, methods, technologies, and processes associated with this concept are an important and urgent issue for the development of the economic well-being of countries. The number of studies devoted to innovation and various ecosystems is huge. The task of this work is to identify the key success factors for the development of an innovative ecosystem and the mechanisms for successful support of innovative companies using the example of the MedTech

industry. Companies benefit from using the resources of the innovation ecosystem; however, many non-standard solutions are less commonly used in practice and may not be available to entrepreneurs. Exactly how MedTech innovation ecosystems contribute to the formation, development, and success of companies is an important under-explored issue in the literature. Successful practices can be tailored to meet the needs of emerging ecosystems in order to increase the likelihood of success for companies and the growth of the MedTech innovation ecosystem as a whole.

The study of the available academic literature confirmed the relevance of the research question, which requires additional attention. The theoretical contribution of the work consists of the development of knowledge about a specific innovation ecosystem and the formation of a successful framework for the possibility of using and copying under other conditions. Identification of the key success factors for the development of a successful MedTech innovation ecosystem can be in demand for decision-makers when it comes to the development of the MedTech innovation ecosystem and the companies participating in it. As a result, the number of new companies will grow, the innovative potential of existing ones will increase, the transition from invention to innovation will be easier and more convenient, and society will benefit from new medical solutions that increase the quality of life.

2.5. Specificity of formation MedTech start-ups

Despite the fact that there are numerous successful large and medium-sized MedTech companies (Vlckova, Thakur-Weigold 2019, Daiberl et al. 2019, Borsci et al. 2018), most of the suggested experience is hardly applicable to start-up companies. Like most other medical research, the commercialization of MedTech results requires a large number of resources. Investors often underestimate the MedTech area due to the long time it typically takes to bring a product to market, the need to refine the product in expensive laboratories, and the frequent lack of business experience among founders from universities (Shah, Robinson 2007, Boni 2018). MedTech start-ups do not have sufficient financial, social, and time resources for successful development, and they suffer from a lack of necessary networks for and experience in the commercialization of products. Local universities are the source of most MedTech innovations and are suppliers of qualified academic staff to the industry, which can include masters, PhDs, postdocs, and senior researchers. However, the successful transit of personnel is limited due to the narrow medical specialization of researchers with little knowledge and skills to commercialize their research results and develop businesses. Start-ups are forced to resort to any available resources that are offered through innovation ecosystems to increase their chances of success. Moreover, there is a problem in the absence of standards for building successful MedTech innovation ecosystems, primarily those associated with the formation of new companies (Chaturvedi, Pappu 2017, Cervini, Dogwiler 2020).

Entrepreneurs may consider high profits if the market chooses their product or solution (Heiss 2017). However, most companies cannot overcome the

existing industrial barriers and business issues. The likelihood of a company failing or not launching a product on the market is very high (Zakery, Saremi 2020). Key obstacles to the commercialization of MedTech innovations include a long development cycle, significant investments, and complex knowledge transfer from laboratories to industry, etc. All this could reduce the attractiveness of the industry for investors and potential entrepreneurs who could start doing business. It is also worth considering the high probability of acquiring start-up companies by large players. MedTech start-ups may set a goal to develop a company up to a certain point, for example, the appearance of a minimum viable product or a technology validation and subsequent sale to large companies that have sufficient resources to bring a product or service to market (Genchel, Mårtensson 2016). Therefore, serial entrepreneurship in MedTech could mean a kind of R&D conveyor, where entrepreneurs develop several projects at once or start working on a new project after the completion of the previous one.

3. Research methodology

This chapter presents information about methodological issues, the chosen research strategy and design, and the data collection approach.

3.1. Research philosophy

Burrell and Morgan (1979) identified four research paradigms: radical humanist, radical structuralist, interpretive, and functionalist. Research refers to positivism, postpositivism, critical theory, and constructivism as key research paradigms (Guba, Lincoln 1994). Subjectivism or social constructionism forms an environment consisting of the personal impressions and experience of an individual and differs from the opinions of other individuals (Eriksson, Kovalainen 2015). Therefore, the studied phenomenon is based on the interpretation of events in the studied reality and the perspectives of case participants. The most common forms of interpretivism and constructionism for qualitative research in social science are subjective and shared meanings (Eriksson, Kovalainen 2015). There are some minor differences between interpretivism and constructionism, but for this study, the terms are used interchangeably. In my work, I hold the view that there is no one single absolute truth. Rather, it is worth considering several functioning realities that are formed under the influence of the researcher and the environment (Hellström 2006). I did not aim to provide a completely objective picture, as I was aiming at participation and the influence on decision-making during the research for Paper 1 and partially for Paper 4. The opinion of our research group was influenced by the research participants; however, we did not set ourselves the task of interpreting the collected data. Rather, we wanted to convey the studied phenomenon of interaction with other companies and persons. Such participation could play a role in solving current business problems (Susman, Evered 1978). Therefore, these studies should be classified as subjective; nevertheless, it was rather a conscious choice to apply theoretical knowledge in practice. In Papers 2 and 3, our degree of influence on research subjects was much lower. The role has been to compare and analyze the current reality (Paper 2), as well as to identify and analyze a phenomenon (Paper 3) that is beginning to change the current state of affairs. We studied the points of view of the research participants on current events and visions of the future. Even within the same study, the opinions of the interviewed participants could differ significantly from each other. For example, managers and advisers from Paper 3 could have different opinions about the development of a life science business accelerator, the choice of participant companies, and so on. The dialogue between the researcher and the research subject could provide more color to the interpretation of the data obtained the longer the cooperation takes place in order to gain a deeper understanding of the events.

3.2. Research strategy and design

Table 2 presents a methodological approach for Papers 1–4 based on the following categories.

Table 2. Overview of the methodological options in Papers 1–4

	Paper 1	**Paper 2**	**Paper 3**	**Paper 4**
Research strategy	Qualitative research			
Research design	Single case study	Multiple case study		
Data collection method	Semi-structured interviews			
Methods of analysis	Content analysis	Within- and cross-case analysis		Narrative analysis
Unit of analysis	Company (CEO, CTO, investor, and opinion leaders)	Companies (CEOs and founders)	Companies (managers and advisors), program participants	Company (CEO, CTO, project managers of TraceRay, and opinion leaders)

To achieve the research aim, a qualitative research strategy was selected as the most appropriate strategy for research (Yin 1998). Qualitative research involves studying the opinions of participants to better understand their positions and how these people use their stories to form a holistic picture (Silverman 2015). The main research design in the examples used in the papers is a single case and multiple case studies. Real-life cases were formed for study in all four papers. A single case study is the basic option for studying a case-oriented approach; it can be especially necessary in various situations where the research has access to limited resources, allowing the opportunity to study novel and complex information (Eisenhardt 1989), as in Paper 1. However, researchers may conduct multiple case studies, as implemented in Papers 2–4. Multiple case study design refers to research with access to several cases in order to gain a deeper understanding of the phenomenon with something that a single case study cannot provide (Yin 1998).

The cases in Papers 1, 3, and 4 are presented to understand the research from the inside and to develop an understanding of the perspectives from the point of

view of various participants (Eriksson, Kovalainen 2015). In Paper 2, we examined the value of resources only from the point of view of the companies. The research data, in view of their international character, underline the importance of the participants' cultural understanding. In Paper 2, we describe different approaches to the formation of values in two countries; in Paper 3, values and different approaches are formed among five European countries.

3.3. Data collection

During the study, interviews were selected for data collection due to the possibility of obtaining information that happened in the past (Patton 1984). The purpose of conducting interviews in qualitative research is to obtain the participants' points of view in the events, i.e., an outside view of how these events took place (Burgess 2003). During the interviews, researchers and interviewees discuss topics related to the purpose of the research and answer research questions (DeMarrais 2004). It is important to get in-depth data about the experience, feelings, and impressions in order to fully understand and describe the reality of the events that took place. Therefore, the researcher will be able to form a comprehensive picture of the events. We strived to conduct interviews and collect data until we stopped receiving new data for the research.

Data for Papers 1–4 was collected through individual and group interviews, both online and offline. Individual interviews were used to prepare all four papers. Group interviews were also used in all papers when there was more than one person who discussed and commented on the selected topic from different points of view (Eriksson, Kovalainen 2015).

