

LIINA JOLLER-VAHTER

The government as
an enabler and accelerator of diffusion
of radical innovations



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

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THE LIST OF AUTHOR'S PUBLICATIONS AND CONFERENCE PRESENTATIONS

Articles in international journals:

- I. **Joller, L., Varblane, U.** (2016). Learning from an electromobility living lab: experiences from the Estonian ELMO programme. *Case Studies on Transport Policy*, 4, pp. 57–67.
- II. **Joller, L.** (2020). Who is embracing the short-term rental of electric cars? A case study on Estonia. *Case Studies on Transport Policy*, 8, pp. 796–881.
- III. **Joller, L.** (2021). Gaining trust advantage for the vaccination certificate platform. *Journal of Business Models*, 9 (4), pp. 94–111.

Other research articles:

Viiding, M., Joller, L. (2012). Energy intensity in northern Europe's economic development – curse or blessing? *Estonian Discussions on Economic Policy*, 2, pp. 306–318.

Ukrainski, K., Varblane, U., Eerma, D., Timpmann, K., Joller-Vahter, L. (2019). Loodusressursside koht Eesti teadmistepõhises majanduses. *Riigikogu Toimetised*, 40, pp. 87–102.

Conference publications

Joller, L. (2012). Eco-innovation in business models – theoretical considerations. DRUID Academy Conference, Cambridge, UK.

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INTRODUCTION

Motivation for the research

My motivation for doing this research is strongly rooted in personal values, willingness, and passion to make positive things happen. Above all, I am passionate about being able to contribute to leading the change, to make steps towards an environmentally, socially, and economically just society. The necessary change calls for innovation at all levels.

There are many inventions that end up in the drawer, or they may get patented but will not be adopted into practice. Although in 1962 Kenneth Arrow still interpreted the concept of innovation as a process of producing knowledge, according to the common view¹ an invention becomes an innovation only when it is adopted on the market. However, in the case of radical technological innovations, this journey is often hindered by a chasm. The chasm, understood as the gap between the “early market dominated by a few visionary customers and a mainstream market dominated by a large block of customers who are predominantly pragmatists in orientation” (Moore, 2007: 5), is a major hurdle in the technology adoption life cycle. Crossing this chasm is a substantial challenge to companies which are ready to provide new technologies, products and services that have the potential to contribute to the well-being of the whole society. Achieving that critical mass of adopters – the point of inflection, defined as when “enough individuals have adopted an innovation that the innovation’s further rate of adoption becomes self-sustaining” (Rogers, 1995: 333) and the adoption accelerates, can be difficult without policy support because of the existence of different systemic failures, which are often related to negative externalities, path dependencies and lock-ins.

We have seen that innovations can have both positive outcomes and negative consequences; however, because of the frequent occurrence of the pro-innovation bias (Abrahamson, 1991; Kimberly, 1981), a thorough analysis for predicting the advantages and disadvantages of the innovations is seldom done (Rogers, 1995: 405). As argued by Fougère and Harding (2012), the literature defining the success of innovations has also been biased towards as fast as possible adoption and diffusion. As a result, our current socio-economic system is influenced also by the innovations which have had unanticipated consequences. These are reflected in “systemic problems” or “systemic failures” (Chaminade and Edquist, 2010; Edquist, 2011).

Society needs to understand better how to speed up the diffusion of positive innovations, and equally, how to hinder the diffusion of innovations that would likely have negative consequences. Stoneman and Battisti (2010: 734) have suggested the definition of technological diffusion as “the process by which the market for a new technology changes over time and from which production and

¹ The current prevailing definition and typologies are based on the Oslo Manual (OECD, 2018).

usage patterns of new products and production processes result". The acknowledged economist Paul Geroski has written "Diffusion is as much a process by which new technologies are developed as it is a process by which usage spreads, and this means that there is probably not a hard and fast distinction to be drawn between technology policies design to generate new technology and those designed to increase the usage of existing technologies" (Geroski, 2000: 623). However, Geroski also states that "diffusion is about matching new technology to what is usually a wide range of different user needs, and this issue is as important on the day when a scientist or engineer first starts speculating about what might be as it is on the day when the last potential user finally catches up with what is" (Geroski, 2000: 623).

Besides the technologies, the impact of innovative business models on the whole socio-economic system naturally depends on their diffusion as well, which in turn depends on the scalability and replicability of the business models. If these qualities of the business models are carefully considered when designing the innovation policy measures, then the main dimensions that are used to characterise the diffusion of an innovation – market penetration rate, geographical coverage, and speed of adoption, will improve.

It has become obvious that policies for supporting the research and development of novel solutions are necessary, however, often they are not sufficient to achieve the desired speed of diffusion. Therefore, the approach for supporting radical innovations with an anticipated positive impact on the broader society should rather be a mix, preferably a synergy of different policies, and the measures should be targeted to match the expected outcome, covering the whole process until the anticipated diffusion has been achieved. Hence, there is a need for innovation in innovation governance itself.

The conceptualisation of the innovation-diffusion process, which is based on the technology adoption life cycle (Rogers, 1995), enables targeting the policy measures to a specific adopter category. The policy design can take advantage of the increasing availability of ICT solutions, which enable collecting information during the experimental testing for analysing the adopter categories and the diffusion process in detail. In particular, the policy measures, which today tend to have a rather general objective, could be more fine-tuned also depending on the motivation triggers of the target adopter category.

The innovation-decision process that involves phases of knowledge sharing (K), changing attitudes (A), and adoption of the practice (P) (Rogers, 1995: 70), provides the means for breaking down the evaluation of the effectiveness of the existing support measures. Due to the common problem that there is a relatively high level of knowledge and even a positive attitude, but still a low rate of adoption (also known as the KAP-gap), it enables differentiation based on the particular anticipated effect of a policy measure.

A country can benefit from being the cradle for the innovative solution even if the main markets are elsewhere; similarly, a country can benefit from being just the lead market – the testbed and pioneer in adopting the solution. Therefore, the innovation policy should consider the wider national strategic goals,

including existing local industries and value chains. A small country can turn the disadvantage of limited resources and small local market into an advantage of agility. I believe this quote is a good metaphor:

“Estonia is like an Inuit kayak. A supertanker takes 16 nautical miles to turn around, but the Inuit can do a 180-degree turn on a dime.”
Lennart Meri (President of the Republic of Estonia from 1992 to 2001)

The two prevalent categorisations of an innovation are based on its subject (e.g. technological versus non-technological), or the extent of the change, ranging from very incremental improvements to radical (disruptive, path-breaking) and systemic changes. The exact conceptual line between radical and incremental innovations can be contested, and in practice it is more a continuum, but it is fair to say that the radical innovations have received more attention in my research and will likely have also in the future.

In this thesis, I have provided three examples of how the diffusion of technological innovations can be accelerated by offering them to the market with appropriate, innovative business models, and explained a few alternative approaches to how the government could act proactively and include innovative business models as a specific target in the innovation policy.

The first two studies are about the options to reduce the negative environmental impact of the transport sector, particularly about ways to accelerate the diffusion of electric vehicles and sharing economy business models in personal mobility. They explain the pilot programme that was conducted in Estonia, whereas the parallel developments in the Nordic countries have been summarised in the comparative studies by Kotilainen *et al.* (2019), Kester *et al.* (2020), and Noel *et al.* (2020). The focus of the third study came in a way by coincidence – the Estonian e-governance solutions have been adopted by other countries for some time, but the Covid-19 crisis created a sense of urgency in many more to strive for the adoption of digital solutions. At the same time, it was voiced by several renowned scientists that the health sector is clearly lagging behind in this megatrend, and that scholarly work to address the reasons behind it is missing. This brought my attention to the importance of trust in the diffusion process, especially in the case of the ecosystem-based platform business models. In both cases, the electromobility and the vaccination certificate, the country was in a situation where there was a unique window of opportunity.

In the hands of the local and national governments, there are several possibilities to seize this opportunity by designing specific policy measures or take a more pro-active role for stimulating the emergence, and for accelerating the diffusion of anticipated radical innovations, which hold the promise of contributing positively to the well-being of the whole society. Accordingly, I have set the research tasks and sub-questions to be answered in this thesis.

The aim and research tasks of the thesis

The general aim of the thesis is to advance the understanding of the role of government as an enabler and accelerator of the diffusion of radical innovations. By referring to “the government”, all the government levels that are engaged in innovation policy design and execution are considered. Further, the term “policy” is used in its wider meaning, extending the individual regulations and support actions, and referring to its origins in Plato’s and Aristotle’s works and the Greek “*politeia*” (Cassin, 2017: 801–803).

RQ: How can the government policies accelerate the diffusion of radical innovations that have a positive effect on society at large?

To fulfil the aim, the following research tasks are put forward and sub-questions are asked:

Task 1: To compose a conceptual framework for studying the role of government as an accelerator of diffusion of radical innovations by integrating the extant knowledge about the diffusion of innovations with strategic niche management (SNM) theory. SRQs:

- 1) What are the main factors (barriers, drivers and enablers) that are influencing the diffusion of radical innovations? Is the governmental intervention justified?
- 2) Which governance approaches and policy measures can be used for crossing the chasm in the diffusion process of radical innovations? In particular, how can experimentation, niche creation and protection accelerate the diffusion of radical innovations?
- 3) What are the main learning aspects that can be learned in the course of the niche experiment (pilot programme)?
- 4) Are the governance approaches and policy measures for accelerating radical innovations universal or context-specific?

Task 2: To present a detailed overview of motivations, governance approaches and policy measures, and subsequent experiences gained from the Estonian electromobility programme ELMO. SRQs:

- 1) What can we learn from the Estonian experience of designing and executing a niche experiment (pilot programme) for accelerating the diffusion of electromobility?
- 2) How should a bundle of policy measures be set up to overcome the “chicken and egg” challenge that is common for systemic radical innovations?
- 3) What role can the new business models play in the adoption and diffusion of new technologies?
- 4) How can a country benefit from being a lead market?

Task 3: To investigate the socio-economic and psychographic profile of the early users of the combination of new technology and new business model, and the government's role in supporting the diffusion, based on the data from the ELMO short-term electric car rental service pilot programme. SRQs:

- 1) How can the diffusion of innovative business models accelerate the diffusion of radical technological innovations for achieving sustainability?
- 2) How can the government policies support the emergence and diffusion of innovative business models that have a novel technology at their core?
- 3) How should the government policies differ depending on whether the aim of the policies is sharing knowledge, changing attitudes or changing behaviour?
- 4) How should the government policies be different depending on which adopter category they are targeted at?

Task 4: To analyse the role of trust in the innovation diffusion path, especially in the context where there is an urgent societal need for globally accepted innovation and not much time for learning through trial-and-error in local or regional niche experiments. SRQs:

- 1) How does the existence or lack of trust affect the diffusion of radical innovations?
- 2) What is the role of governments in building trust?
- 3) What is the role of governments in creating international interoperability between national data governance approaches?
- 4) How can the extant knowledge about building successful commercial platform business models contribute to creating the globally accepted vaccination certificate platform?

Task 5: Consequently, based on the above, to make recommendations for governance approaches and policy measures for accelerating the diffusion of radical innovations for larger societal impact. SRQs:

- 1) Which governance approaches and policy measures are most effective for accelerating the diffusion of radical innovations?
- 2) How is the country-specific context influencing the appropriate governance approaches and policy measures?
- 3) How is the domain-specific context influencing the appropriate governance approaches and policy measures?
- 4) Whether and how should the policies be aimed specifically at each innovation-decision process phase and adopter categories?
- 5) How can the experiences from the niche experiments (pilot programmes) be used for creating policy measures?
- 6) What are the advantages and disadvantages of being a lead market or a lag market?

The structure of the thesis

The thesis is comprised of an introductory chapter, which explains the extant understanding of the government's enabling and accelerating role in the diffusion of radical innovations, and existing research gaps in this literature stream. It is followed by three case studies, which exemplify some alternative innovation policy measures that have been planned and executed in Estonia to support the diffusion of radical innovations. The sequence of the studies follows the top-down logic where first the government's role as a context creator and infrastructure provider is highlighted. Thereafter, the examples show how the government can take the role of a pioneer user and even the role of a car rental start-up founder. In the last study, the government has the role of providing trust credit for its companies which have developed technologies with the potential to achieve fast global diffusion. Finally, in the last chapter, the findings are summarised, and their policy implications outlined. The general structure of the thesis is presented in Figure 1.

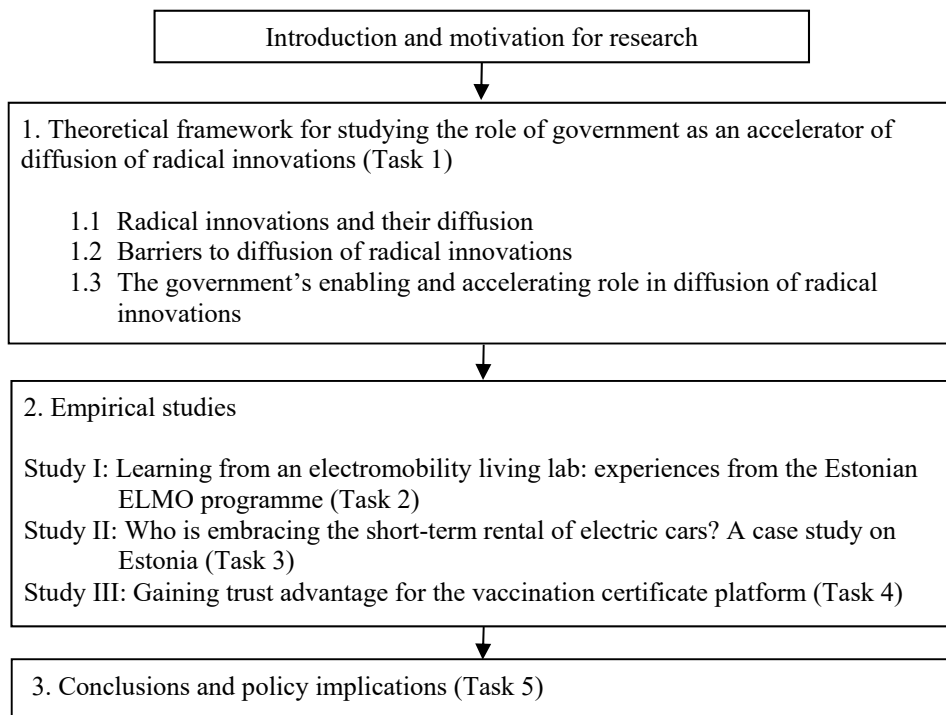


Figure 1. The structure of the thesis.