The flexibility of interviewing varies from strict adherence to open discussions. For this study, semi-structured interviews were selected because of their ability to combine a more or less structured list of questions with a flexible approach for obtaining additional information and clarifications (Silverman 2013). The interviewees knew the main topics of the interview as they received the necessary information during the preparation by email or phone. However, the order and wording of the questions could change, and additional and clarifying questions were raised during the meetings. As additional sources of information, we used competitors' websites, industrial reports and market forecasts, and news, and we participated in specialized conferences, etc. On the one hand, this approach made it possible to obtain data from other sources and compare it with the information collected during the interview. On the other hand, the information collected from other sources allowed us to discover new perspectives that required clarification from the research participants. Thus, we aimed to triangulate the data and reduce the likelihood of bias during the study (Yin 1998).

The collection and processing of data for the papers took place throughout constant cooperation with the companies. Samples for the articles were both random and non-random depending on the purpose of the article. Discussions about the possibility of commercializing research in Finland, Sweden, Denmark, Germany, and Holland were conducted with the support of senior researchers

and were confirmed by the studied companies. Companies were mainly represented by founders, chief officers, in some cases also by project managers, investors, industrial opinion leaders, and state officers. Additionally, we required knowledge outside the studied area; therefore, we collected data from other markets and performed in-depth analysis from open sources, etc. After analyzing the collected data, we proposed new business models and other approaches to generate more value for the customers.

4. Results

4.1. Addressing the research question

We used some of the participants of the MedTech innovation ecosystem to better understand the processes of interaction and their role in business development. **Figure 1**, based on the research questions in Papers 1–4, suggests the key factors influencing the development of companies from the side of the innovation ecosystem. Papers 1 and 4 highlight collaborations between participants within the innovation ecosystem as well as other ecosystems. Papers 2 and 3 are more focused on the role of public support in the formation and development of the MedTech innovation ecosystem.

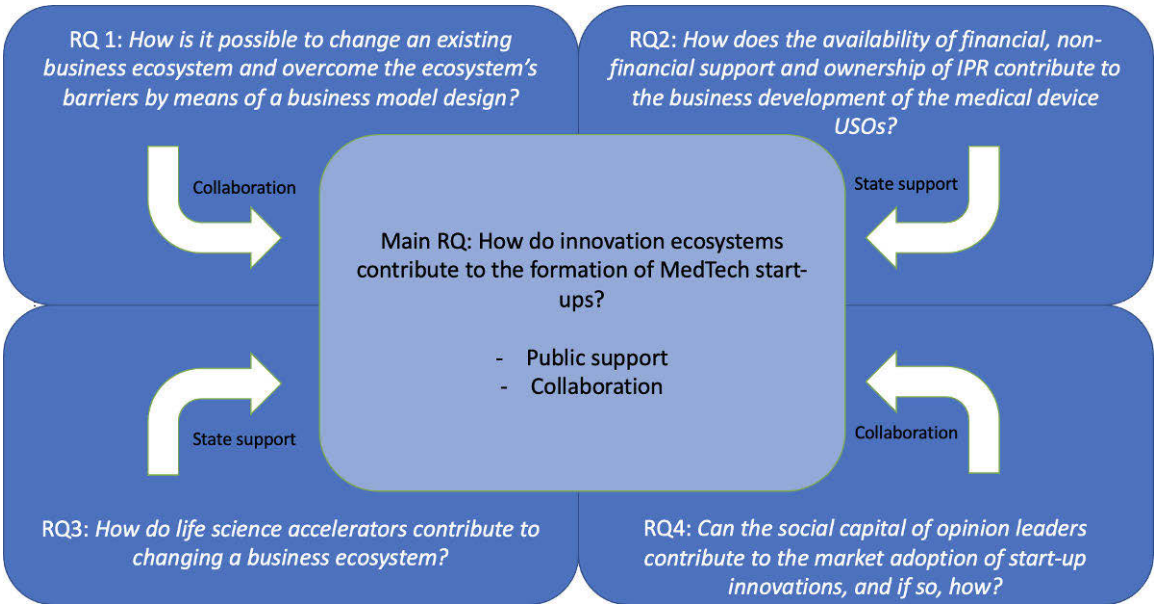

Figure 1. Contribution of research questions in papers to the main research question of the thesis.

4.2. Overcoming industrial conservatism by business model design (Paper 1)

RQ1: How is it possible to change an existing business ecosystem and overcome its barriers by means of a business model design?

Paper 1 contributes to the research question of the thesis in two ways. First, we consider exactly how the MedTech innovation ecosystem functions using the example of a veterinary orthopedic device ecosystem. We've found that key interactions affecting the entire market are happening between device

manufacturers and the veterinary community. On the one hand, veterinarians are ready to change the existing practices of treating animals if they see the advantages of new solutions over the previous generation of products or services. On the other hand, decisions that have an opportunity to change the market may be at the intersection of several areas of expertise. The size of the veterinary market compared to the human one makes it less attractive for doing business for the new companies. Despite the fact that pet owners are willing to pay for the health and care of their pets, the human orthopedic market similar to the researched one is much more developed. It is in the human market that the majority of resources and innovations are concentrated. However, trends in the human orthopedic market can be adapted to the needs of the veterinary one. New solutions in both markets usually require significant time and financial resources, which are often not available in start-up companies. Therefore, collaboration between practicing veterinarians and product manufacturers is essential to creating new products. The veterinarian's duty is usually to evaluate the idea and test the prototype of the product. However, the opinions of different veterinarians may differ from each other, thereby putting the manufacturing company in a difficult position and, with a certain probability, pushing the development of a product that may not be in demand. Thus, a new kind of business model, atypical for this industry, can be a way to create and capture value for a start-up in this market. The MedTech innovation ecosystem supports start-ups with a network of professionals providing expertise and market knowledge. We address the role of opinion leaders in developing new products and promoting them, and this interaction is explored in more detail in Paper 4.

Second, we consider a business model innovation as a way to overcome existing industrial barriers for a MedTech start-up. The use of new technologies assists in becoming a significant participant of the innovation ecosystem, creating its own ecosystem, and expanding the boundaries of the market. A start-up may face difficulties in attracting partners to its network. This is primarily due to the insignificant position in the market and the lack of a clear advantage for the partners from cooperation. However, this limitation may be interesting for other potential partners who have not previously considered this market in general or a niche in particular. Development in this direction can create value for the entire industry. In our case, such value may appear due to the formation of a new niche that did not exist before and is associated with the accelerated recovery of the animal, reducing the risk of subsequent operations, as well as attracting new participants as manufacturers of feed and accessories for animals. Therefore, consideration of the business model of one participant may not be enough to understand the processes taking place in the entire innovation ecosystem. In Paper 1, we consider a single case of how a change in the business model for one company or the emergence of a new company with business model innovation could affect the entire innovation ecosystem and bring changes to it.

4.3. Financial resources and intellectual property rights for university spin-off companies in Finland and Sweden (Paper 2)

RQ2: How does the availability of financial and non-financial support and ownership of IPRs contribute to the business development of medical device USOs?

Paper 2 highlights how the innovation ecosystems of two countries are contributing to the formation of university spin-offs (USOs) and the transit of knowledge from laboratories to the market. We found that the diversity of financial and non-financial support for start-ups and the ownership of IPRs have a major impact on a company's registration in the particular innovation ecosystem and on its further development. Public organizations in Finland and Sweden play similar roles and have similar tools for promoting the innovation ecosystems of the two countries, and they play an important role in the early stages of company development. However, we later identified a gap in the Finnish innovation ecosystem that threatens companies' success. Companies find it difficult to overcome the Valley of Death period. We assumed that increased competition for the resources of the innovation ecosystem could increase the number of disruptive projects in Finland; however, we did not find confirm that in the course of the study. In turn, Swedish entrepreneurs can receive financial support at all stages of development, which reduces the likelihood of failure. Moreover, the grant system for supporting entrepreneurs is more widespread in Sweden, while private foundations in Finland are doing this to a lesser extent. The Finnish innovation ecosystem has less lock-in for companies. Start-ups may not consider a Finnish MedTech innovation ecosystem or a domestic market as sufficient, tending to shift toward a more attractive one. Therefore, the attractiveness for new and existing companies is reduced. At the same time, a Swedish innovation ecosystem offers a balanced program of non-financial support, such as entrepreneurship training, networking, expertise, etc., which combines long and short programs. As the experience of Finland shows, chaotic programs may have an insignificant impact on the level of entrepreneurship and the network of participants in the innovation ecosystem. In general, it is worth noting that start-up Swedish entrepreneurs are less obsessed with finding sources of funding than Finnish representatives. Swedish entrepreneurs are more confident in finding funding and more focused on product and team development and, therefore, have fewer barriers to moving from academia to industry.

We also found that the Finnish approach to the allocation of IPRs to inventions significantly reduces the desire of scientists to commercialize products and their likelihood of registering a company. According to the existing rules, Finnish scientists are obliged to share the IPRs for an invention with their university, whereas Swedish scientists receive all IPRs and additional resources for commercialization. The results of the study also show that Finnish entrepreneurs have doubts about the success of cooperating with university technology transfer offices (TTOs). Such offices are more interested in selling

their stake to any investor or to the start-up itself without caring about the development of the company or what such a deal will lead to. The participation of the university as a stakeholder of the company also hinders the attraction of investments due to red tape and the not-always-clear value that it represents for a new investor. The decline in revenue from royalties to the university also demotivates entrepreneurs and investors.

If Swedish universities contribute in every way to the formation of start-ups, then Finnish universities, to a certain extent, hinder this development. This includes not only the formation of new companies and products in the market but also the slower transition of laboratory personnel to the industry, subsequent cooperation, and new projects with companies.

In the case of Sweden, competition and simultaneous cooperation with the same advanced Danish MedTech innovation ecosystem brings its own features to development. Entrepreneurs from the Swedish Lund region do not have much difficulty registering and developing a start-up in the Copenhagen innovation ecosystem, and they receive bonuses from it instead of from the local one.

4.4. Life science business accelerator in the developing business ecosystem (Paper 3)

RQ3: How do life science accelerators contribute to changing a business ecosystem?

Paper 3 offers an analysis of life science business accelerators as new participants of innovation ecosystems. Life science business accelerators started mainly with the financial support of the European Regional Fund over the past five years. They are short-term (usually up to one year) training programs for company development. Business accelerators are aimed at non-financial support for companies that have already reached a certain level of development and are striving for a new stage. To a greater extent, life science business accelerators do not contribute to the formation of start-ups but are aimed at their promotion and development. Companies that participate in this program are mainly interested in finding an investor or entering a new market. We found that, despite the differences in business models, business accelerators are major contributors to the development of innovation ecosystems and the companies involved in them in three ways. First, there is the networking of mentors working with participating companies. The professional experience and expertise of mentors that were most often obtained in the course of work in top positions in medium-sized companies are the main parameters of the satisfaction of the participant. We expected that participants in the business accelerator program would rely on the entrepreneurial experience of mentors, but the lack of such experience did not become a limitation for either the founders or the program managers. Some life science business accelerators provide an opportunity to change their business advisor, including to increase the network or gain access to the target audience. Second, there is the development of entrepreneurial skills of program participants. Companies participating in the programs reported that prior to

business accelerators, there was a gap in ecosystems to develop entrepreneurial skills. Former university staff often lack the knowledge and competencies to run a business or meet new challenges, such as negotiating with investors, sales, and marketing. After graduating from, for example, a business incubator, companies were left to their own business and experienced difficulties with networking and development. The growth of companies implies a lower priority for scientific skills and an increase in business ones. Therefore, business accelerators have taken their niche in local entrepreneurship training for managers and company founders who have already passed the initial stage of business development and are actively developing their companies. Third, there is a project-based approach to solving the tasks set by participating companies. The program participants highly appreciate the impact of the business accelerator program on the development of companies. Most of the participants achieved their assigned task within a short time after the end of the program. A project-based approach to addressing the challenges of participating companies also distinguishes acceleration programs from the entrepreneur support programs previously offered by the innovation ecosystem, for example, business incubator programs.

We have also identified potential sources of growth for the development of life science business accelerators. First, there is cooperation with companies from other countries. At the moment, business accelerators are mainly focused on local projects within the local innovation ecosystems. However, additional projects and competition among companies for resources could add value and diversity to innovation ecosystems. Moreover, the sustainability of an innovation ecosystem is also determined by the ability to resist the emergence of new, sometimes disruptive companies that are trying to change existing rules and bring the state of the innovation ecosystem to a new level. Therefore, collaborating with projects from outside their innovation ecosystem could be potentially interesting from a development perspective. Second, there is the formation of a pan-European program that would be able to combine European markets, resources and expertise in order to form competition primarily in the U.S. market. Currently, the European market is not a single whole for MedTech companies working on it. In particular, scattered European programs such as business accelerators provide little opportunity to work together, relying heavily on mentor networking. Therefore, the European market is losing its attractiveness, while the formation of a single innovation ecosystem could contribute to business development.

4.5. The role of opinion leaders' social capital in innovation development (Paper 4)

RQ4: Can the social capital of opinion leaders contribute to the market adoption of start-up innovations, and if so, how?

Our findings in Paper 4 are a set of parameters that determine the formation and development of relationships between industrial opinion leaders and start-ups.

Companies may be interested in collaborating with opinion leaders because of their high class of expertise, cost reduction in product development and testing, and the subsequent promotion and sales of products. In turn, opinion leaders could be interested in cooperation if they can solve a significant problem in the industry and have confidence in the project team. Opinion leaders show interest in participating in projects that have the potential to address global industry challenges. Partnering an opinion leader with a start-up may not involve financial rewards. The initial project for cooperation must be innovative, but continued cooperation is possible in more regular projects. Opinion leaders could assist companies in finding the best path to successful development, starting with an assessment of the research results in terms of practice and potential and market assessment for the proposed solution. An opinion leader's network impacts the initial sales markets, which usually include distributors and other veterinary clinics. The value of collaborating with an opinion leader forms like a snowball. At the initial stage of the project, the opinion leader helps assess the importance of an idea for the market, recommend a design, etc. After that, the opinion leader could test the product prototype and recommend the necessary changes. At the sales and marketing stage, the opinion leader recommends a product or solution that was developed under their control to other market participants. The reputation of a leader plays an important role in the professional community. Therefore, other professionals become more interested in cooperating with the project if they see the participation of the opinion leader in it. In turn, start-ups could be confident in the recommendations of opinion leaders. Negative comments or test failures will not be related to a lack of professional competence of the opinion leader.

As a disadvantage of cooperation, it is worth noting that the workload of the opinion leader can slow the development of the project. The team of the company cannot demonstrate incompetence in their field since the opinion leader may doubt the success of the project and not give a second chance.

A summary of the papers in terms of their contribution and answers to research questions is proposed in Table 3.

Table 3. Summary of research papers

Research question	Main contributions of the paper	Contribution to answering the main RQ
Paper 1. Kulkov, I., Hellström, M. and Wikström, K. (2021), "Struggling with conservatism: entrepreneurships' challenges in business model design," *International Journal of Value Chain Management*, Vol. 12 No. 1, pp. 45–61. https://dx.doi.org/10.1504/IJVCM.2021.112844		
How is it possible to change an existing business ecosystem and overcome its barriers by means of a business model design?	• Initiating change in conservative ecosystems through innovation • Using CIMO-logic to demonstrate how a business model innovation creates value for participants in an innovation ecosystem • Creation and capture of value at different stages of cooperation	• Business model design becomes an opportunity for market positioning • Use of technology creates value in a conservative market • Other market participants contribute to value creation of the start-ups
Paper 2. Kulkov, I., Berggren, B., Eriksson, K., Hellström, M. and Wikstrom, K. (2020), "The importance of financial resources and ownership of intellectual property rights for university spin-offs: the cases of Finland and Sweden," *Journal of Small Business and Enterprise Development*, Vol. 27 No. 7, pp. 1125–1147. https://doi.org/10.1108/JSBED-09-2019-0308		
How does the availability of financial and non-financial support and ownership of IPRs contribute to the business development of medical device USOs?	• Role of financial resources and IPRs on business development of university spin-offs • The role of universities in the development of innovation ecosystems • Role of TTO in the development of innovation ecosystems	• Different innovation ecosystems offer various conditions for the formation and development of university spin-offs • Universities see their role in ecosystem development differently

Research question	Main contributions of the paper	Contribution to answering the main RQ
Paper 3. Kulkov, I., Hellström, M. and Wikström, K. (2020), "Identifying the role of business accelerators in the developing business ecosystem: the life science sector," *European Journal of Innovation Management*, Vol. 24 No. 4, pp. 1459-1479. https://doi.org/10.1108/EJIM-04-2020-0139		
How do life science accelerators contribute to changing a business ecosystem?	• Analysis of the parameters of business accelerators for the development of innovative ecosystems • Identification of the program participants' priorities	• The role of business accelerators as a new participant in innovation ecosystems in the market development • Analysis of the benefits of companies' participation from participation in the program
Paper 4. Kulkov, I., Barner-Rasmussen, W., Ivanova-Gongne, M., Tsvetkova, A., Hellström, M. and Wikström, K. (2020), "Innovations in veterinary markets: opinion leaders' social capital," *Journal of Business & Industrial Marketing*, Vol. 36 No. 13, pp. 1-14. https://doi.org/10.1108/JBIM-02-2020-0098		
Can the social capital of opinion leaders contribute to the market adoption of start-up innovations, and if so, how?	• Market adoption of medical innovations • The role of opinion leaders in business development at different stages • The role of social capital in developing innovations	• The role of opinion leaders in business development for start-ups • Identifying the advantages and disadvantages for start-ups in cooperation with other market participants