Methodology

The research in this thesis adopts a multi-methodological approach, utilising a variety of data sources, methods and theoretical viewpoints to provide answers to the research questions. Thus, the procedure did not follow a linear process. Instead, it was performed according to an iterative puzzle-solving process, evolved by the interaction between theoretical foundation and empirical material. In the thesis, I have used both qualitative and quantitative analysis. The methods of each of the empirical studies are explained in more detail in the sub-chapter of the respective study.

Initially, for building the conceptual framework for the thesis and positioning the individual studies, a thorough literature review was conducted, which included academic sources, as well as policy papers from a wide array of topics related to the research question. In the theoretical framework, the most relevant concepts and views according to the author of the thesis have been briefly explained. While the topics at hand provide a significant amount of new academic papers each year, for composing the theoretical framework and introduction, the more well-established scholarly works have been preferred. The choices have been made based on the necessity for understanding the three empirical papers and repeating the articles themselves has been avoided.

The three empirical studies were conducted as stand-alone academic papers, each having their own specific research questions and methods section. The common object of the studies is the government's approach to supporting the acceleration and diffusion using a mix of traditional policy instruments and more proactive approaches, but each of the articles tackles a different subject. By referring to government, I mean the whole group of institutions which, from the country's perspective can influence the innovation policy and the selection environment, and I do not specifically analyse the communication or job division between various government agencies that differ country by country.

The cases are outliers, particularly regarding the level of pro-activeness taken by the government, but also considering the agility and responsiveness to seize the window of opportunity.

Study I: Learning from an electromobility living lab: experiences from the Estonian ELMO programme

The in-depth case study investigates the motivations behind, planning and execution of one electromobility niche experiment that encompasses several sub-projects and a mix of incentives. The study follows the timeline of the policy-making and execution path, which took place at a time when there were no lead markets as role models and no specific previous knowledge available. The case is analysed from a systemic perspective and by employing the living lab framework.

The analysis is based on publicly available secondary data and several semi-structured expert interviews. The list of interviewees (Appendix 1) also includes stakeholders from other countries as their insights contributed to the under-

standing of the broader context and electromobility pilot programmes in other Northern-European countries. The guiding questions of the semi-structured interviews (Appendix 2) are broader than the focus of the studies that are included in this dissertation because they also contributed to building the basis for another applied research project that was running in parallel (led by professor Raimo Lovio and Armi Temmes from Aalto University). Examples of studies where some of the interviews were also indirectly used include Temmes *et al.* (2013) and Temmes *et al.* (2014).

Study II: Who is embracing the short-term rental of electric cars? A case study on Estonia

The fact that the ELMO short-term rental service of electric cars is a combination of new technology and new business model makes the analysis of drivers and barriers of diffusion, and relevant potential policy measures more challenging.

The qualitative case study methodology has been considered useful in management research (Gummesson, 1991), and it has also been dominating the research on business models. However, to get a better understanding of who are the people who form the subgroup of pioneers and early adopters of an innovation, in the second study I use econometric analysis.

The database for the analysis consists of 14,810 unique rental sessions during almost two years of the pilot project, i.e. all rent sessions starting from launching the service on 11.07.2013 until 31.05.2015. In the database, each session was characterised by the client's national personal identification number, registration number and model of the car, time and place of starting the session, time and place of ending the session, length of the session, and kilometres travelled. During the first 690 days of the pilot project, the rental cars had been driving for ca 1,870 km per day, resulting in a total passage of close to 1.3 million kilometres.

For compiling a detailed picture of the users who represent the “innovators”² and “early adopters” categories on the innovation diffusion curve, the rental database was merged with the 2011 National Population and Housing Census³ database, consisting of a wide variety of socio-economic data about 1,294,455 Estonian permanent residents.

² Sometimes called “pioneers”.

³ <http://www.stat.ee/phc2011>

Study III: Gaining trust advantage for the vaccination certificate platform

In this study, the case of the digital vaccination certificate is addressed in the platform business models' framework, and the role of trust in gaining competitive advantage – the trust advantage – in its fast and widespread adoption is particularly exemplified. This case was written in parallel with the actual development and piloting of the vaccination certificate platform, not *ex-post*, as common in business model literature. Therefore, the article covers the niche planning and setup phase, and cannot draw conclusions about its full implementation or phase-out processes. Retrospectively, we know that the final implemented solutions deviated from the initial plan, but it is also rather clear that considering the overall digitalisation trend one day the countries will come back to this issue.

It is a case study with strong links to the rich literature on the phenomenon of trust, and how the government can provide trust credit. In this case, among others, a Memorandum of Understanding (MoU) was signed between the government of Estonia and WHO⁴, and it is also one of the concrete projects under the wider international collaboration for the digitalisation of government services where Estonia and Germany collaborate⁵. Hence, looking back on the analysed period we can see that the experimentation continues in a slightly different format, and it has also been given an extended timeframe. So far, the role of trust as a source of competitive advantage and as an enabler of diffusion of innovations has been studied only indirectly, and no studies are known about the government's role as a trust credit provider.

Discussion and conclusions

In order to draw conclusions, I pull together insights from all three empirical studies. I use the analytical, as well as the systems approach. The system approach differs from the analytical approach in that in the analytical approach, the whole is seen as the sum of its parts. According to the systems (systems thinking) approach, the whole may be greater (or lesser) than the sum of its parts (Churchman, 1968). It is applicable in this particular case because, first, also in a business model, the different components should be consistent and, if possible, reinforce one another. Second, the trust towards a platform-based business model, and towards the products or services it offers, can only be created when considering the motivations of all platform ecosystem stakeholders together. Third, the different instruments of the policy mix and other support from the government can also create reinforcing effects.

When writing the first case study about setting up the Estonian electromobility programme, I started off by looking at the stakeholders and their interactions in the living lab framework (e.g. William J. Mitchell, Kent Larson,

⁴ https://vm.ee/sites/default/files/Estonia_for_UN/Rasmus/who_estonia_mou_05.10.2020.pdf

⁵ <https://www.itu.int/en/mediacentre/Pages/cm06-2020-ITU-Estonia-Germany-DIAL-digital-transformation-government.aspx>

and Alex Pentland), which was widely used for describing and analysing experimental policies back in 2015. The experimentation in a living lab requires a conductor and stakeholders, typically the experiment is somehow temporarily isolated from the rest of the society, and new knowledge creation is an important outcome. The living lab experiments are usually supported with public funding and sometimes take place in a “grey” regulative environment.

However, during the active writing period of the first electromobility-related cases, I also became acquainted with the SNM school of thought and scholars (e.g. Johan Schot and Frank Geels) and found that it partly overlaps with the living lab and is even more suitable for me because of its elaborated connections to the regime level and broader context that surrounds the nascent innovation. Hence, the discussion and conclusions are presented in the framework of the strategic niche management (SNM) theory (Kemp *et al.*, 1998; Schot and Geels, 2008), which provides a good framing for studying the design of the support measures for socially desirable and path-breaking innovations, which often need protection from the existing market pressures.

Contribution of individual authors

Liina Joller-Vahter has been either the sole or the main author of all the three studies that are included in this thesis. The first study was co-authored with Prof. Urmas Varblane, who was also my supervisor and mentor throughout my doctoral studies. The author of the thesis wrote most of the first paper, whereas the fruitful discussions with the co-author gave many insights and valuable guidance. The second and third studies are solo-authored.

Acknowledgements

When acknowledging the people who have had an impact on writing this thesis and shaping my doctoral journey, I should definitely start with my supervisor Urmas. Throughout the years, he has been an inspiration way beyond the thesis supervisor's role. Additionally, in the first study years I got a lot of support from Tõnis, Mervi and Inna, my first colleagues at the Chair of Entrepreneurship.

My academic works have been strongly influenced also by several research visits, most of them were made possible by the support of the doctoral school grants. In the chronological order, I would like to recall with kinds words the collaboration with Asel and Alasdair at the Technopolis Group, Armi and Raimo at the Aalto University and Anna and Rolf at the University of St. Gallen. Given that the faculty in Tartu is rather small and we cannot have an expert in house for every specific topic, these international collaborations cannot be overestimated.

Throughout the years I have received constructive feedback from so many that it would be impossible to mention everyone. From the colleagues I would like to thank separately Maaja, as she was the one who gave a lot of boosting energy for finalising the third paper, and the thesis itself as well, and also Andres who already several years ago advised on options for the econometric analysis of the second study. Additionally, I would like to thank Andrew, who has helped to fine-tune the text, and whose good advice has always exceeded the correction of the grammar. In the context of finalising the doctoral studies I would like to thank those who gave good feedback for the “umbrella” of the thesis, especially the opponents and discussants at the pre-defence.

The Ph.D. journey would not have been as enjoyable as it was without my fellow doctoral students, with whom we had so many fruitful philosophical discussions, especially during the earlier years of my studies.

It would have been difficult to pursue doctoral studies without the support from my family. I am grateful for my husband Priit and daughter Silvia for their understanding when I have had challenges in dividing priorities between work and home, and Karl, who is a tireless driver for life-long learning, as he constantly reminds me that even a PhD degree is not sufficient to answer all the Why?-s that a 5-year old may come up with.

ABBREVIATIONS

AFV	Alternative Fuel Vehicle
BEV	Battery Electric Vehicle
BMI	Business Model Innovation
CO ₂	Carbon dioxide
DSP	Dominant Social Paradigm
ETS	Emissions Trading Scheme
EU	European Union
EV	Electric Vehicle
FFV	Flexi Fuel Vehicle
GDP	Gross Domestic Product
GPS	Global Positioning System
GPT	General purpose technology
ICE	Internal combustion engine
ICT	Information and communication technology
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IT	Information technology
MLP	Multi-Level Perspective
MoU	Memorandum of Understanding
NEP	New Environmental Paradigm
NGO	Non-governmental Organisation
NIMBY	Not-In-My-Back-Yard
NIS	National Innovation Systems
OECD	Organisation for Economic Cooperation and Development
RED	Renewable Energy Directive
RQ	Research question
SI	Systemic Innovation
SME	Small and medium size enterprise
SNM	Strategic Niche Management
SRQ	Sub-research question
TEP	Techno-economic paradigm
TEPs	Test and Experimentation Platforms
TIS	Technology Innovation Systems
TM	Transition Management
WHO	World Health Organisation

1. THEORETICAL FRAMEWORK

1.1. Radical innovations and their diffusion

I start by explaining the key concepts and terminology related to innovation, and how I understand “radical” in this context. Furthermore, I highlight the main contributions to the literature on the diffusion of innovations, and the factors that have been found as the main barriers to the adoption and diffusion. Thereafter, based on the extant literature, I bring forward the main enablers and accelerators for the diffusion of radical innovations, and the current understanding about what is the government’s role in it. Derived from my motivation to write this thesis, I hereby focus particularly on innovations, which hold a promise for achieving broader positive societal impact, not just increasing the wealth of a few entrepreneurs.

Innovation

It was Joseph Alois Schumpeter⁶, whose works (1939; 1942) gave a boost to the academic discussion about innovation in its current prevailing meaning. It would not be possible to cover here the whole rich history of innovation research, therefore in the theoretical framework, the main emphasis is on the aspects that are crucial for understanding the context of the three presented case studies.

In this thesis the term “innovation” is used as defined in the latest edition of the Oslo Manual (OECD/Eurostat, 2018): “An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit’s previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process).” According to this definition, the term “innovation” can be used both for describing an activity or the outcome of the activity.

Dosi (1982) makes an important distinction between continuous changes and discontinuities in technological innovation, specifying that “continuous changes are often related to progress along a technological trajectory defined by a technological paradigm, while discontinuities are associated with the emergence of a new paradigm” (Dosi, 1982: 147). The technological discontinuity is inevitable (Anderson and Tushman, 1990). Freeman and Perez (1988) have taken a systemic perspective and derived from that, specified that the difference arises based on whether the innovation can or cannot be used without changing other features of the system, i.e. whether it changes the existing techno-economic paradigm (TEP).

Dosi (1982), who favours evolutionary economics (over the neoclassical view), argued that solely the market mechanisms are insufficient to explain the emergence of new technological paradigms. He further claimed that the inno-

⁶ <https://www.econlib.org/library/Enc/bios/Schumpeter.html>

vation cannot be explained as a one-directional process, instead, the emergence of new technological paradigms “stems from the interplay between scientific advances, economic factors, institutional variables, and unsolved difficulties on established technological paths” (Dosi, 1982: 147), which all together “define the process of selection of new technological paradigms among a greater set of notionally possible ones” (Dosi, 1982: 147).

Innovation has been studied mainly at firm level or national level. For firms, innovation can be a cornerstone in creating competitive advantage, or in another wording, a strategy to outperform competition (Govindarajan and Kopalle, 2006: 189; Porter, 1979 and 1985). Innovation studies at the national level have created a rich literature stream on National Innovation Systems (NIS) (e.g. Freeman, 1982, 1987; Lundvall 1985, 1992; Nelson and Rosenberg, 1993; Patel and Pavitt, 1994; Metcalfe, 1995; Edquist, 1997, and many others), where the traditional view on the government’s role as an enabler and accelerator of innovation has been extensively discussed.

Business model

The works of Everett M. Rogers (1995; 2003) and Geoffrey Moore (2007) provided the first insights and inspiration when I started my doctoral studies to focus on business model innovations. The concept that was novel back then soon started to provide new books and papers in extensive amounts. Among them were the ontologies, typologies, and patterns, e.g. the work of the BMI Lab, led by Oliver Gassmann (2020).

In the thesis, I use the business model and business model innovation concept in its broader meaning of value creation and capture logic (Amit and Zott, 2020), and not narrowly as a graphical abstract, e.g. the Osterwalder and Pigneur’s widely used canvas (2010). The business model concept in this thesis is primarily used as the subject of change, i.e. when the value creation and capture logic changes, it enables the acceleration of diffusion of new technology or products.

Radicality

The extent of risk and uncertainty associated with innovation depends upon its amplitude (extent of the change), which can be measured along the innovation continuum, ranging from the very radical innovations to very incremental improvements on the other end. According to the earlier works of Schumpeter (1942), radical innovations create major disruptive changes, whereas incremental innovations continuously advance the process of change. Half a century later, the distinction has become more specific, for example, one of them contrasting that radical innovations are the innovations, which advance the performance frontier faster than the existing technological trajectory (Gatignon *et al.*, 2002).

Despite the rather broad general discourse, there are few suggestions for how exactly the line of distinction should be drawn in empirical studies. Among the few, Stoneman and Battisti (2010) have suggested using cross-elasticities of demands, but it has not been widely used, most likely because of a lack of good data. For the empirical cases that are presented in this thesis, it can also be defined by using the systemic perspective approach – the difference arises based on whether the innovation can or cannot be used without changing other features of the system, i.e. whether it changes the existing techno-economic paradigm (TEP) (Freeman and Perez, 1988).

The above is also in line with Danneels (2004) and Govindarajan and Kopalle (2006), who note that the literature on disruptiveness (the term initiated by Christensen, 1997), which is one of the key characteristics of innovations, is rather limited, and the existing discourse is lacking consensus on reliable and valid measures. They continue: “Without formalizing the disruptiveness concept with a reliable and valid measure, it is difficult to conduct rigorous research to uncover the causes of the innovator’s dilemma and identify mechanisms to help incumbents develop such innovations” (Govindarajan and Kopalle, 2006: 189). Hence, they propose a definition that “a disruptive innovation introduces a different set of features and performance attributes relative to the existing products and is offered at a lower price” (Govindarajan and Kopalle, 2006: 190). At the time of introduction, it is targeted at a niche market and relatively more price-sensitive customers instead of the mainstream market, as its performance is inferior to the alternatives. The latter inferiority aspect can be disputed, and Christensen and Raynor (2003) further identify two types of disruptions: “new-market disruptions” and “low-end disruptions”, where, respectively, either a new customer segment or the more price-sensitive mainstream market may see value in the innovation when the product is introduced.

As explained above, despite being quite often used as synonyms, in conceptualising innovations the terms “radical” and “disruptive” can have different meanings. Additionally, the “niche customer” of a disruptive innovation differs from the “early adopter” of the radical innovation in two respects: “(a) the niche customer segment has not been described as one that could influence the rest of the mainstream market, either via their opinion leadership or by being role models, and (b) the niche segment, unlike early adopters, is typically more price-sensitive than the rest of the market.” (Govindarajan and Kopalle, 2006: 191)

In summary, both the radical and disruptive innovations are worth attention. However, as the focus of this thesis lies more on the radical innovations, as described by Rogers (1995) and Moore (2007), hereafter I will continue using this term.

Adoption and acceptance

Already in 1957 Griliches showed in his dissertation how the potential adopters (corn farmers in this case) calculated the pros and cons of adopting the hybrid seeds. These arguments were in line with the assumptions that the adoption and diffusion are determined by economic rationality. Later, Donnelly and Etzel (1973: 295) have suggested that “the degree of newness of a product is a major factor in determining who tries it”, bringing in the cognitive factors.

Rogers (1995: 250–251) has further systematised the variables determining the rate of adoption to five general categories: 1) the perceived attributes of an innovation, 2) the type of innovation-decision, 3) the nature of communication channels diffusing the innovation at various stages in the innovation-decision process, 4) the nature of the social system, and 5) the extent of change agents’ efforts in diffusing the innovation (Figure 2).

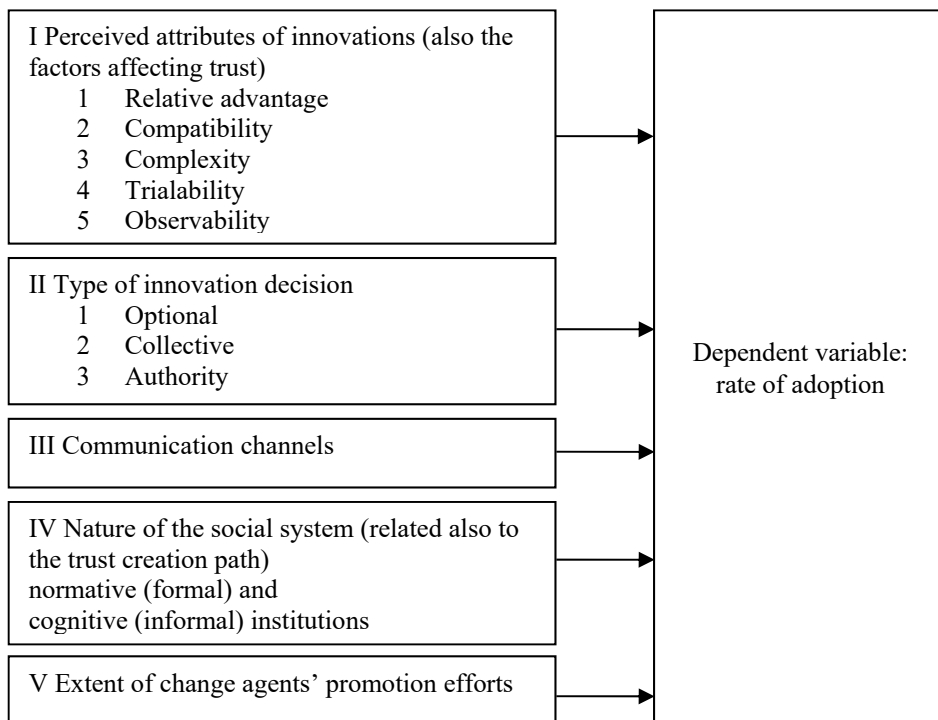


Figure 2. Variables determining the rate of adoption of innovations (Rogers, 1995: 207; Carlsson and Stankiewicz, 1991; Bleda and del Rio, 2013; amended by the author)

The explanation of each of the categories in Rogers’ work can be taken into more detail, and when the government is willing to accelerate the diffusion of radical innovations, it is a well-established base on which to start building the framework.

The relative advantage is benchmarked against the idea it supersedes, the compatibility reflects consistency with existing practices and values, complexity describes to what extent the innovation is difficult to understand and to use, trialability is the degree to which an innovation may be experimented without making commitments, and the observability reflects how visible the results of an innovation are to others (Rogers, 1995: 250–251). In the context of this thesis, it is relevant to add to Rogers’ framework the distinction between the normative and cognitive institutions (Carlsson and Stankiewicz, 1991; Bleda and del Rio, 2013), which define the nature of the social system.

The user acceptance has sometimes been misused as a synonym for adoption (e.g. Mahajan, Muller, and Bass, 1990), however, I see that it is necessary to keep these terms distinct, and use the term “acceptance” just in the meaning similar to “tolerance”. As has been explained by Wüstenhagen, Wolsink, and Bürer (2007), it also encompasses the acceptance of adopting decisions of other members of a social system (e.g. acceptance of wind turbines near home). However, the adoption studies can still find it useful to learn from user acceptance patterns.

Diffusion

Plainly, the speed of adoption is the “relative speed with which an innovation is adopted by members of a social system” (Rogers, 1995: 206), and the diffusion reflects the aggregated adoption decisions. In addition to the speed, the adoption has also been described and measured spatially (geographical spread during a fixed time), or as the rate of adoption, reflecting market penetration at a certain moment and fixed space. Battisti and Stoneman (2003) have further differentiated between the extensive and intensive margin of innovation diffusion.

Building on the works of Everett Rogers (1962; 1995; 2003), Moore (2007) has further emphasised that based on the technology adoption life cycle (Figure 3), which is based on the sequence of adoption (who are the first buyers), the most crucial phase in the diffusion process of radical innovations is when the visionary “innovators” and “early adopters” have embraced the new solution, but the pragmatic consumer segment called the “early majority” is still doubting and calculating the pros and cons. This crack between these phases has been commonly called the “chasm” and a large stake of the diffusion literature is focused particularly on crossing this chasm⁷.

⁷ In the literature about financing the innovation process this has been referred also as “bridging the valley of death”.

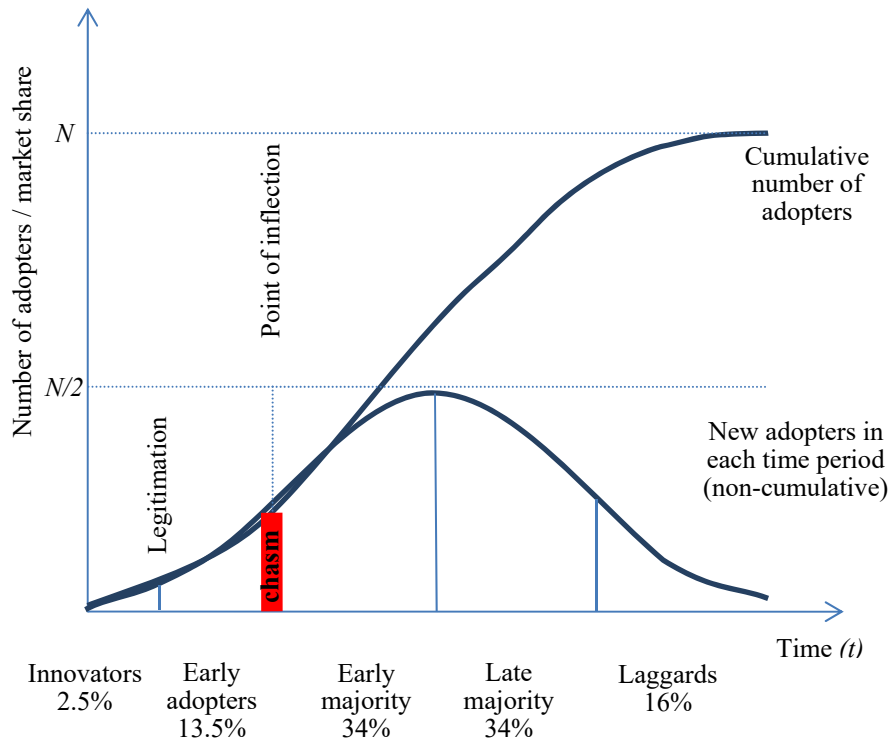


Figure 3. The classical technology adoption life cycle and the innovation diffusion S-curve (composed by the author, based on Rogers, 1995 and Moore, 2007)

The chasm appears because the motivations and the innovation-decision processes of these two customer segments are distinctively different. The “early adopter” segment is respected by peers, they are opinion leaders or role models for other members of the social system, and usually also less price-sensitive than the rest of the market. The “early majority”, on the other hand, also have above average social status, but they are not opinion leaders in the area of this particular innovation, and they are much more price-sensitive than the first two categories. Hence, the opinions of early adopters may influence the early majority, and through that affect the whole diffusion process.

In the case of the diffusion of radical innovations, which are usually more complex and less compatible with current practices, each of the first three adopter categories has its own important role to play. A big limitation of the literature stream that tries to apply the S-curve concept in practice is, however, that often the academic works, as well as the applied policy measures are grounded on the investigation of the consumption patterns and values of the more visionary consumers, but in practice, these arguments might not, and usually do not, convince the pragmatists. This leads to the argument that the policy measures

for accelerating the diffusion of radical innovations cannot be universal throughout the stages of the diffusion process of a particular innovation.

The S-curve concept (Figure 3) deals with different types of consumers and assumes the innovation itself to remain relatively the same. This may sound unrealistic when thinking of real-life situations. The new ideas may evolve and improve along pre-determined paths, but may also arise from very unexpected combinations of extant knowledge, and then they are characterised by high risk and uncertainty. This gives another justification for why in the case of radical innovations experimentation can be a particularly relevant policy tool.

The literature on innovation diffusion is enormous, and it sprawls over several disciplinary boundaries. In the literature review on the developments of innovation diffusion research, Meade and Islam (2006) summarise that the main models of the diffusion of innovations were established already by 1970, and from there onwards the modifications have just added greater flexibility and improved forecasting accuracy of already existing models. The key contributions from the earlier period of diffusion research include Fourt and Woodlock (1960), Mansfield (1961), Floyd (1962), Rogers (1962), Chow (1967) and Bass (1969). Geroski (2000) has analysed the literature on modelling the diffusion of innovations and summarised that the main contributions can be grouped into four conceptually different modelling approaches:

- 1) epidemic models;
- 2) probit models;
- 3) models of density dependence;
- 4) technology choice models.

Although modelling the diffusion is not central in this thesis, I believe a brief overview of these four approaches helps to understand the complexity of parameters that may affect the diffusion, and further the variety of places where barriers may exist, and consequently the multitude of subjects of policy interventions to accelerate diffusion.