4.6. Summary of research results

To explore how innovation ecosystems contribute to the formation of MedTech start-ups, sub-research questions have evolved throughout the study. Answers to the sub-questions form recommendations on which resources a start-up can receive from the innovation ecosystem in the course of its development. Finally, the following results, offering a way to answer the main research question, have been identified:

1. Business model innovation is a way to define a position in the market and create a niche for development, to create and capture value that sets the company apart from competitors. Business model innovation could be based on a specific product or service, as well as ways of doing business. We offer start-ups to consider the possibilities of several areas of knowledge to form a unique offer and differentiate from competitors. This was primarily demonstrated in Paper 1, where a unique business model was formed at the intersection of several areas of knowledge, and its application shaped a new niche. Additionally, Papers 1 and 4 highlight opinion leaders' involvement as the basis for business model innovation in the focal market. Undoubtedly, the use of a single case in Papers 1 and 4 has some limitations on the results proposed in them. We were forced to use a single case study in these Papers due to the company's uniqueness in the market, as well as its business model innovation.
2. Universities are one of the key players in the formation and development of MedTech innovation ecosystems. They are important not only as a source of ideas for commercialization, providing expertise and knowledge, but also as an important promoter of the personnel's transition from academia to industry. Therefore, the approach taken by the state and its representative universities to support the commercialization of developments plays an important role in the formation of an innovation ecosystem, the transition of academic personnel to industry, and the emergence of start-ups. The state should carefully approach the creation of legislation and infrastructure for the existence and development of innovation ecosystems. At first glance, insignificant details may hide a significant slowdown in the development of the innovation ecosystem and hinder the development of the industry. This was evident from Paper 2, where we compared the successes of MedTech's advanced and emerging innovation ecosystems. The different approaches and contributions of the universities of the two countries make different contributions to the development of the entire innovation ecosystem.
3. Life science business accelerators play a role in the development of companies that have already reached a certain stage of business development and need certain skills and networks to reach the next level of development. The business accelerators under study are free of charge for participants; all costs are covered by public funding, so business

accelerators are more attractive to entrepreneurs. Entrepreneurs actively share their experience of participating in the acceleration program within the innovation ecosystem, both in success and in failure to achieve their participation goals. This conclusion is based on the findings of Paper 3, which offered an analysis of a new entrant to innovation ecosystems in several European countries.

4. Other participants of the innovation ecosystem influence the formation of MedTech start-ups according to their role and purpose. Such participants of innovation ecosystems as opinion leaders influence the development of the industry with the support of their social capital. Using social capital to shape a start-up's unique offering could provide an advantage during the formation and development phase of a company. The role of some participants in the innovation ecosystem may change over time depending on the type of collaboration. Paper 4 contributes to this in this case. Social capital can become one of the company's resources allowing it to gain advantages over other companies in the market.

These challenges affect the formation of MedTech start-ups and the development of innovation ecosystems. Therefore, the first step in forming a new company is to offer an innovation for the market, which, for example, could be formed at the intersection of several areas of knowledge or be based on business model innovation. Further, the process of forming a MedTech start-up takes place, which is actively influenced by the university, offering public resources for business and team development. At the moment, it is necessary to correctly assess the possibility of obtaining IPRs and to form a team to manage the project. After achieving a certain success, the business accelerator may help further promote the company in order to achieve a certain goal in gaining access to new expertise, or the network could give a new impetus to the development of the company. In turn, the use of social capital is necessary for the development of the company at all levels. Social capital makes it easier to access expertise and networking and reduce costs at all stages of the product and company, etc. The establishment of cooperation between the participants of the MedTech innovation ecosystem is an important factor in the formation of start-ups and business development.

Summarizing the results of the research, Paper 1 recommends using a flexible approach to the formation of value for the customer and applying opportunities to offer a unique product based on market knowledge, as well as under the influence of atypical decisions. Promising business niches can, for example, be formed at the intersection of several areas of knowledge or be adapted from other industries. Paper 2 demonstrates that similar innovation ecosystems have different approaches and characteristics that affect the development of the company and its chances of success. Appropriate use of the opportunities to build a company using an optimal innovation ecosystem can increase the chances of a company's success. Paper 3 offers an analysis of new market entrants who provide mentoring services, contact with other innovation

ecosystems, and business skills training to accelerate business development of the companies. MedTech company participants of business accelerator programs positively assess their participation in the program and achieve their business goals using new experience. In turn, Paper 4 gives recommendations to entrepreneurs at any stage of the formation and development of a business about exactly how to use the social capital of the participants in the innovation ecosystem in case there is a lack of financial and time resources. This approach allows companies to reduce costs and increase the speed of product development and time-to-market at the lowest cost.

As a result, the research question can be split into two parts. The key contribution of the MedTech innovation ecosystem is the ability to use public resources and support, as well as cooperation in the form of using internal and external relations for business development.

1. The use of public resources includes financial support at different levels of company formation and development, financing of theoretical and applied research, coverage of costs for searching for patents and the patenting process, and grants and loans for small businesses. Non-financial support includes the provision of expertise, training programs, and mentoring, etc.
2. Collaboration includes links within the innovation ecosystem, as well as interaction with external innovation ecosystems, markets, industries, etc.

5. Discussion

The aim of this study was to examine the processes of commercializing innovations by new MedTech companies. The research was done using qualitative research, content analysis, within- and cross-case analysis, and narrative analysis to understand how MedTech innovation ecosystems contribute to the formation and development of start-ups. The study generates knowledge and analyzes successful practices for the development of MedTech innovation ecosystems and various approaches to stimulate the formation of companies. We found the following key findings in our study:

1. Public support is a key factor in the successful formation and development of MedTech innovation ecosystems. Innovation ecosystems can have options for using financial and non-financial support.
2. Collaboration between participants within the MedTech innovation ecosystem, with participants in similar ecosystems in other cities and countries, as well as representatives of other industries, is the second key factor in the successful development of an innovation ecosystem.

Figure 2 demonstrates the process and results for answering research questions. The implications of the results are discussed further in Chapter 5.

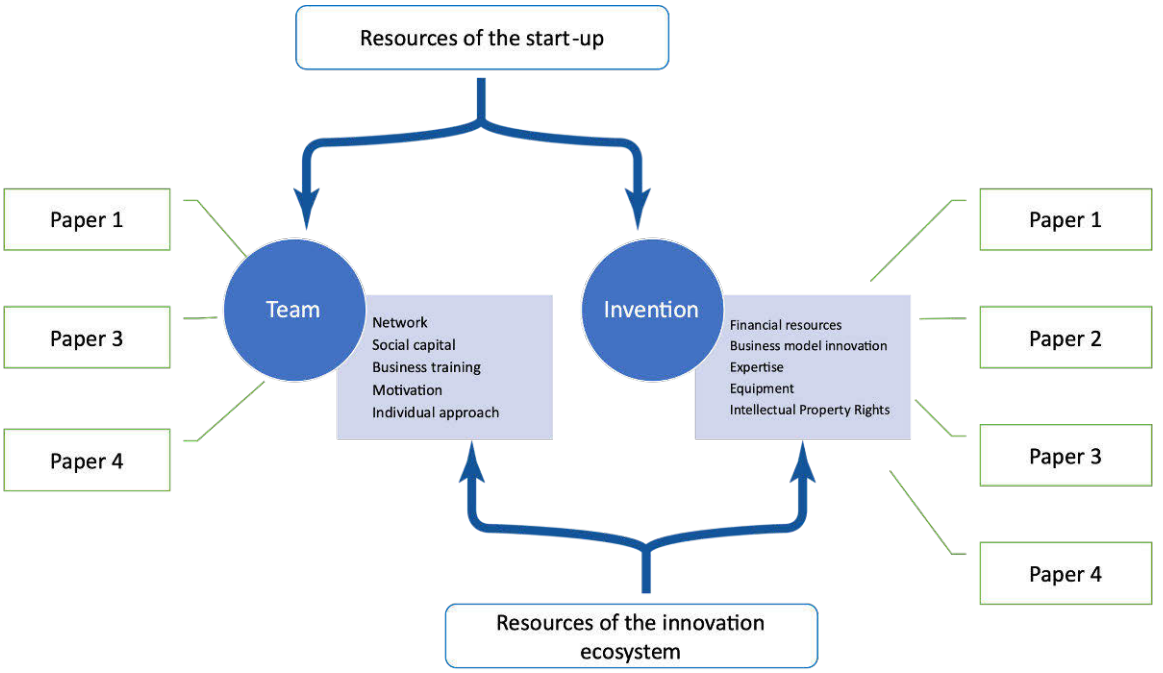

Figure 2. Influence of the MedTech innovation ecosystem on the development of start-ups.