First, the epidemic model “builds on the premise that what limits the speed of usage is the lack of information available about the new technology, how to use it and what it does” (Geroski, 2000: 603). It is based on the assumption that if the new technology is significantly better, each firm would adopt it when they hear about it. Hence, the determining factor of the diffusion of an innovation is the speed of the spread of information about it. However, as a limitation, the models usually assume that there is one common source that shares the information with the market, and this rate of sharing information directly determines the rate of adoption. This is usually not the case as the information from the common source is mixed with information from current users, i.e. “word-of-mouth”. Neither does the possession of information in reality automatically and immediately result in adoption. Hence, according to the epidemic model, the shape of the S-curve is explained that first, as the number of users increases, also the number of people who will pass information by word-of-mouth

increases, and later, as the number of users exceeds the number of non-users, the number of people who do not have information will quickly decrease.

The main weakness of this model is that it can explain the diffusion process only after the initial market introduction phase as it requires that the first innovators have already started using it. Another big limitation of the epidemic model is that it takes the market size (and diffusion speed) as fixed, but in real life sometimes the new technology can find a completely new market(s)⁸, especially if the technology gradually improves.

Some scholars (e.g. Marengo, 1992) have gone deeper and argued that what the diffusion of information actually does is decrease uncertainty and consequently reduce risks. Therefore, the S-shape of the diffusion curve and the adopter categories reflect the risk-averseness of market segments. I see that this could be elaborated further by bringing in the concept of trust, and the third article of this thesis brings some examples.

Second, a common alternative to the epidemic model, the probit model (used also in the second study in this thesis), analyses individual adoption decisions of private individuals or firms based on some differentiating characteristic(s) that hypothetically determine the adoption decision. Hence, the challenge with probit models is to identify these particular relevant characteristics x_i and find measurable data for describing them. Looking at it from the policy perspective, depending on the particular innovation and the wider context (e.g. market structure), the characteristics of the potential adopters, as well as the threshold level, can be quite entrenched or they may be easily influenceable. Furthermore, the influence can come from various sources, including suppliers of the new technology and the government.

The probit models often encompass various types of adoption-related costs, e.g. costs related to acquiring information and learning, switching costs, and opportunity costs. Contrary to the epidemic models, the increase of available information and subsequent decline in the uncertainty is considered exogenous in the probit models.

Third, the models of density dependence, which are based on the organisational ecology literature, assume that the speed of diffusion is determined by the sum of the “natural rate of increase” and the “carrying capacity” of the niche. They analyse the forces of competition and legitimation, where “competition arises whenever resource constraints limit the number of organizations which can survive in a particular market or social setting, and depends mainly on population density”, and “legitimation is the process by which a new type of organization becomes accepted, institutionalized or simply just taken for granted, and it clearly depends amongst other things, on the number of such organizations already in existence” (Geroski, 2000: 616). Hence, according to

⁸ A widely known example: “I think there is a world market for about five computers” – attributed to Thomas J. Watson, Chairman of the Board of International Business Machines, in 1943.

this model, the higher density initially helps to accelerate the diffusion and then ultimately limits their take-up.

Similarly to Rogers' (1995) categorisation of adopters, it is also possible to focus on the time it takes to reach the inflection point. The inflection point as the dividing point allows studying separately the determinants of diffusion in the initial period, and what matters later on. During the legitimisation process, the new technology becomes established, and by reaching the inflection point, this process can be considered finished. Furthermore, as the adoption speeds up, the relative return that the non-users can gain if they adopt will start to decrease. This is also the main reasoning behind the density-dependence models, and the earlier works include Hannan and Freeman (1989) and Hannan and Carroll (1992). However, in case of the platform-based business models this logic can be contested.

Fourth, the technology choice models, which are based on the phenomenon of information cascades. These are situations in which it is optimal for an individual to follow the behaviour of the preceding individual without regard to his/her own information. It has been found that the presence of network externalities can further strengthen the information cascades' effects (Bikhchandani *et al.*, 1992). Information cascades have been used to explain "herd behaviour", e.g. Banerjee (1992). Geroski (2000: 619) has identified three phases in a diffusion process driven by information cascades: "the initial choice between A and B, the lock-in to A, and then the bandwagon induced by imitation".

The technology choice models can be applied to products, business models, and more generally to the key enabling technologies. The work of W. Brian Arthur (e.g. 1989) is one of the most cited in this category of diffusion models.

In practice, the diffusion curves tend to be asymmetric, do not follow the ideal S-curve, and are only roughly consistent with what the models can predict. Most of them do not factor in the possibility that the innovation may fail, i.e. not diffuse at all.

When thinking of creating favourable conditions for diffusion, a good starting point is when there are just no barriers, hence, I will elaborate more specifically on the prevailing barriers, and subsequently on possible approaches the governments can use to remove them. The discussion leads to my argumentation that the policies should be based on a thorough analysis of the roots of the barriers in a specific adopter category and addressed subject, and the mix of policy measures should be precisely targeted to their elimination.

1.2. Barriers to diffusion of radical innovations

The commonly identified barriers to adopting radical innovations and accelerating their diffusion are negative externalities, path dependencies and system “lock-ins” (OECD, 1998). These phenomena are considered a result rather than a cause of systemic failure (Woolthuis *et al.*, 2005). They, their interrelations, and their effect on the diffusion of radical innovations are further elaborated in this sub-chapter.

Path dependency and “lock-in”

Already in 1985 Paul A. David wrote about the phenomenon of path dependency, by exemplifying the emergence of the QWERTY keyboard as a dominant design⁹. It has been found (Utterback and Abernathy, 1975; Abernathy and Utterback, 1978; Utterback and Suárez, 1993) that because of path dependency, the majority of the innovations are incremental, and are following certain technology evolution cycles. In these cycles, the firms may become restricted by their own earlier decisions, but this “lock-in” situation may result from the interconnectedness with the social and economic environment as well (Woolthuis *et al.*, 2005).

Generally, the standardisation of a common tool, such as the keyboard, can be beneficial to all stakeholders. For example, it enables users to customise their behaviour and producers to achieve economies of scale; hence, it can result in increased efficiency at both ends. As argued by North (1990), who has devoted much of his research to studying path dependency, because of a multitude of simultaneous frictions even the institutional conditions change gradually along existing paths rather than by achieving immediately an optimal situation. For example, while the reasons for the QWERTY design, which originates from the mechanical construction of the typewriter, have been irrelevant for a long time, and scientifically proven superior alternatives exist, this setting of the letters still dominates. Hence, the dominant design may also become a barrier to achieving further efficiency.

The rationale that the QWERTY case explains the phenomenon of path dependency has also several opponents (e.g. Hossain and Morgan, 2009; Vergne, 2013). They argue that its dominating market position rather came from the entrepreneurial savviness that took into consideration the consumers’ needs and the logic of the market. Among other things, Vergne (2013) puts under question, when and whether at all the dominant design can overlap with the optimal solution. This question further feeds the debate on whether the government intervention to accelerate radical innovations can be justified if it is not sure that the dominant design that is evolving thanks to the government intervention is the optimal solution. It has also been highlighted by Gripenberg, Sveiby, and Segercrantz (2012) that in the innovation research the discourses on

⁹ A dominant design is a specific path, along an industry’s design hierarchy, which establishes dominance among competing design paths (Utterback and Suárez, 1993).

innovation and its consequences have been dangerously separated. As the total impact and optimality of a solution can often be unveiled only retrospectively, the recent decade has shown an increase in interest in the unintended consequences of innovations (Borrás and Edquist, 2019). Ending up in a “lock-in” situation with unintended negative consequences of innovations is something that the innovation policy should aim to avoid.

The majority of the extant literature deals with technological innovations, therefore, the works on the organisational inertia (Nelson and Winter, 1982; Hannan and Freeman, 1989), and absorptive and dynamic capabilities of the agents (Teece *et al.*, 1997; Cohen and Levinthal, 1990) could provide insights to analyse the cases of this thesis further.

Externalities

The “externalities, whether positive or negative, render the market (at least partially) inefficient, because they are responsible for a gap between private marginal income and marginal social costs” and “in the absence of appropriate incentives, the market – as a device for obtaining the social optimum – is deficient” (Callon, 1998: 247–248). Hence, externalities have been considered the major reason why an economy might not rely solely on a market system and why the policy interventions are justified.

The common classification of externalities divides them into three general types: cost and benefit externalities, consumption and production externalities, and network externalities. Due to the different dimensions that the classifications are based on, I find it practical for analysing specific cases to arrange them in a matrix (Table 1).

Table 1. The generalised matrix of externalities

Type of externality	Cost externality (negative)	Benefit externality (positive)
Consumption	Negative consumption externality	Positive consumption externality
Production (input/output)	Negative production externality	Positive production externality
Network	Negative network externality	Positive network externality

Source: Composed by the author

The cost and benefit externalities (also referred to as negative and positive externalities) impose either costs or benefits to people who are not compensated by them or have not paid for them, respectively. Therefore, negative (i.e. cost) externalities encourage excessive pollution and resource intensity, and sometimes can encourage delayed market entry (Deneffe, 1993); and positive (i.e. benefit) externalities “discourage private investment by socializing the benefits”

(Callon, 1998: 248). For example, people living in the city centre can either suffer from contaminated air or have to buy an air purifier, which would be an extra cost for them. Likewise, when the use of conventional cars is not restricted, they could benefit indirectly from clean air when other people are using zero-emission vehicles. However, benefit externalities may create market inefficiencies just as cost externalities do.

Consumption and production externalities refer to whether an externality is caused by consuming or producing a good. For example, consumption of traditional oil-based transport fuels imposes a cost externality because cars pollute the air when they drive, and fuel production imposes a cost externality because the ecosystem surrounding drilling and refineries is affected. Sometimes the production externalities can be difficult to count because they may be transferred to less developed countries, to the so-called “pollution havens” (Dicken, 2007). The production externalities have been further divided as output externalities and input externalities, depending on whether the external cost or benefit is directly related to the firm’s input or output factors. If a product is not for final consumption, but an input of another product or process, then it depends on the viewpoint whether it can be considered as a consumption or production externality.

Products “for which the utility that a user derives from consumption of the good increases with the number of other agents consuming the good” (Katz and Shapiro, 1985: 424) are affected by network externalities, or as (Liebowitz and Margolis, 1994: 133) have put it “goods exhibit network externality wherever the consumer enjoys benefits or suffers costs from changes in the size of an associated network, that is, changes in quantities demanded”. The network externality can also be both positive and negative, although, as reviewed by Liebowitz and Margolis (1994), positive network effects have been the focus of this literature.

A good example of a positive network externality in the context of the current thesis would be the high density of compatible recharging options for electric vehicles (especially during the initial take-up period). It allows recharging providers to exploit economies of scale (compared, for instance, with rare existing hydrogen recharging providers). However, along with the increase in the uptake of electric cars (either purchased or rented), the same aspect may also become a negative network externality. Continuing with the same amount of service spots, it happens, for example, that when the number of electric cars increases, the recharging network becomes overloaded in the sense that there will be no free charger available whenever a driver would need it. Hence, the effect on an individual driver (adopter) may change in the course of the diffusion process. There is a common presumption that markets, where network externalities exist, are relatively more path-dependent, i.e. that they are biased towards existing products” (Katz and Shapiro, 1992). In a way, this finding from more than two decades ago already showed what has been widely voiced now – that once the platform-based business models achieve scale, they can

provide strong positive network effects, and are extremely difficult if not impossible to compete with.

In addition to the matrix in Table 1, the externalities can be transboundary, intergenerational, and their effect may be either direct or indirect. For example, Ansuategi and Perrings (2000) have studied externalities with respect to their transboundary (when the effects are far-displaced) and intergenerational (when the effects are long-delayed) nature. They find that "where a significant proportion of the environmental impacts of economic activity occurs outside the territories in which those activities take place, the de-linking of growth and environmental degradation is less likely to happen" (Ansuategi and Perrings, 2000: 353) and that "countries are less likely to abate emissions the more the damage affects the population of other countries" (Ansuategi and Perrings, 2000: 363), which is the result of the so-called NIMBY¹⁰ symptom. Howard (2012) argued that intergenerational externalities are tougher to solve than intragenerational externalities (i.e. those for which the affected parties are all contemporary).

The above overview of various types of externalities is an important base for understanding why the literature describes a wide variety of cases where externalities can cause market failures, defined by Callon (1998: 247) as "the best result that could have been obtained was not achieved in practice". As has been found by several scholars (e.g. Liebowitz and Margolis, 1994; Callon, 1998; Ansuategi and Perrings, 2000) hampering the diffusion of innovations, both technological and non-technological ones, is one of the effects of externalities that requires governmental intervention in a systemic manner. However, because of the interdependent nature of the socio-economic system, there is also a tendency to overexploit the concept. Therefore, in case of any particular failure, it should also be differentiated between relevant and irrelevant externalities.

Bleda and del Rio (2013) have analysed the conceptual relationship between the market failure and the system failure rationales. They make explicit that "the definition of market malfunctions in an evolutionary context contrasts with the concept of market failures in the neoclassical view, which has its origin in the different ways in which markets and their functioning are conceived in both economic approaches" (Bleda and del Rio, 2013). Additionally, they explain under which circumstances the systemic failure is superior to the market failure, and in which cases they exist in parallel. Several authors, e.g. Woolthuis *et al.* (2005), have offered a categorisation of failures for innovation policy design.

Dopfer and Potts (2009), in their micro-meso-macro framework, have distinguished three levels of coordination market failure in the evolutionary framework: deep coordination failure of knowledge or generic rules to fit together, surface coordination failure of the market agents to interact, i.e. to connect and carry this knowledge, and operational failure of agents' activities and behaviours to connect. Several authors (OECD, 1998; Smith, 2000; Jacobsson and Johnson, 2000; Arnold, 2004; Woolthuis, 2005; Carlsson and Jacobsson, 1997;

¹⁰ NIMBY is an abbreviation of "Not-In-My-Back-Yard" mindset ("nimbyism").

Edquist, 1997; Rotmans *et al.*, 2001; Foster and Metcalfe, 2001; Metcalfe, 2005; Nelson, 2009; Chaminade and Edquist, 2010) have suggested that out of all possible types of imperfections, the government intervention is most justified in the case of system failures.¹¹

Digging deeper, the roots of some of these barriers can be both evolutionary or may be caused by a mismatch in the current rule complex, including rules related to and created by both the normative (formal, legal) and cognitive (informal, social) institutions¹² (Carlsson and Stankiewicz, 1991; Bleda and del Rio, 2013), and enforcement procedures (North, 1990). Roland (2004) has also generalised that when it comes to institutional change, typically the social and cultural norms are “slow-moving” institutions, and the legal and political institutions tend to be “fast-moving”, which further supports the reasoning of the role of the government as an accelerator of the diffusion of radical innovations.

In conclusion, the barriers to the diffusion of radical innovations may be rooted in a variety of historical developments in normative and cognitive rules, as well as their enforcement practices. All these can be influenced by the government by taking a systemic approach to designing a policy mix, which creates favourable conditions for the diffusion of radical innovations. The policy mix can be built by combining the traditional and novel intervention approaches.

Even if the majority of the society will agree that the change is needed (including technological and non-technological radical innovations), the question still remains how the transition to the new setting should be governed and managed? What kind of policy interventions are necessary, and socially and economically justified? These questions have been partly answered in the writings on transition management (Schot *et al.*, 1994; Rotmans *et al.*, 2001; Smith *et al.*, 2005; Geels and Schot, 2007; Meadowcroft, 2011; Sovacool, 2016; and others) and SNM (Kemp *et al.*, 1998; Rip and Kemp, 1998; Schot and Geels, 2008; Smith and Raven, 2012). The government’s enabling and accelerating role will be further elaborated in the next chapter and the three case studies.

1.3. The government’s enabling and accelerating role in the diffusion of radical innovations

The previous chapter explained that mainly because of negative externalities, path dependencies, and system lock-ins, in the case of some socially desirable innovations the free-market conditions may not support the diffusion of novel solutions at a sufficient or essentially necessary pace. This is when the government’s role as an enabler of path creation and accelerator of diffusion can be

¹¹ Sometimes referred to as “systemic failures”, “systemic problems” or “system malfunctions”.

¹² The institutions in this context are defined as the social and legal norms and rules that underlie economic activity, and their role extends beyond traditional neoclassical economics described by Nelson and Winter (1982).

crucial. In this thesis, when referring to the “solutions” I mean the combinations of technologies and business models – technological innovations (e.g. VoIP, AI, ML, blockchain, CRISPR-Cas9, etc.) as enablers of the radically new business models, and vice versa, the business model innovations as accelerators of diffusion of radical technological innovations (e.g. the short-term rental option may accelerate the uptake of electric cars).

In this chapter, I bring a broader perspective and a brief review of the standpoints of four different schools of economic thought. I find it relevant because the neoclassical, evolutionary, transformative, and quasi-evolutionary approaches have distinctively different views on the justification of governmental intervention for accelerating or hindering the diffusion process of innovations, especially influencing the market formation process. Furthermore, I bring examples of the governance approaches and policy measures that have been suggested by different schools of thought. Thereafter I move the focus towards the more recent and proactive approaches, which are further explained in the three case studies.

Neoclassical view

According to the neoclassical economic theory, based on the assumption that agents strive to maximise their utility, the innovations that are useful for the consumers would diffuse through a natural balance between supply and demand. However, empirically this is often not the case, and the utility maximisation may not be straightforward. Already in 1968, Hardin wrote in his seminal article “The Tragedy of Commons” how a group of individuals, who are acting independently and rationally according to each’s self-interest, may behave contrary to the best interests of the whole society.

In the neoclassical view, the markets constantly strive towards equilibrium, including the optimal balance in information generation and spread. Accordingly, the aim of policies is that the right amount of resources are allocated that would ensure the markets move towards this equilibrium. The agents, who are considered to be rational and selfish, make their decisions and act according to the incentives posed to them. To understand their decision-making rationale, it is necessary to differentiate between the terms “risk” and “uncertainty”. “If knowledge is invariant, agents do not face true uncertainty in their interactions, only risk as it is only operational characteristics that are uncertain” (Marengo, 1992 via Bleda and del Río, 2013: 1048) and they do not learn from an evolutionary point of view (Dosi *et al.*, 2005).

According to Arrow (1962), the governmental support for new inventions is well justified until the expected marginal social benefit from the invention equals the marginal social benefit in alternative use, but there he refers to work that is usually done in universities. Regarding diffusion, the neoclassical approach suggests that the failures are caused by problems in communication and information coordination, and allocation of resources for the production and distribution of new knowledge (Bleda and del Río, 2013).

Evolutionary view

The evolutionary viewpoints among economists became more visible after the publication of the seminal book by Nelson and Winter (1982). According to the evolutionary view, the markets are dynamic, and in this dynamic process, systemic failures may sometimes occur. In evolutionary markets firms constantly face uncertainties, and limited knowledge is one of the hindering factors for the diffusion of innovations. According to the evolutionary view, the failures may also have their origin in the exogenous disturbances, i.e. factors that are external to the market, e.g. changes in other related markets, disturbances in the financial system, changes in the relevant social, political or legal environment (Bleda and del Rio, 2013). More recently, Gruber (2020) has pointed out the main limitations of the existing adoption-diffusion theories, and possible contributions from the evolutionary view, particularly in the context of radical innovations.

According to the evolutionary view, the competitive advantage comes from the firms' capability to adapt and learn, including their absorptive capacity (Cohen and Levinthal, 1990). Improvement of the knowledge-related capabilities can increase a firm's absorptive capacity and hence contribute to its long-term competitiveness. The uncertainty aspect is related also to the adoption decisions of potential users, and further to the notion of trust and the firm's ability to build trust, which is the focus of the third study in this thesis.

In the evolutionary framework, the role of the government and the goal of its innovation policy is therefore mainly to accelerate the diffusion of existing knowledge and at the same time enable the creation of new knowledge. This can be done by enhancing agents' dynamic capabilities (Teece *et al.*, 1997) and their learning processes (Young, 2009; Metcalfe and Ramlogan, 2005).

The evolutionary viewpoint, described in detail also by Potts (2000), is partly in line with the policies that support entrepreneurial experimentation and the ecosystems that enable such experimental learning (e.g. testbeds, living labs, sandboxes, or even hackathons).

Transformative change view

The transformative change view is one of the recent approaches to frame the role of technology, innovation, and innovation policy in society. Combining the transition management approach (Rotmans *et al.*, 2001; Kemp *et al.*, 2007; Loorbach, 2010) that has been applied in the Netherlands already more than a decade ago, it has been developed by scholars who form the Transformative Innovation Policy Consortium¹³. According to Schot and Steinmueller (2018), the transformative change view criticises (but does not completely rule out) the previous approaches to support and manage predominantly technological R&D that takes place in universities' labs and feeds the economic-growth-oriented resource-depleting societal progress. They also criticise the policymakers' abi-

¹³ <https://www.tipconsortium.net>

lity to foresee the long-term consequences of their decisions, e.g. results of the R&D work that they have chosen to support.

Instead, to overcome this long-dominant pro-innovation bias they suggest that for solving the global grand challenges (e.g. the transition to a low-carbon and inclusive economy) we need transformative change and the transformation (or transition) of socio-technical systems. This can be challenging because it includes a large variety of actors, and changes in many elements, including infrastructures, regulations, user practices and preferences, cultural values, etc. This transformative change could be achieved via a transformative innovation policy that encourages open discussion about alternative pathways among all stakeholders as well as experimentation as the main way to learn and find the optimal path for society (Schot and Steinmueller, 2018). With a few exceptions (e.g. Ghosh *et al.*, 2021; Molas-Gallart *et al.*, 2021), at the moment this academic discussion is mostly of a narrative and philosophical nature. Hence, this transformative innovation policy still lacks a comprehensive toolbox for applying it in practice and measuring its outcomes quantitatively. The work by Mazzucato *et al.* (2020) strives to operationalise the mission-oriented part, however, they also focus mainly on the R&D phase, leaving untouched the scaling-up challenges that are important for achieving wider diffusion.

Multi-level perspective view

Common to transition theories is that the social and technological changes are understood as evolving together, each influencing the other. The framework of multi-level-perspective (MLP) of niche-regime-landscape (Geels, 2002) is useful in explaining the slowly emerging transition of passenger transport and the barriers caused by the existing regime (Nykvist and Whitmarsh, 2008; Geels, 2012; Whitmarsh, 2012). It conceptualises the long-term, relatively stable elements that provide the context for transitions as the socio-technical landscape, which include, for instance, global political constellations and conditions for trade. The regimes influenced by the landscape are the prevailing, mainstream order that is to some extent taken for granted. In the case of transportation, Mazur *et al.* (2015) have defined the regime by aspects such as the type of fuel, the type of vehicle powertrain, corresponding production infrastructures, as well as beliefs and habits of the relevant actors. Or as exemplified by Raven and Verbong (2007), fuel cells or batteries in cars are not only replacing a part of the car but can also create new functionalities such as a car as a small portable power station.

Several authors (e.g. Raven, 2007; Geels, 2010; Markard and Truffer, 2008; Konrad *et al.*, 2008) have emphasised the role of multi-regime interactions as a mechanism for triggering change in socio-technical regimes. Raven (2007) has demonstrated that the regime interactions can both create barriers as well as new opportunities, and Raven and Verbong (2007) have shown how the innovation both creates and is created by multi-regime interactions and suggested their typology: competition, symbiosis, integration and spill-over between the regi-

mes. Competition, symbiosis and integration have often occurred as successive phases, where in the case of symbiosis the two regimes become mutually dependent, and furthermore, in the case of integration they more or less become one. Spill-over refers to the transfer of rules from one regime to another, either intended or unintended (Raven and Verbong, 2007). Extant research on the multi-regime interactions shows that crossing the traditional regime boundaries is most likely in the case of radical and disruptive innovations, which need to destabilise existing technological trajectories (Markard and Truffer, 2008).

The MLP assumes that transitions are the outcome of long-term interaction processes between the levels of niche, regime, and landscape (Raven, 2007). For example, within the MLP framework, electromobility represents a niche innovation, which is not yet competitive compared to the, until now, very stable incumbent regime of oil-based passenger transport (Geels, 2012). However, the electromobility niche is clearly influenced by at least two regimes: the regime of personal mobility and the regime of energy, the charging (and de-charging) infrastructure being the binding element of interaction between the two regimes.

Quasi-evolutionary view and the strategic niche management approach

Aside from the scholars that strongly argue for either neoclassical or evolutionary views, there are several who propose different combinations of them. For example, Rennings (2000: 319) has suggested that “a theoretical framework integrating elements from both neoclassical and evolutionary approaches should be pursued in order to consider the complexity of factors influencing innovation decisions as well as the specific role of regulatory instruments”. Bleda and del Rio (2013) have expressed that neoclassical market failures can also be considered coordination failures that occur in an evolutionary market at its operational level. More recently, Schot and Steinmueller (2018) who have proposed the transformative change view, suggest that the combination of earlier approaches can be a way forward, but also add a strong mission orientation and wide stakeholder engagement aspect to it.

Strategic niche management (SNM) is one of the more recent approaches to theorise the quasi-evolutionary approach to managing and supporting the diffusion of radical innovations. SNM is useful for understanding how the diffusion of radical innovations can be accelerated by providing them with temporarily protected spaces – niches, which allow socio-technical experimentation with co-evolution of technology, user practices, and regulatory structures (Kemp *et al.*, 1998; Smith, 2007; Schot and Geels, 2008; Geels, 2010; Smith and Raven, 2012; Temmes *et al.*, 2013; and others). Niches develop through three internal processes of learning, voicing of expectations and creation of networks (Schot and Geels, 2008; Smith and Raven, 2012). The learning aspects in niche development have been operationalised by Schot and Geels (2008) to include: technical aspects and design specifications, market and user preferences, cultural and symbolic meaning, infrastructure and mainte-

nance networks, industry and production networks, regulations and government policy, and societal and environmental effects.

In niches the novel technologies and practices may find protection – shielding, nurturing, and empowerment (Smith and Raven, 2012), and eventually grow to challenge the dominant regime; or they may, like many inventions, remain limited. Shielding represents temporary measures to reduce the selection pressures of the regime and nurturing represents measures targeted at enhancing the niche-internal processes. The third type, empowerment, is the least studied and represents the work carried out to relate the niche with the incumbent regime (Verhees *et al.*, 2013; Smith *et al.*, 2013). It involves networks of actors who contribute to mobilising resources for niche development and help change the selection environment (Kern *et al.*, 2014). The niche can be empowered within the existing regime (fit-and-conform) or include a transformation of the regime (stretch-and-transform) (Smith and Raven, 2012). Furthermore, Verhees *et al.* (2013: 287) specified that “shielding, nurturing and empowering are not temporally successive phases, but instead analytical abstractions of different types of concrete work by (networks of) innovation advocates”.

Although recognising the landscape factors and the play rules of the regimes within it, the niche protection measures are most influenced by the governments’ guiding motivations and expectations for the situation after the protection ends. Based on the example of electromobility, we can see that the motivations may be rooted in the wider global trends and policies, but once the country has already decided to create an electromobility niche experiment, its overarching goal would naturally be achieving high penetration of EVs. However, the expectations for how the country would benefit from the niche experiment may be quite different, ranging from environmental, health and climate change mitigation-related goals to supporting the national economy and local companies and standing out with the country’s pro-innovation image.

In general, the analyses based on the SNM framework have mostly dealt with one novel technology and one geographical region at a time. There are a few examples of country comparisons (e.g. Nykvist and Whitmarsh, 2008; Ulmanen *et al.*, 2009; Lovio and Kivimaa, 2012), which all show marked differences between the countries studied. On the other hand, as the protection can only be temporary, we also know little about how to phase out the protection, how other countries could learn from these experiences, and exactly how this could eventually enhance the diffusion of radical innovations beyond geographical boundaries.