Public support and collaboration are the key resources that MedTech's innovation ecosystem offers for start-ups. Papers 1–4 have different perceptions of exactly how innovation ecosystems contribute to the two key internal factors of the MedTech start-up success, namely the team and the invention (Hasche, Linton 2018). Public support includes financial and non-financial instruments. Among the financial instruments of public support, it is necessary to note grants, loans, credits, etc. In turn, non-financial instruments are programs that offer additional skills, opportunities, and infrastructure for business development, namely business training, provision of access to equipment and laboratories, transfer of IPRs, motivation, etc. Collaboration includes all types of networks, the use of social capital of the innovation ecosystem's participants, expertise, searches, and provision of individual support required by a particular company for success, and so on. These types of contributions are related to the formation of a business model innovation built on the acquisition of new knowledge, collaboration with new partners, and the use of resources that were previously unavailable. The reader of Papers 1–4 can trace exactly how we described the contribution of the MedTech innovation ecosystem to the development of start-ups. All of the papers offer theoretical and practical contributions to the innovation of start-ups, while team development is more visible in Papers 1, 3, and 4. In my papers, I did not set myself the goal of identifying and analyzing all possible resources of the MedTech innovation ecosystem. However, I tried to identify new and atypical solutions that could impact the formation of new companies and increase interest in the commercialization of MedTech research.

Next, I offer a detailed discussion of exactly how the MedTech innovation ecosystem contributes to the development of start-ups, as well as theoretical contributions to the existing literature and practical implications for participants and interested persons. The key task of chapters 5.1 and 5.2 is to present the results in a more generalized way and to offer general recommendations for the formation of successful MedTech innovation ecosystems.

5.1. Public support

State influence on the formation and development of the MedTech innovation ecosystem is essential in terms of achieving the required results. First of all, the state should formulate the development priorities of the areas and industries that could bring the greatest return. The MedTech industry is chosen most often based on its early successes in the medical and engineering fields. The formation of a long-term strategy lies with policymakers, who may not have sufficient knowledge in the field of development, specifically MedTech innovation ecosystems. Copying the principles of building other formed innovation ecosystems or transferring successful experience from other places may not give the required results, leading to an ineffective waste of financial and time resources. However, the basic principles of developing innovation ecosystems can be borrowed from existing business experience. The key participants in the development of the MedTech innovation ecosystem and representatives of the state are universities. Through universities, the state invests in long-term basic

research, establishing collaboration with other players both within the innovation ecosystem and for cooperation with representatives from outside. A public grant system for theoretical and applied research stimulates competition among researchers. In turn, TTOs aimed at promoting ideas for the commercialization of university research results and transferring academic projects to industry stimulate the formation of start-ups. However, the different approaches in their activities, as presented in Paper 2, have a significant impact on the likelihood of the formation and subsequent development of USOs. Entrepreneurs evaluate TTO performance differently depending on the innovation ecosystem. On the one hand, the TTO could be a consultant and assistant in the search and selection of the optimal development strategy, a source of necessary contacts and resources. From the other side, it could be considered by companies as a source of disincentives that want to obtain a part of the revenues or shares without making a significant contribution to the business. In the short term, TTOs may compensate companies for a small part of the costs of patenting or marketing; in the long term, however, they are a brake on the development of a start-up. The studied examples in Paper 2 make it clear that developing the innovation ecosystem is a long-term project, contrary to obtaining quick returns on investment, and it significantly reduces the attractiveness of the innovation ecosystem and the emergence of new projects.

In turn, the formed infrastructure of the innovation ecosystem stimulates the transition of laboratory research results to commercialization and the proposal of innovations in the open market. These transfers of research results from universities to industry are not possible without the transfer of trained university personnel. It is not always possible to motivate senior researchers to leave the university and engage in risky business. However, this transition is best suited for graduates, PhDs, postdocs, and other researchers. The established relations with the university allow nascent entrepreneurs to preserve and use scientific expertise, access the latest developments, and collaborate with previous and other research groups. Openness to cooperation at MedTech is an important factor that creates a predisposition for success in this industry. In the course of our research, we found that public support is one of the most important factors in the transfer of academic personnel to the industry. However, most of the academic staff with medical and engineering backgrounds suffer from a lack of business knowledge and practice. One of the limiting factors for private investment in MedTech is the unpreparedness of young entrepreneurs to manage a new business. In the laboratory environment and at the initial R&D stage, academic knowledge is a priority; however, further development requires a greater concentration on negotiations with investors and partners, marketing, and sales. Some of the companies from Papers 2 and 3 have chosen to hire professional managers, incentivizing them with company shares or wages. However, the founders of most companies try to independently master the required management skills without attracting additional personnel for key positions in a start-up. In this case, public programs for obtaining the required skills are more in demand than ever. Public business incubators and accelerators

offer office space, registration assistance, project appraisal assistance, initial company promotion, and more (see Paper 3). These centers offer general entrepreneurial courses or highly specialized presentations, such as those related to patenting or marketing tools. Start-ups receive support in the form of training, gaining access to an incubator or accelerator network, and mentoring from an experienced entrepreneur or participant in an innovation ecosystem. In most cases, access to entrepreneurial courses and mentoring may be available after completing the business development programs.

State infrastructure for the development of the MedTech innovation ecosystem could create prerequisites for attracting private capital. Angel and venture capital investment companies are looking at an investment area with great interest, which is backed by constantly generating attractive ideas, projects, staff, and infrastructure. In part, the presence of private investment in the innovation ecosystem is also associated with IPR, as we demonstrated in Paper 2. Private capital is less interested in collaborating with companies that have university representatives as shareholders or have some obliging factors such as royalty or license agreements. The state should provide infrastructure and demonstrate openness and understanding of how the formation and commercialization of value will take place. The growth of state revenues should be due to an increase in taxes from the activities of companies and not short-term commissions from the production activities. In Paper 2, we demonstrate different approaches using the example of innovation ecosystems in Finland and Sweden. Finnish universities' approach to IPRs is identified more by a fast return on funds, which can have a chilling effect on the development of a particular company's business and, as a result, the entire innovation ecosystem. In turn, the Swedish approach of cooperation is aimed at sustainable development, employment growth and, as a result, an increase in state revenues due to taxes. The results of our research and export statistics of the focal countries show that the number of new MedTech companies in Sweden is much higher than the Finnish ones, and the likelihood of success is higher in Sweden than in Finland for the commercialization of MedTech innovations. To some extent, Finnish universities turn out to be a constraining factor in the development of the innovation ecosystem.

The availability of obtaining rights to research results also affects the choice of where companies are registered. The proximity of countries and the openness of their borders allow entrepreneurs to choose the best offered conditions. It is clear that the majority of aspiring entrepreneurs choose the local innovation ecosystem and do not want to cross the border to found a company. However, as we see in Paper 2, MedTech entrepreneurs from the innovation system of Lund, Sweden could take advantage of the innovation ecosystem of Copenhagen, Denmark, which is close by and accessible for daily commuting. Countries get additional competition, which affects the quality of projects. Innovation ecosystems are forced to invent their own lock-in for entrepreneurs in order to keep promising projects in their local market. However, most MedTech innovation ecosystems focus on supporting local projects. The constraints are

not only visa issues. As we found in Paper 3, public-owned life science business accelerators generally consider small projects from other countries for relocation to the local innovation ecosystem. In most cases, projects from developing countries are not seen as promising for investment by the innovation ecosystem. However, it is worth noting the start of changes in this approach. For example, new business accelerators offer compensation for relocation and participation in their program for entrepreneurs who can convince management of the promise of their project. Therefore, the openness of the innovation ecosystem and the ability to cooperate will play a role in the development of the local innovation ecosystem and its sustainability and attractiveness for new projects.

Consequently, some intangible resources of the MedTech innovation ecosystem could contribute to an early or less painful transition of the Valley of Death for participating start-ups. An important role is played by the specifics of the promoted technology, representatives of public organizations, and the personalities of entrepreneurs who are ready to develop the industry and change the existing rules. Intangible assets of the innovation ecosystem are represented by infrastructure that enables business development. For example, training ambitious entrepreneurs and their business skills shifts the Valley of Death in time, shortens its duration, and brings it closer to the moment when industrial or venture capital investments will be available for the company. Serial entrepreneurship within the same innovation ecosystem, including failures, also shortens the duration of the Valley of Death for these and other entrepreneurs. An advanced innovation ecosystem should have the resources to retain entrepreneurs within itself since it can take a long time to form successful experiences and breakthrough technologies; nevertheless, the number of resources required to retain entrepreneurs will decrease as their number of projects grows. Unsuccessful projects can also enrich the innovation ecosystem with their expertise and dissemination of information to other participants. On the other hand, creating a comfortable environment for venture capital could become an additional incentive for the development of an innovation ecosystem. Reducing the level of risk for investors will have a positive effect on their attraction to the focal innovation ecosystem. Innovation ecosystems that can prepare and deliver information for specialized investment companies may facilitate investments in the earlier stages of start-ups. Being able to freely disseminate information about research results could increase the chances of others in the innovation ecosystem of getting the resources they need, such as expertise or data from the open market. Moreover, infrastructure investment helps reduce costs at the initial stage of a company's development. For example, the MedTech innovation ecosystem benefits from the development of rapid prototyping capabilities by reducing the start-up costs of innovative companies and increasing the number of attempts to test research results in practice. Such infrastructural innovations are especially useful because they spread the costs of formation among many companies and generate new jobs.

5.2. Collaboration

Identifying the key participants and their roles in the innovation ecosystem is an important factor in understanding its formation and development. Opportunities and influence on change are more important among some participants, which in turn has value for companies to do business. Collaborating with such advanced participants provides additional opportunities that are worth using to gain a competitive advantage. For example, in Papers 1 and 4, I found that it is common practice for companies to collaborate with practicing veterinarians in the veterinary innovation ecosystem. Such cooperation is based on business interaction and is not much different from practice in other industries. Basically, cooperation is carried out on a supplier-customer basis. However, collaboration with special veterinarians (who have more weight in the industry than others) and start-ups could be expanded and used at different stages of development, which has not been used previously. The driving force behind this collaboration is the social capital of the advanced veterinarians (opinion leaders) who use it to influence the industry. In Paper 4, I found out exactly how cooperation arises, what is necessary to undertake a start-up to obtain and retain an opinion leader in the project, and also how to non-financially interest an opinion leader in cooperation. A start-up will be able to use the resources of its innovation ecosystem more efficiently and can use the network of the opinion leader to penetrate and develop in other innovation ecosystems and markets. The lack of such collaboration in the focal industry was caused, to a greater extent, by the conservatism of the market. In turn, this conservatism leads to unattractiveness for new companies and participants, a decrease in competition and number of innovations, and low growth rates. The application of new approaches to do business and the business model innovation give an advantage in competition, make the company more visible in the market, and optimize the speed of product development. Moreover, the established relationships and successful experience may allow for continued collaboration between a start-up and opinion leaders in the next project and maybe even result in less innovative projects. Perhaps cooperation in less innovative projects will not be as intensive, but the existing experience could allow for using the previous developments and could also affect the development of the project. With the traditional approach to product development and promotion, a company may require significant resources to make changes to the existing sustainable innovation ecosystem, which are often lacking in a start-up. Lack of time and revenues from a project could demotivate entrepreneurs and lead to company failure. The sustainability of the MedTech innovation ecosystem and the creation and capture value also depend on an increased relationship between participants. In Paper 4, I investigate the relationship between market opinion leaders and start-ups and analyze that cooperation is possible not only with financial support but also for solving issues that are important for the industry and society. The financial component fades into the background, providing an opportunity to jointly shape trends and change the world. Therefore, the innovation ecosystem represented by experienced opinion leaders contributes to supporting the formation of

MedTech start-ups through experience, expertise, and networks. The use of a resource such as the social capital of opinion leaders could become a decisive factor for the success of a start-up.

It is more difficult to attract large businesses to participate in the development of a new MedTech innovation ecosystem. Large Swedish pharmaceutical companies such as AstraZeneca and Pharmacia (later acquired by Pfizer) can form their own ecosystems for successful development. In turn, large international companies may induce policymakers to develop this industry, as in the case of Sweden. The leave of such large companies from the market, for example, due to the transfer of the headquarters or the R&D center, formed the preconditions for many small projects in this region. In Paper 2, the vast majority of employees in the moved company did not agree to relocate and left the company. However, this case has allowed for the formation of many new companies that have continued to operate in this or related areas. According to the interviewed representatives of the companies for Paper 2, the number of personnel employed in the formed innovation ecosystem significantly exceeds that of the removed company. The trained and experienced personnel were able to establish internal communications and offer R&D, consulting, marketing, and other services to colleagues they worked with earlier. As a result, the renewed innovation ecosystem has created multiple narrow specializations and products that, thanks to the previously acquired experience, have become competitive in new markets. Therefore, the departure of large players from the market is not always a negative factor for the development of the MedTech innovation ecosystem; however, it requires a thorough and high-quality approach to use the opportunities, primarily from the state policy. In turn, the formed network between the innovation ecosystem's participants made it possible to effectively transform the innovation ecosystem, bringing it to a new level of development and making it more sustainable at the expense of many small companies.

Collaboration with companies from other industries gives a company a fresh perspective on value creation. Most of the potential academic entrepreneurs have a narrow specialization, which somewhat limits ideas for commercialization. The study of similar innovation ecosystems – in our case, the human and veterinary ecosystems in Papers 1 and 4 – as well as different areas of knowledge, ours being medicine and engineering, allowed the company to form the prerequisites for creating its own innovation ecosystem. Formed trends and successfully implemented projects in other markets can be adapted to the MedTech industry.

Paper 3 analyzes the role of a new participant of the MedTech innovation ecosystem: the life science business accelerator. The objectives of these business accelerators are to develop companies and the whole innovation ecosystem. Some of the studied accelerators consider its role in the development of a limited number of companies, offering them all available resources and striving to develop companies to the maximum. Scouts of such business programs are looking for the most promising projects from their point of view on their own, though the support of such companies usually takes a long time. Other

accelerators are more interested in maximizing the reach of companies, providing a chance to support all interesting ideas and promising projects of the innovation ecosystem. Life science business accelerators offer short intensive programs for numerous batches of companies. These business accelerators are aimed at creating links within the innovation ecosystem, developing projects based on local expertise and knowledge.

Initially, companies participating in the business accelerator program are recruited from one region; however, business accelerators are rapidly moving to the national level, collaborating with companies from any city and thereby becoming a national project as I see it in Paper 3. Among life science business accelerators, cooperation at the level of managers and mentors is widespread; the exchange of experience is a frequent practice. As a result of cooperation, there is increased access to expertise, which may not be available in the local market, and trends in further development are formed. However, the disadvantage of life science business accelerators is their concentration on local projects. In most cases, new projects from other innovation ecosystems are not considered, and support is distributed among companies registered in the local ecosystem.

5.3. Theoretical contribution

This thesis attempts to link together two research areas: innovation ecosystems and start-ups.

- Start-ups: the thesis especially emphasizes the topic of innovation transfer from research laboratories to the industry (Lowe 1993, Rasmussen, Moen & Gulbrandsen 2006), as well as ways to reduce the likelihood of failure in the MedTech companies' early stages of development (Hasche, Linton 2018, Blevins et al. 2018). Papers 1, 2, and 4 discuss more about the role of start-ups and provide theoretical contributions to the existing literature.
- Innovation ecosystems: the thesis addresses the need to increase the study and clarify the understanding of the formation and development of innovation ecosystems (Adner 2006, Fukuda, Watanabe 2008) using the example of MedTech, particularly the role of participants in the innovation ecosystem in the formation of new and developing start-up companies. Papers 2 and 3 make a theoretical contribution to the development of MedTech innovation ecosystems and address this direction.

The contribution of the thesis relates to the understanding of the processes that provide the MedTech innovation ecosystem for the transit of the research results and personnel laboratories to industry and the commercialization of research, the formation of start-ups, and their development at the initial stages of business.