Potential benefits of being the lead market

International diffusion of innovations has been theorised assuming that countries adopt innovations at different times and are influenced by the behaviour of other countries (Dekimpe *et al.*, 2000). The countries that both adopt the innovation at an early stage and are able to enhance the adoption of their innovation design in other countries are called lead markets (Beise, 2004). The lead market

is not necessarily the locus of the innovation itself, but the lead market position improves the competitive advantage of the nation (Beise, 2004) and often benefits the companies in the lead market country. As the lead market usually can maintain the lead in penetration rates, thus it also benefits from learning-by-using (Beise and Rennings, 2005b).

Beise (2004) identified five factors that enhance the development of a lead market: 1) price advantage, 2) demand advantage, 3) transfer advantage, 4) export advantage, and 5) market structure advantage. Price advantage means that the cost of the innovation design is affordable to the consumer either through the efficiency of production, large scale of adoption, or economic policy instruments (Beise and Rennings, 2005a). In the case of electromobility, the initially high purchase price is often lowered by tax exemptions or purchase subsidies. Another source of price advantage is the price of electricity for charging the vehicles. A relative price advantage is developed in countries with a high price of fuels (Zubaryeva *et al.*, 2012).

Demand advantage is based on the contextual factors, which make the benefits of the innovation visible, e.g. for electromobility it is considered to be extant in densely populated countries with mild climate conditions and short distances, and a high level of wealth in the population. It can be enhanced with a high density of charging points, access to dedicated lanes and free parking in cities (Zubaryeva *et al.*, 2012).

International diffusion of innovations is enhanced by transfer advantage and export advantage, as well as market structure advantage. In the case of radical innovations, the diffusion of policies is also relevant (Beise and Rennings, 2005a), and hence the transfer advantage refers to the ability of a country to shape the preferences in other countries. This includes the demonstration effect (Dekimpe *et al.*, 2000), which helps to evaluate the usability of the innovation in the potential follower country.

Export advantage develops through the willingness of commercial actors to develop an export business out of the innovation, and the policy measures that enhance this possibility. This is often the case in small markets, such as Denmark, which became the lead market in wind energy because of the export orientation of its wind turbine industry (Beise and Rennings, 2005a).

Market structure advantage develops when internal competition improves the efficiency and innovativeness of the actors and innovation designs. The third independent study in this thesis suggests that Beise's (2004) list of factors that enhance the development of a lead market could and should be extended by the trust advantage.

Policy approaches to enable and accelerate diffusion

Based on the main barriers to the diffusion of radical innovations that were outlined previously, it can be summarised that the aim of the government's interventions should be either to remove or correct the externalities, eliminate lock-ins and path dependencies that hinder the diffusion of innovations that are

anticipated to provide positive outcomes for the whole society. Hence, the justification of the government’s interventions arises from situations where the market mechanisms are not sufficient for achieving this.

Broadly taken, the public policy instruments have been divided into three main categories: 1) regulatory instruments, 2) economic and financial instruments, and 3) soft instruments (Borrás and Edquist, 2013; see Table 2), also called “sticks, carrots, and sermons” (Bemelmans-Videc *et al.*, 2003).

Table 2. Examples of policy instruments in innovation policy.

Regulations	Economic transfers	Soft instruments
<ul style="list-style-type: none"> • Intellectual Property Rights • Universities and PROs statutes • Competition policy about R&D alliances • Bioethical regulations 	<ul style="list-style-type: none"> • “En bloc” support for research organisations and universities • Competitive research funding • Tax exemptions • Support for venture and seed capital 	<ul style="list-style-type: none"> • Voluntary standardisation • Codes of conduct • Public-private partnerships • Voluntary agreements

Source: Borrás and Edquist, 2013

It has been acknowledged that often the traditional innovation policy tools for supporting either the supply or demand side (Edler and Georghiou, 2007), and particularly R&D tax incentives, have some, but limited effect on creating new inventions (Mansfield, 1986; Hall and Van Reenen, 2000). Therefore, the taxonomy and intervention rationale of Edler and Georghiou (2007) are continuously being advanced, for example by Weber and Rohracher (2012) combining the Innovation Systems and Multi-Level Perspective frameworks, Edler and Fagerberg (2017) integrating goals into the taxonomy, Fagerberg (2018) emphasising the complementarities between innovation policy tools and calling for a holistic innovation policy, Kuhlmann and Rip (2018) claiming the need for new forms of cooperation, and several others.

The existing innovation policy taxonomies are based on different criteria, as they are also derived from a variety of categorisation needs. However, it can be observed that it would be difficult to fit the newer approaches, e.g. the creation of test and experimentation platforms, living labs, sandboxes, accelerators, hackathons, etc. smoothly into the picture. It gets even more challenging with differentiating between the variety of complementarities, “holistic approaches”, “policy mixes”, and other similar border-breaking approaches that are described in the empirical studies of this thesis – the government taking the role of a start-up founder, or the government as an international “salesman” and trust credit provider. The latter more proactive, participatory or executive approaches are aligned with the quasi-evolutionary view and its justification of policy interventions for innovation diffusion.

In addition, the institutional settings that differ across nations may have a major impact, for example, “the time horizon of agents, the role of trust and the actual mix of rationality” (Lundvall *et al.*, 2002: 220). The government’s enabling or accelerating role also varies greatly throughout the stages of the innovation process – from the creation of the initial idea to reaching the mass market. For a truly holistic approach, all the enlisted aspects need to be differentiated and targeted, based on the individual’s innovation-decision process (e.g. knowledge, attitudes, and behaviour). For this, the following schema is proposed (Figure 4).

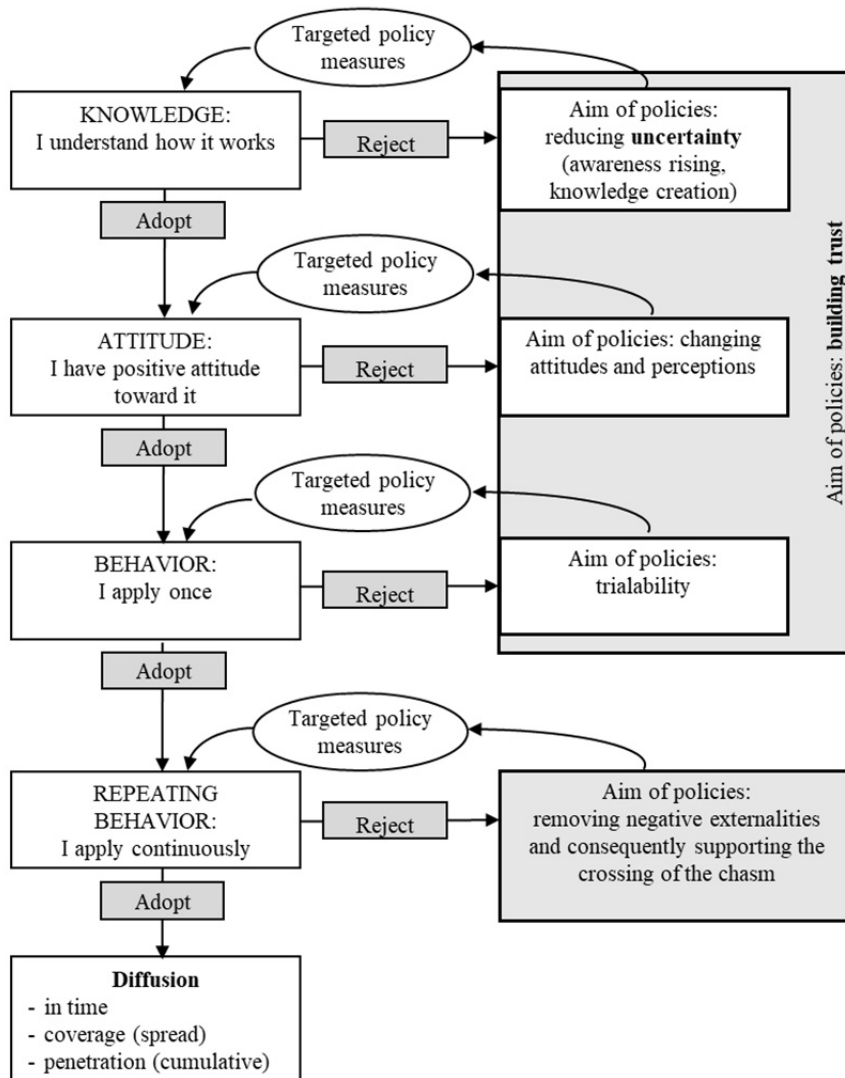


Figure 4. Targeting specific bottlenecks in the innovation diffusion process (composed by the author)

Hence, the quasi-evolutionary view, where SNM is one of the prevalent operational frameworks, is acknowledging the need for a holistic innovation policy that is defined as a “policy that integrates all public actions that influence or may influence innovation processes” (Edquist, 2019: 871) to tackle systemic failures. Yet, from the managerial perspective, the call to focus on everything does not sound viable and reasonable. Therefore, this thesis proposes that while having a holistic approach and policy mix, the underlying problems should be unbundled, and the focus of the policies should still be clearly set to the “weakest links in the chain”, i.e. clarity about the underlying failure is needed. Then, and then only, can the policies maximise their effect as an enabler or accelerator of diffusion of radical innovations.

There is no consensus among the scholars about if, or to what extent and in which format, the government’s intervention can be justified. The opinions range from “the role of government is not to run commercial enterprises” (Mazzucato *et al.*, 2020: 432) to “future innovation policy designs can build on ‘creative corporatism’, a concept in which governments (and/or related international alliances) will adopt the crucial role of facilitating broader, more diverse ‘varieties of cooperation’ in advanced capitalist economies” (Kuhlmann and Rip, 2018: 451). There are several aspects of innovation policy disputed at once, so it may be also that scholars that agree on one aspect will disagree on the other.

2. STUDIES

3. DISCUSSION AND CONCLUSIONS

3.1. Discussion

Innovation is a word that to the majority resonates with progress and positive outcomes, but we need to acknowledge that some innovations have also brought us unintended, negative long-term consequences, for example, social inequality, resource depletion, and anthropogenic climate change. Yet, innovations are also seen as solutions to these challenges, and therefore we seek their quick and wide diffusion. From the extant literature and our daily practices, we know that incremental innovations are usually not sufficient for achieving the social, environmental, and economic sustainability of the society in the anticipated pace. Therefore, we need to support the promising radical innovations and ensure that their diffusion is not hampered by market or systemic failures.

The analysed cases tackled innovative solutions (combinations of a technology and a business model) that can potentially have a positive effect on the whole society, giving strength to the justification of government's interventions to support their uptake and wider diffusion. Therefore, this thesis aimed to advance the understanding of the roles that the government can play in accelerating the diffusion of radical innovations, mixing the supply and demand-side measures, and combining them with approaches that go beyond the traditional innovation policy instruments' palette. The three cases can be considered outliers with respect to the additional proactive and "hands-on" support that the government has decided to provide, leading even to the government taking up the role of a start-up entrepreneur.

Each of the three studies in this thesis brought an example of governments' intervention rationale. In the third case, the article additionally mentions some aspects that were planned, but not fully implemented during the observed period. Hence, the cases describe the government's actual or potential role in setting up pilot programmes (niches according to the SNM framework). They exemplify that the actual niche setup needs to take into consideration the existing context, particularly the externalities enforcing the *status quo* or driving change, barriers as seen from the potential users' perspective, e.g. lock-ins, path dependencies, and the subsequent complexity of the user's decision-making process (Figure 4 in Chapter 1.3). Table 3 below highlights the general characteristics of the niches that were covered in this thesis.

Table 3. General characteristics of the niches covered in the studies of this thesis

Characteristics of the niches	Study I Learning from an electromobility living lab: experiences from the Estonian ELMO programme	Study II Who is embracing the short-term rental of electric cars? A case study on Estonia	Study III Gaining trust advantage for the vaccination certificate platform
Main subject of experimentation	Combination of new technology and new business model, interactions between the ecosystem parts and enabling infrastructure	Combination of new technology and new business model	Combination of new technology and new business model
Space	Estonia – nationwide scope	Two biggest cities – Tallinn, Tartu	International/global
Period	2011–2014 (2017)	2013–2017 (study 2013–2015)	2020–2021
Externalities	<ul style="list-style-type: none"> - Related to CO₂ emissions and their national reduction targets - Related air quality in local cities - Both positive and negative network externalities possible with EV charging infrastructure 	<ul style="list-style-type: none"> - Related to streets that are overpopulated with personal cars, traffic jams, full parking lots, etc. 	<ul style="list-style-type: none"> - Possibility for positive network externalities if widely adopted
Barriers	<ul style="list-style-type: none"> - Ca 2x higher price of EVs - Lack of short-term car rent providers - Few possibilities to test-drive EVs - Lack of EV charging station providers - Low awareness about electromobility in general, and particularly potential economic gains - Investments made in ICE fleet 	<ul style="list-style-type: none"> - Lack of short-term car rent providers - Few possibilities to test-drive EVs - Investments made in current ICE fleet - Externalities related to CO₂ emissions and their national reduction targets 	<ul style="list-style-type: none"> - Trust deficit: <ul style="list-style-type: none"> - towards vaccines - towards governments - towards IT companies - towards data handling technologies and practices generally
Government's role	Founding/executive/accelerating	Founding/executive/accelerating	Enabling/accelerating

Source: Composed by the author

From the first study, we can learn that the diffusion of radical innovations often faces the “chicken and egg” problem. This systemic challenge that holds several path dependencies and lock-ins at the same time, cannot be solved by the market forces alone, or it will take a lot more time than the society is willing to accept. It also shows that besides the positive externalities that the government’s intervention can create (e.g. cleaner air in the cities in this case), the country also has the possibility to benefit from becoming a lead market and create new business opportunities for local firms. With the chosen approach Estonia quickly became the number one country in building the nationwide EV fast-charging network, but it did not fully exploit the potential to become a lead market. The creation of new business opportunities remained limited, and after the niche protection ended, the *status quo* lasted for several years. The other main reason was likely that the protection phase-out was not planned well enough, or that its implementation did not go as planned.

The first and second studies are interrelated, the latter being “zooming” into one of the projects under the broader electromobility pilot programme. In particular, the second study gives insights into the socio-economic and psychographic profile of the early users of the EV’s short-term rental service. The results indicate that, as has been also previously known from EVs purchase intention studies, the socio-economic and psychographic characteristics together matter less than the individual’s values. However, it appears that the profile breakdown of short-term rental model clients differs from the EV buyers’. There may be several reasons behind that, including broader national context, but I have attributed this to the lower perceived risk (of losing invested money), and subsequently lower trust-related barriers in the case of trying out the rental service. As at that time most EV-related studies were conducted based on surveys about people’s intentions, in this study I was able to take advantage of the detailed data about actual events in the near past and contribute with results that are not affected by the common survey biases and are therefore more reliable.

The second study also shows that when investigating the diffusion, it is important to delineate between the internal and external margin, as emphasised by Stoneman and Battisti (2010), hence, encouraging to make the first trial is not sufficient for that the majority would become repeat users. Additionally, this study brings a good example of how a new business model can accelerate the diffusion of radical technological innovation. For both research subjects (new technology and new business model adoption) there might emerge own adopter categories, each having its own approach for gaining and processing new knowledge, changing attitudes, building trust and changing behaviour. Therefore, different policy interventions would be effective for each adopter category and type of innovation.

The third study about the role of trust, and the potential role of government as a trust credit provider, differs from the first two cases manifold. The sense of urgency created by the Covid-19 pandemic provided a window of opportunity to reform the paper-based vaccination certificates and bring more transparency in the whole area of vaccinations worldwide. The digital, distributed-ledger-

technology-based format that enables interoperability would give many benefits to stakeholders, but perhaps the increased transparency would be the main positive externality from the perspective of the global community. In this case, we can observe a strong path dependency however, from an economic perspective the lock-in should not be a major issue.

In this example, the government is not taking part in active execution but instead is willing to become the first client. Second, and perhaps even more importantly, the country's 10+ years of global e-governance role model status provides a reference for trustworthiness, e.g. the government has an enabling role. The scope of the niche experiment is not limited to having a local pilot programme; instead, it can be described as a "born global" and the formation of international cooperation is a crucial part of the niche protection. Additionally, as the suggested solution was a platform-based business model, we already know that the support would be needed only during the upscaling until network effects emerge, and then, if no major mistakes are made, the model becomes self-sustaining.

In all three cases, we can observe traditional innovation policy instruments (Edler and Georghiou, 2007; Borrás and Edquist, 2013) combined with novel proactive and more "hands-on" roles that the government has taken to support the diffusion of these solutions (products and services together with their business models). Table 4 summarises the main policy instruments and approaches used in the analysed cases.

The soft instruments also included what has been referred to as the creation of networks and public-private partnerships. For example, Mitsubishi Corp. collaborated with Tallinn University of Technology on the technological aspects of the vehicles; ABB, Now! Innovations, and G4S were pooled together to arrange the development and maintenance of the fast-charging network; KredEx Foundation was *de facto* the government unit responsible for executing the programme. I do not go into details about this aspect in this thesis, but it should be noted that the programme, and especially the more proactive approach also required a good collaboration between the related ministries and their subdivisions. Followingly, in Table 5, I summarise the empirical studies according to the SNM framework.

Table 4. Summary of main policy instruments and approaches used in the analysed cases (composed by the author)

		Study I	Study II	Study III
Instruments' classification by Borrás and Edquist (2013)	Regulations	<ul style="list-style-type: none"> - Some exceptions from parking fees - Use of bus lanes allowed 	None	<ul style="list-style-type: none"> - Favourable (compulsive) regulations in the home market
	Economic transfers	<ul style="list-style-type: none"> - Investment into the charging network - Direct subsidies for car purchases - Some support for universities - Government (social workers) form ca half of the first clients 	<ul style="list-style-type: none"> - Subsidised short-term car rent price 	<ul style="list-style-type: none"> - Government as the first paying client
	Soft instruments	<ul style="list-style-type: none"> - Media and promotion campaigns - Showrooms - 24/7 helpline - Public-private partnerships 	<ul style="list-style-type: none"> - Media and promotion campaigns 	<ul style="list-style-type: none"> - Public-private partnerships and international cooperation agreements
	Novel proactive and "hands-on" support	Government as the founder, owner and operator (through subcontracted firm) of charging network	Government as the founder, owner and operator (through subcontracted firm) of car rental service	Government as the export salesman and trust credit provider

Table 5. Detailed characteristics of the niches covered in the studies of this thesis.

Characteristics of the niches	Study I Learning from an electromobility living lab: experiences from the Estonian ELMO programme	Study II Who is embracing the short-term rental of electric cars? A case study on Estonia	Study III Gaining trust advantage for the vaccination certificate platform
Subject			
Technology	Electric vehicles, public fast chargers, private slow chargers	EVs; ICT solutions for keyless opening and starting of the car, app	Blockchain for e-governance
User practices	- Charging instead of refuelling - Less flexibility in planning the trip	- Renting instead of buying - Charging instead of refuelling	- Doctors entering doses in the global decentralised system - Using a digital certificate at the border
Regulatory structures	Some adjustments in national regulations, e.g. Traffic Act		Global governance and harmonisation agreement needed
Niche-internal processes			
Learning (about)	- User acceptance of EVs - Optimal location of fast chargers - Durability of EVs in the Nordic climate	- User acceptance of EVs and short-term rental service	- International interoperability and harmonisation
Voicing of expectations (narratives)	Estonia as an electromobility lead market: public fast-charging infrastructure so reliable that range anxiety stops being a barrier for EV use and demonstration efforts are sufficient for fulfilling the informative, observability and trialability needs	Estonia as an electromobility lead market: reduced need for car ownership, personally owned cars replaced by using short-term rental service	Estonia as an e-governance lead market: all vaccine certificates around the world are digital, national systems are harmonised and reliable/trustworthy, and Estonian companies provide a technological solution and operational platform for this
Creation of networks	Public-private partnerships	Public-private partnership	Network of national health authorities and ministries, starting via WHO and continuing bilaterally

Source: Composed by the author

Table 5. Detailed characteristics of the niches covered in the studies of this thesis (continued)

Characteristics of the niches	Study I Learning from an electromobility living lab: experiences from the Estonian ELMO programme	Study II Who is embracing the short-term rental of electric cars? A case study on Estonia	Study III Gaining trust advantage for the vaccination certificate platform
Protection	<ul style="list-style-type: none"> - Internal combustion engine fleet - Personal transportation based on car ownership - Gasoline/diesel stations' network 	<ul style="list-style-type: none"> - Personal transportation based on car ownership - Traditional car rental, mostly targeting tourists 	<ul style="list-style-type: none"> - Handwritten yellow cardboard certificates, unchanged since 1969 - Visual check at applicable borders
Nurturing	<ul style="list-style-type: none"> - Social workers as the first users - Generous purchase subsidies for the first ca 600 private buyers 	<ul style="list-style-type: none"> - Fixed and subsidised prices for first users throughout ca 3 years 	<ul style="list-style-type: none"> - National government as the first user and prototype tester
Empowering and connection to the existing socio-technical regime(s): “fit-and-conform” or “stretch-and-transform”	<ul style="list-style-type: none"> - No specific activities for empowerment - “Stretch-and-transform” the refuelling/recharging behaviour; now it is most common to charge at home or work 	<ul style="list-style-type: none"> - No specific activities for empowerment - “Stretch-and-transform” 	<ul style="list-style-type: none"> - Government support in international sales, building relationships with other governments and international organisations - “Fit-and-conform”
Planned protection phase-out	Privatisation (open tender for each of the pilot programme parts separately), but not covered in the study. The fast-charging network was privatised after the experimentation, but the new owner is also a state-owned company	Privatisation (open tender for fleet and trademark) is not addressed in the study. The fleet and brand were later brought by a start-up company, which is now publicly listed at Nasdaq Tallinn	<ul style="list-style-type: none"> - Protection is needed only for takeoff, network effects would ensure natural self-empowerment - Should remain decentralised, but at the same time international governance is needed

Among the temporary protection that governments can provide is being agile in establishing a favourable regulatory context that would encourage users to change their consumption, and more broadly, behavioural practices. Tables 4 and 5 summarise the main approaches used by the Estonian government to support the diffusion of the analysed solutions. If we think purely about the underlying technology, we need to acknowledge that the opportunities have been in our hands for a long time (from electric vehicles that were first introduced to the market over 100 years ago, to blockchain that has also been in use over the decade). However, there have been various reasons why their diffusion has slowed. Therefore, by using the SNM framework terminology it can be said that if the government wanted to accelerate their diffusion, it had to create protective niches for them.

Besides the innovation itself, the specific context in a country certainly plays a role in the diffusion. The texts of the individual studies do not include many country comparisons, however, the developments in neighbouring Nordic countries were followed in parallel with the writing process, and other scholars, e.g. those in the research group of Benjamin Sovacool (Kotilainen *et al.*, 2019; Kester *et al.*, 2020; Noel *et al.*, 2020) have provided rich background material on this. The domain-specific contextual factors are mainly relevant in the lock-in-related barriers, as in the transportation, infrastructure and energy sector the other recent investment decisions into technologies may need to reach maturity before the innovative solutions can be employed. However, they may also be non-technical, for example, cultural aspects of acceptance of ICT solutions, or trust in (personal) data governance in general.

The clarity and arrangement of the three internal processes (learning, voicing of expectations and creation of networks) through which the niches develop (Schot and Geels, 2008; Smith and Raven, 2012) are crucial for achieving the expected outcome. As operationalised by Schot and Geels (2008), they may include technical aspects and design specifications, market and user preferences, cultural and symbolic meaning, infrastructure and maintenance networks, industry and production networks, regulations and government policy, and societal and environmental effects. The learning aspects that the pilot programmes provide should not be underestimated, meaning that there is also value in the experiments that may seem a failure at first sight.

The main lessons from the electromobility pilot programme setup study have been discussed in the living lab framework. As transportation has remained the sector where carbon reduction targets have not been achieved, the electromobility case can be a good reference for supporting the uptake of biogas and hydrogen vehicles and providing a suitable infrastructure. Lessons from the vaccination certificate case, on the other hand, provide insights for upscaling other digital and platform-based (governance) solutions, in the health sector and far beyond.

There are many ways how a temporary protective niche can be set up, and this depends on the government's underlying motivations and expectations for the new situation. These motivations can have a longer-term, more visionary

nature, or a very concrete and practical goal. In the analysed cases they ranged from becoming a lead market to becoming an e-governance or sustainability pioneer. In both cases, the vision of a small and agile country as a perfect testbed for new solutions has been voiced. In parallel, there are also more concrete, quantified goals, e.g. how much the CO₂ emissions in the transport sector should be reduced, etc. Voicing of expectations, as well as all other communication around the niches, can vary also depending on the specific target group.

The dominant designs from which the studied niche experiments received shielding, were both of technical and behavioural nature – ranging from vehicle propulsion technology to the mental readiness to accept use-based models instead of ownership and sharing personal data in a digital format. In the case of the electromobility-related experiments, the nurturing was especially strong, as the government (with its agencies) itself took up the executive role similar to a start-up founder. The vaccination certificate, on the other hand, received nurturing through support in international relationship-building, particularly in building trust.

The empowerment, as also explained by Raven and Verbong (2012), helped to bridge the solution from the niche to the mass market. The empowerment in the form of building a favourable selection environment for electromobility continued beyond the timeframe that was under investigation in the empirical studies of the thesis. Free parking in larger towns, as well as the right to use bus lanes, are still in place and although smaller in amount, there have also been rounds of additional purchase subsidies available. This, together with similar developments in other countries, wider EV model options from vehicle manufacturers, and subsequent competition bringing prices down, has changed what Kern *et al.* (2014) call the selection environment.

According to the aims of the analysed niche experiments, in the first two cases the country was defined as the target market, whereas the third case would only be a success if it would be able to challenge the global dominant regime. In the wider perspective, the first two analysed cases are connected to the regime of energy. The broader electrification trend, together with increasing availability (and in some cases distributed production) of renewable electricity, has further empowered the development of electromobility so that we could refer to this transformation as stretch-and-transform of the regime. On the other hand, in the second study (the EV short-term rental experiment) the challenge to change the vehicle propulsion technology seems relatively smaller when compared to the required change in behaviour when switching from the ownership-based mindset to using the “rent as you go” business model. Therefore, if we consider it as a socio-technical experiment, we can easily conclude that this also matches the stretch-and-transform relation with the incumbent regime.

Niche experiments are always temporary, and typically they are also implemented in a limited geographical space. The case about the vaccination certificate is especially challenging because of its obvious international scope. In an ideal case, because of the required network effects, the launch of the

digital certificate system would be international (if not global) from day one. This is because, first, the existing dominant solution is also global, and second, even if the two competing systems would be used in parallel for a limited time, or if the new digital system would be issued only in selected countries, their acceptance still needs to be global for the whole system to make sense. Accordingly, the endeavours to create a favourable selection environment(s) should be rooted in establishing harmonisation in regulations and technical interoperability readiness. We can assume that a person who is travelling across borders has a mobile phone capable of presenting the QR code or similar to prove his/her vaccination status (if not, the code could still be printed on paper as well). Hence, leaving out the digitalisation aspect, from the users' perspective it can easily fit-and-conform to the existing behavioural practice. Similarly, the vaccination in the certified clinics as well as the checking procedures on applicable borders could fit-and-conform with the existing regime. However, despite the potential benefit to stakeholders, as explained in the third article, reaching these international agreements can be a major hurdle in the diffusion process.