I continue the important topic of studying the reasons for the success and failure of start-ups using the example of the MedTech industry (Hasche, Linton 2018, Klafstad 2019, Chaturvedi, Pappu 2017). Papers 1 and 4 offer non-standard solutions to increase success in the formation and development of companies through an original business model. At the same time, in Paper 2, I touch upon the important problem of studying institutional barriers that restrict the development of innovation systems depending on the characteristics of a particular country and industry (Laurell 2018). I do this by identifying good practices and comparing them with emerging innovation ecosystems.

In Paper 2 and partly in Paper 1, I investigate exactly how university TTOs influence and inspire academics to leave the university environment and retrain as entrepreneurs. I identify that ownership of IPRs is an important factor in the success of a company and the growth potential of the entire innovation ecosystem. Nascent entrepreneurs receive support for their actions, recommendations from more experienced participants who have a specific industrial background, and a network to manage business activities. However, I complement existing research (Heinonen 2015, Blevins et al. 2018) by discussing the existing shortcomings of such cooperation and possible threats to business development. Paper 2 is in line with work on the effectiveness of cooperation with TTOs in terms of start-ups (Shapin 2003, Sapir, Kameo 2019). I complement the study of Goel and Göktepe-Hultén (2018), demonstrating on the one hand that companies can receive various benefits and, on the other hand, that they will encounter obstacles that will inhibit the desire to commercialize their research, depending on the chosen innovation ecosystem.

In Paper 4, I apply the theory of social capital (Dubos 2017, Häuberer 2011) in practice and demonstrate exactly how social capital could contribute to the business development of start-ups. First, I complement existing knowledge about the market acceptance of innovation through the use of social capital (Khoshmaram et al. 2020, Branstad, Solem 2020). I discovered that socially important participants in the innovation ecosystem – opinion leaders – matter at the stage of research, help assess potential results for commercialization, help develop a prototype, and are active in testing and sales. The reduction in time and financial costs at all stages contribute to an increase in the chances for the commercialization of MedTech innovations. Moreover, the process of establishing cooperation with other market participants when using opinion leaders' social capital is faster and more efficient than without it. Other market participants are interested in cooperation with a start-up if opinion leaders are involved in the project. The prestige from participation and trust in the project is diminishing for regular participants, and the need to pay for their services for a start-up is reduced. Leveraging the resources and advice of early adopters leads to faster business development, especially in countries where the opinion leaders of the project are represented. Other market participants, for example, distributors, can also be influenced by the social capital of opinion leaders and can reduce the cost of participation in the project (La Rocca et al. 2019). I also note that the type of collaboration and the role of participants in the innovation

ecosystem can change over time (Adner 2006). If the innovation ecosystem sets itself the task of providing expertise, networking, investment searches, and innovation commercialization, then the participants may change their roles depending on their partners, time and ways of collaboration. Second, in Paper 4 and partly in Paper 1, I study exactly how the process of building trust between opinion leaders and start-ups for successful cooperation in projects occurs (Truog, Curtis 2018, Turcotte et al. 2015, Liu et al. 2015, Sudha, Sheena 2017). I also look at what types of projects may be chosen for cooperation by opinion leaders, how to maintain interest in cooperation in future projects, and what limitations exist for start-ups in such collaboration. I also highlight the goals of opinion leaders from cooperation with start-ups.

Examples of developing and applying a business model innovation in Papers 1 and 4 complement numerous studies on innovation and business model innovation with the example of a mature or conservative industry (Chesbrough 2010, Flammini et al. 2017, Roaldsen 2014). Product innovation and business model innovation contribute to the identification of new business niches that were not interesting to traditional companies (Kulkov et al. 2021). However, continued use of the business model innovation may generate interest from other companies, which will require the company to continually work on improvements. Open innovation can be part of a start-up's roadmap to conquering the market (Chesbrough, Kim & Agogino 2014; Igartua, Garrigós & Hervas-Oliver 2010). The resources of the innovation ecosystem are more focused on joint product development by a group of companies, creating additional value for customers and lock-ins to retain partners within projects (Enkel, Gassmann & Chesbrough 2009; Ketonen-Oksi and Valkokari 2019). Participants in the innovation ecosystem can commercialize innovation in a variety of ways and offer value both collectively and separately to the customer (Boni 2018). The key advantage of this approach is the creation of greater collaborative value than that of individual companies or other participants (Adner 2006).

This research starts by exploring a new participant of the MedTech innovation ecosystem: the life science business accelerator. Despite the already sufficient popularity of business accelerators in other industries, for example, IT (Brown et al. 2019, Davila, Foster & Jia 2010), business accelerators in the MedTech industry are underrepresented in the innovation ecosystems of countries that pay attention to the development of the focal industry. I study parameters of business accelerators operating in the innovation ecosystems of several European countries and look at how they influence the development of start-up companies. I close this gap in the literature by proposing specific frameworks in the field of MedTech and demonstrate exactly how business accelerators interact with other participants inside and outside of innovation ecosystems. These parameters affect the development of innovation ecosystems, as well as start-ups and more advanced companies offering products and services to the market. An important distinguishing characteristic of life science business accelerators is cooperation with companies that is free for participants,

with all costs covered by public funding. Therefore, I point out the peculiarities of life science business accelerators from other industries, for example, IT, where services are provided by obtaining a share of the participant's company. It is guaranteed that investments are attracted or the search for the necessary personnel depends on the needs of the company (Cohen, Hochberg 2014). Life science accelerator programs do not guarantee achievement of the tasks that companies set for themselves from participation, but most reach their goals after participation or are generally satisfied with the program and cooperation with mentors and other companies from the batch. I agree that it is not entirely correct to compare commercial business accelerators and non-profit projects. However, such a comparative analysis would help to develop a new vision for the development of business accelerators, which in turn will help the development of the entire innovation ecosystem.

I address the topic of entrepreneurial skills training as an important factor in the growth of an innovation ecosystem (Oosterbeek, Van Praag & Ijsselstein 2010; Von Graevenitz, Harhoff & Weber 2010; Jusoh et al. 2011). The majority of MedTech nascent entrepreneurs have academic knowledge in their narrow field of expertise, while business skills remain in demand on the part of founders. Growth in the demand for business skills occurs together with the development of the company, while the need for medical skills decreases. Business accelerators play a role in providing training programs for MedTech companies; however, these programs are most often short-term courses and do not provide sufficient knowledge in management. Participating companies are interested in developing their own business skills and are less likely to attract professionals from MedTech or related industries. Business accelerators could contribute more to the development of innovation ecosystems through collaboration with universities (Ye, Zhong 2012; Vandeweghe, Fu 2018). Students could better understand the benefits of working in start-up companies, and companies would have access to new human resources for their development.

5.4. Practical implication

The key implications of this study include practical advice for researchers and ambitious entrepreneurs in the MedTech area, as well as policymakers who have an influence on the formation and development of MedTech innovation ecosystems. In addition to entrepreneurs and companies seeking to commercialize the results of their scientific research, many other members of the MedTech innovation ecosystem could benefit from greater integration within the innovation ecosystem and with external participants, along with the formation and development of new innovation ecosystems. I offer the following guidelines for entrepreneurs and start-ups:

- It is critically important for a MedTech entrepreneur to understand that the success of a company largely depends on the status of the innovation ecosystem, what material and non-material resources can be provided for use. Moreover, innovation ecosystems are transcending the

traditional approach to defining an industry (Moore 1993), thereby changing the approach to value creation and classic types of cooperation.

- Entrepreneurs should try to identify what non-obvious opportunities can be used to recognize a niche in the market (Cervini, Dogwiler 2020, Heiss 2017). Such benefits may form the basis for a business model innovation that could increase the likelihood of a company's success.
- Some participants in the innovation ecosystem consider the benefits of cooperation not only in terms of increasing income (Fehr, Gintis 2007, Belenzon, Schankerman 2015) but also in terms solving more global problems for an industry or society, for example, reducing disease and suffering in patients, reducing the use of resources, etc. Determining the motivation for cooperation or proposing promising projects for participation may reduce the required resources for the project. Understanding the logic of key participants' actions in the innovation ecosystem will contribute to the formation and application of the required business model in practice.

I emphasize that a systematic approach to the development of MedTech entrepreneurship and innovation ecosystems in countries that prioritize this direction is necessary. The combination of public funded short-term and long-term programs kickstarts the formation of the MedTech innovation ecosystem. Such activities include basic and applied research, as well as the preparation of the required infrastructure for the transit of personnel to the industry.

The results of our research should stimulate qualified university personnel to move into the industry and apply their knowledge and skills to commercialize the research results. As a first step for potential entrepreneurs, I recommend making an overview of exactly what conditions innovation ecosystems offer for such a transfer, for example, business incubators and accelerators can guide the market, evaluate an idea and give recommendations for its improvement, or provide initial business advice and mentoring (Frimodig, Torkkeli 2017). The required business skills can be improved during transit preparation and also after the company is founded. A TTO may provide support for aspiring entrepreneurs (Manbachi et al. 2018, Heinonen 2015). However, not all options for cooperation with the TTO may be attractive for start-ups (Pitsakis, Giachetti 2020). In such cases, the assessment and recommendations of other participants in the innovation ecosystem who have previously cooperated with the TTO can facilitate and stimulate this collaboration.

I offer an analysis of why and how developing cooperation between companies and opinion leaders occurs (Weng, Zhang 2021). On the one hand, this was not obvious, but on the other hand, a desirable opportunity for many companies to cooperate with respected representatives of the industry was analyzed, and the results were proposed for use by entrepreneurs. I propose a number of practical steps that could contribute to the emergence of collaboration. A start-up could increase the chances for initial collaboration if it has an innovation, an ability to solve global problems of the industry,

professionalism from the company's team, and indisputable competence in their field. It was identified that parameters outside the scope of professional activity and appealing to environmental values, for example, reducing emissions, are not of much interest to opinion leaders. Nevertheless, further cooperation in less innovative projects is possible as a result of the growth of trust and social capital of the project participants. Further projects may be less industry-changing, but they should be in the sphere of interests of the opinion leader and should correspond to the company's strategy. A company can use the social capital of the opinion leader at the stage of market analysis, prototyping, testing, marketing, sales, etc. Other market participants are more willing to contribute to the project if they see the participation and role of the opinion leader in the project. However, cooperation with opinion leaders does not only bring benefits for the company.

Therefore, entrepreneurs in the MedTech innovation ecosystem can receive additional bonuses if they have knowledge about its functioning and development. First of all, it is necessary to pay attention to the resources that the innovation ecosystem offers and compare it with innovation ecosystems in other countries. The size and range of support can play a leading role in a start-up's success. Innovation and the business model based on it is an essential step forward for a company. The lack of an invention, most often based on medical university research, significantly reduces the chances of cooperation with investors and other players in the market. Second, companies should take a closer look at the non-financial tools available in the ecosystem, such as mentoring, entrepreneurial skills development, and more. Networking is very important to success, not only within the industry but also at the intersection with other areas of expertise. However, the hidden potential of an innovation ecosystem is difficult to predict. In our case, the atypical interaction of the company with opinion leaders gave the company an advantage that was previously hidden from other participants. It is difficult to recommend specific steps to take advantage of hidden opportunities as they are individual. Third, it should be noted that not all participants in the MedTech innovation ecosystem are profit-oriented. An example would be state programs to support entrepreneurs or enthusiasts seeking to change the world. Government support gives more opportunities for companies to obtain funding or find partners without parting with the company's share.

I also offer practical recommendations for policymakers that are responsible for the development of the MedTech innovation ecosystems. I address the issue of IPR ownership as a way to develop the MedTech innovation ecosystem. The study demonstrates that the transfer of the rights to research results to researchers provides an incentive for a painless transition of academic personnel into the industry. This transit increases employment and the stability of the innovation ecosystem (Flipse, van der Sanden, Maarten & Osseweijer 2013, Teizer et al. 2012). Moreover, such a transit keeps qualified personnel in the local innovation ecosystem, preventing the transition to new but less well-known conditions. However, full ownership is not a key parameter for the successful

development of the MedTech innovation ecosystem. Companies from U.S. universities share the rights to university research results, and the U.S.-based MedTech innovation ecosystem is the largest in the world (Vlckova, Thakur-Weigold 2019, Letourneur et al. 2021).

Policymakers in advanced and emerging innovation ecosystems increasingly view the launch of business accelerators as a step toward development. Business accelerators are considered as hubs that attract companies and quickly transition the companies to a new level of development. First, companies gain access to expertise and networking. Second, investors can consider business accelerators as a source of projects for investment (Dempwolf, Auer & D'Ippolito 2014). Policymakers should be interested in forming business accelerators since they form connections between participants within the innovation ecosystem and with companies, resources, and expertise not available in the local market, and they stimulate the growth of companies (Vandeweghe, Fu 2018, Ye, Zhong 2013). In turn, the innovation ecosystem can change simultaneously with the transformation of the business accelerator. This research shows that life science business accelerators change their business model over time; for example, there is a geographic expansion of the accelerator's area of influence from the regional level to the national and possibly international level. The business accelerator development strategy can be based on this principle. Meanwhile, the companies' satisfaction of participating in the business accelerator contributes to the growth of new companies in the innovation ecosystem and its sustainability.

Taking advantage of the countries that have been developing MedTech innovation ecosystems for a longer time will be interesting for new innovation ecosystems and managers responsible for their formation. Identifying and applying successful practices provides benefits in the form of reducing time and investment costs, allowing a short turnaround to form the required infrastructure for the emergence of a new type of business. Moreover, the MedTech industry is export-oriented and characterized by the increased added value, where the role of small companies in the formation of innovations and subsequent changes is difficult to overestimate. The application of the winning practices from Papers 2 and 3 gives an understanding of exactly how to apply successful experiences when building new MedTech innovation ecosystems. Papers 1 and 4 suggest the non-obvious opportunities offered by innovation ecosystems to entrepreneurs to achieve better results and increase chances for success. Findings in this study can be applied to other industries as well. A large number of industries are now showing slow growth or even stagnation, so new technologies, business models, necessary new infrastructure, methods of creation, and capture value will be in demand outside MedTech.

5.5. Limitations and recommendations for future research

Solutions and recommendations for MedTech companies and innovation ecosystems developed in this thesis have an industrial specificity. However, the more general guidelines can be carried over to other technology industries. This includes the processes of formation and development of

companies and innovation ecosystems described in Papers 1–4. The proposed recommendations can be applied by stakeholders in the formation or development of a new innovation ecosystem, as well as by potential founders of MedTech companies considering the possibility of transit into the industry and commercialization of the university research. For correct reproduction, it is necessary to apply the proposed logic and structure with the required adaptations to local opportunities and institutional rules. The adaptation of the presented possibilities to the new context should not cause major difficulties. If the prerequisites for forming the required innovation ecosystem are similar to those under consideration, similar strategies can be used by policymakers, as well as by the founders and management of MedTech companies.

One of the limitations of this study is to focus more on the specifics of creating innovation ecosystems and forming MedTech start-ups in Europe. Little attention has been paid to competition with other advanced MedTech innovation ecosystems, such as the United States or emerging markets in Asia. However, the competition between European innovation ecosystems was out of the scope of the study. European founders are more likely to form their companies in local innovation ecosystems; however, companies from emerging markets seek to obtain the benefits of locating companies in more advanced innovation ecosystems.

Companies already in the more advanced stages of development than start-ups and that have not been acquired by global MedTech players are looking to expand into other major markets. It would be interesting to investigate how innovation ecosystems form ways of keeping them within the innovation ecosystem and what requests are generated by medium-sized businesses for the development of the required ecosystem.

Another limitation of the study is the lack of a clear assessment of the effectiveness of the innovation ecosystem. Researchers pay attention to various parameters, for example, the number of new companies, the contribution of the industry to export, the number of new jobs, etc. What is the return on investment from a specific entrepreneur support program, such as a business accelerator? It would be interesting to compare the innovative MedTech ecosystems and their participants formed through public, private, and public-private investments, and how to attract private capital to form the required infrastructure, improve management efficiency, reduce the likelihood of company failure, etc.

In Papers 1 and 4, we considered a single case study, which introduces its own limitations on the application of the knowledge gained. It is necessary to explore in more detail the emergence and development of relationships between market opinion leaders and companies when working on a pro bono basis. I am confident that researchers will be able to make many additions when researching this type of collaboration in other countries and industries.

A deeper approach is required to study the mechanisms and reasons for the emergence of cooperation between participants in the innovation ecosystem.

The purpose of such a study could be to analyze various industrial barriers to restructuring the innovation ecosystem. For example, collaboration between government agents and private businesses may not overlap in interests, thereby reducing the efficiency of the innovation ecosystem and increasing the likelihood of business failure and founder disappointment.

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Factors influencing the formation of new companies

This thesis focuses on how the medical technology (MedTech) innovation ecosystems contribute to the formation of start-ups. The MedTech innovation ecosystem is characterized by a large number of innovations, which are more concentrated in the pharmaceutical industry, biotech, medical devices, and healthcare information technology fields. The thesis proposes a model of a successful ecosystem that could be claimed by policymakers who make decisions about the development of the industry.

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