Table 5 summarises protection phase-outs, which were not covered in the studies, as they had not yet taken place. In the first two cases where the government had taken the founder's and operator's role, it was clear that if the experiment turned out successfully, one day they would be privatised. The vaccination certificate, no matter where developed and piloted, and despite its decentralised nature, would eventually require some form of autarchic global governance. It would be essential to maintain the trust of the international community.

Retrospectively, it can also be summarised that the country did not use the full potential of niche experiments, even in the case of the two first electromobility-related ones. Estonia had the opportunity to become a lead market in electromobility by building the first nationwide fast-charging network in the world, but later exploited the lessons learned only partially. The reasons were likely rooted in the weaker planning (or execution) of the protection phase-out stage, but also in the lack of local companies ready to provide related products and services, particularly those which would be ready to expand their offerings to the international markets.

However, and perhaps even most importantly, the niche experiments created the opportunity to learn about policy intervention options, and these can be valuable for enabling and accelerating the diffusion of other radical innovations in the future. The country is continuously experimenting with new approaches, with examples like e-residency¹⁴, Bürokratt¹⁵, etc. Hence, the benefit may still rise with a time lag, for example from the country's reputation as being an attractive innovation testbed site.

¹⁴ <https://www.e-resident.gov.ee/>

¹⁵ <https://www.kratid.ee/burokratt>

After elaborating the government's enabling and accelerating role in the diffusion of radical innovations, I would like to take a final step back to give a reminder of why it is needed at all. The majority of academic works, and similarly the innovation policy practice, are strongly influenced by what Rogers (1995), Abrahamson (1991), and Kimberly (1981) have called the pro-innovation bias, meaning that the results of the innovations are *a priori* considered positive. This, unfortunately, also means that many poor innovations have received the protection that they did not deserve. Therefore, together with developing even more powerful approaches for the government to support the diffusion of radical innovations, it is crucial to advance knowledge for evaluation of the long-term and indirect consequences as well.

3.2. Conclusions and policy implications

Governmental support for the diffusion of radical innovations that hold promise to contribute to the well-being of the whole society can be and should be finely targeted at addressing specific barriers, the main ones summarised in Chapter 1.2. From the perspective of a potential individual adopter, they should be focused on the bottlenecks in the innovation diffusion process (e.g. low awareness, negative or neutral attitudes, lack of trialability, and negative externalities).

In the niche experiment, besides experimenting with the technologies, products, and business models, the subject of experimentation can be the policy instruments and more broadly governmental innovation management approaches themselves as well. In all three cases that are included in this thesis the government has stepped out of its comfort zone and has been more proactive compared to the traditional innovation policy practices. It is not common that the government starts running a network of car charging stations, it is not common that it launches and starts to operate a car rental start-up, nor is it very common that the government provides trust credit in such a proactive way as was in the case of the vaccination certificate.

The main takeaways from these studies can be summarised as follows:

- For fast market uptake of radical innovations, the proactive role of the government is crucial. It is especially justified in the cases where the whole society would benefit from the quick and wide diffusion of that innovation. Furthermore, the importance of government rises when the innovation at hand requires cross-national collaboration.
- The role of government should be differentiated according to the specific aim in the different diffusion process stages and broken down into different adopter categories. The aims of government support actions extend from general awareness creation and building trust in the innovation adopters to removing economic barriers.
- The radical innovations that relate to multiple regimes require a systemic approach to avoid the “chicken and egg” problem. Similarly to the platform-

based business models, often one of the stakeholder groups can be subsidised to achieve the critical amount of users at the take-off phase. However, as the support can be only temporary, together with creating the incentives, the protection phase-out process should be planned as well.

- If the governments want to have more impact on the innovation diffusion processes in their country, they should consider adding the experimentation-based approaches (including niche experiments) to their policy mix as an equal or even preferred approach to the traditional innovation policy instruments.

Consequently, it can be summarised that the diffusion of the addressed innovative solutions would likely not have been as broad and quick as it was with the proactive and “hands-on” intervention approaches of the government. Hence, I hope that this work provides some food for thought about new approaches that can be used to enable and accelerate the diffusion of radical innovations. I also hope that the role of the government as a potential co-creation, innovation, and experimentation platform member or orchestrator, and as the trust credit provider will gain even more interest among researchers and will be increasingly applied in practice.

3.3. Contribution to the literature and future research needs

The thesis contributes to more than one literature stream, and it remains to be seen where the author and other scholars will dedicate the most potential in the future. The main contribution to the innovation policy literature lies in showcasing how the government (a country’s regulatory and executive institutions together) could take a proactive and hands-on approach in enabling and accelerating the diffusion of radical innovations that they consider to be potentially benefitting the whole society. The niche experiments that were analysed in the cases combine the traditional innovation policy tools with novel approaches in a policy mix that provides the innovations temporary protection from the incumbent regime. An aspect specifically related to the SNM approach is that the thesis emphasises the importance of planning and executing the protection phase-out. The majority of the empirical as well as conceptual studies using the SNM framework still focus on setting up and operating the niches. However, to reach the mass market and become the new dominant solution the phase-out is equally crucial.

The contribution to the innovation diffusion literature that has long historical roots and a well-established theoretical base is indirect. I consider the electromobility studies relevant in showing how the analysis (and supporting) of the usually separated subjects – the new technology and the new business model can be done together, and how they could even be reinforcing each other. Hence, here lies the main connection to the business model literature as well. Another novelty lies in showing the internal and external diffusion margins

based on the real-life data of rental service users, and the differences in the socio-economic profile of these early adopters, which assumably influence their individual bottlenecks in the innovation diffusion process.

I see a lot of potential and need for further research in connecting the two strong and important knowledge streams of innovation policy and innovation diffusion. It is quite surprising that so far, they have largely developed without significant overlaps, but it could be that it is because one usually has the entrepreneur's perspective and the other the policymaker's interests prioritised.

In the third study, I explicitly bring in the notion of trust, the concept that has a history longer than any of the previously mentioned ones. Despite the opulent research on trust by philosophers and psychologists, its practical application in economics has mainly remained connected to the game theory. However, as I have argued, it is strongly connected to innovation diffusion, even more to success in business model innovation, and absolutely crucial for the success of global platform-based business models. A few notable written works towards this direction have been published as executives-oriented books, but these indicate plenty of further research directions. Additionally, although the cases here have been written from the government's perspective, the importance of trust and potential trust advantage in competition between firms is another promising research avenue. This, on the other hand, links directly back to the factors affecting the diffusion of innovations.

Taken together, perhaps the knowledge gaps have been most imminent in combining these literature streams together to advance the capability to detect specific bottlenecks in the innovation diffusion process, which is a necessary precondition to address them appropriately by the government.

The other general conclusion is that there is a huge need for developing better analytical tools to predict the unintended and indirect consequences, otherwise, with increasingly effective support to innovations, we might give support to technologies or solutions that we later regret. It can be argued that the global society currently needs some radical innovations because some time ago, either the long-term consequences of innovations were not foreseen, or the perspectives of all stakeholders were not considered. It is also possible that some innovations with knowingly negative results have been promoted, especially when there have been alluring short-term profits to be gained. This means that there is also a gap in knowledge that needs to be filled about how to slow down adoption if the consequences are not clear, or how to prevent innovations with (possibly) negative consequences from diffusing at all.

3.4. Main limitations of the thesis

Retrospectively, we can see that sometimes the long-term and indirect consequences of innovations are very hard to predict and not all innovations are necessarily positive from the whole society's perspective. For a long time, we have had a pro-innovation bias prevailing both in academic works as well as

policy and corporate practice. The collaborative path creation, suggested by the transformative view, may provide some help here. However, I do acknowledge that also in the case of the studies that are included in this thesis, we are not able to see all potential long-term implications, and that these may also include some negative consequences (e.g. related to recycling of EV batteries or increased need for energy to meet the needs of broader digitalisation trends, or things that we are currently not aware of). Hence, despite emphasising this research need, this thesis, however, is not able to fulfil this plentiful gap. It rather strives to contribute to minimising this need in the future by taking a systemic approach and combining the technological innovations with necessary or likely concurrent transformations in the whole society already in the early phase, and before the policy decisions to enable or accelerate radical innovations are made.

It needs to be kept in mind that each of the individual studies has their own limitations. The first two interconnected studies that are about accelerating the uptake of electromobility would not have happened exactly in this way and so early if the excess amount of carbon quota would not have been available. The vaccination certificate that was developed to fulfil the urgent need during the Covid-19 pandemic did not follow the logic of the optimal solution. Perhaps the time was too scarce, or perhaps lack of trust? However, considering the speed of digitalisation in the public services, we can hardly image that after a few decades we still use the yellow cardboards... Hence, the limitations actually point towards a need for follow-up studies, incl. integration of the legal, technical and behavioural aspects.

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APPENDICES

Appendix 1. Interviewees

Interviewed electromobility experts and politicians (2012–2014)

Name	Organisation and position
Mr Ola Elvestuen	Member of the city council of Oslo
Mrs Eva Solvi	Transnova, director
Mr Hans Håvard Kvisle	Norwegian Electric Vehicle Association, project manager
Ms Kristina Kitsik	Ministry of Economic Affairs and Communications
Mr Jarmo Tuisk	KredEx, ELMO project manager
Mr Criss Uudam	ABB Eesti AS, project manager of electric vehicles' fast-charging network
Mr Jyri Häkämies	Confederation of Finnish Industries, managing director; former Minister of Economic Affairs
Mr Martti Korkiakoski	Tekes, EVE-program manager
Mr Elias Pöyry	Eera Oy, business consultant

Contributors to the joint knowledge creation during the seminar in Brussels on January 29th, 2014 (Liina Joller was the main organiser of the half-day seminar)

Name	Organisation and position
Mrs Laure Chapuis	Cabinet Member of the EU Transport Commissioner Siim Kallas
Mr Hugues Van Honacker	Directorate-General for Energy and Transport, European Commission
Mr Henry Wasung	HyER, European Electromobility Observatory
Mr Bert Witkamp	Industry Liaison, Head of Industry Task Force, AVERE
Mr Toomas Haidak	Ministry of Economic Affairs and Communications of Estonia, Head of Transport Development and Investments Division

Informants from the World Electromobility Symposium (EVS27) in Barcelona on November 17–20th, 2013

Name	Organisation and position
Mr Jos Streng	European Electro-mobility Observatory & HyER
Mr Steffen Moeller-Holst	H2MOVES Scandinavia, SINTEF, Norway
Mrs Marianne Molmen	City of Oslo, Norway
Mr Harald N. Rostvik	Bergen School of Architecture, Norway
Mr Petter Haugneland	Norwegian Electric Vehicle Association, Norway

Appendix 2. Questions for the semi-structured interviews

Part I

1. What do you (your country) want to achieve by enhancing electromobility? (less environmental impact, more sustainable world, business opportunities, etc.)
 - What is the most important?
2. What are the main barriers to increasing the number of electric cars (in your country)?
 - What is the most important?
3. What are the main drivers for increasing the number of electric cars (in your country)?
 - What is the most important?

Part II

4. Which countries do you see as lead markets in electromobility and why?
5. What has been done in your country to accelerate electromobility? (politicians, companies, etc.)
 - What is the most important?
6. Do you see any controversies in current incentive package (in your country)? If yes, then which? Are the existing measures coherent? (e.g. economic, environmental, social, technical aspects)
7. In your opinion, what is the most efficient way for accelerating electromobility? What should be done to establish optimal conditions for wider diffusion/adoption of electric vehicles? (You may emphasise the importance of existing practices, incentives or add additional ones)

Part III

8. In the context of radical technological innovations, we often talk about the so-called “chicken and egg” problem. In your opinion, how we could/should overcome it in the context of electromobility? (*supporting hint: what is the role of infrastructure*)
9. How do you envision the future of electromobility (in your country)?
10. What are the business opportunities related to electromobility?

Additionally, related to above questions:

- *How has it changed during the past couple of years?*
- *Could you name other persons in your country who have influence on the development of electromobility?*

SUMMARY IN ESTONIAN

Riigi roll radikaalselt uuendusliku innovatsiooni leviku võimaldaja ja kiirendajana

Töö aktuaalsus ja motivatsioon

Käesoleva dissertatsiooni temaatika on olnud tegelikult aktuaalne juba aastakümneid. Kui varasemalt mõõdeti innovatsiooni edukust peamiselt majanduskasvu suhtarvudega, siis just viimasel dekaadil on nende kõrval võrdse koha leidnud looduskeskkonna ja sotsiaalse võrdõiguslikkusega seotud mõõdikud. Aina tihedamini on innovatsiooni peamine eesmärk sõnastatud just läbi suurte ühiskondlike väljakutsete, ning laiema kasusaajate ringi tõttu õigustatud riigipoolset sekkumist nende innovatsioonide turuletuleku võimaldamiseks ning nende kiirema leviku toetamiseks.

Uusi tehnoloogiaid ja tooteid leiutatakse palju, kuid vaid väike osa neist jõuab laiemasse kasutusse. Sel on mitmeid põhjuseid, kuid peamised on varasema kirjanduse põhjal kokku võttes negatiivsed välismõjud, rajasõltuvus ja lukustatus varasemate otsuste tagajärgedesse (ingl k. *negative externalities, path dependency, lock-in*). Everett Rogers'i poolt kirjeldatud üldistatud innovatsiooni leviku kõverat (Rogers, 1962) leiab selle ideaalkujul praktikas harva. Üks peamisi ohustajaid on turuletuleku varajases faasis nn. surmaorg või kuristik (ingl. k. *valley of death or chasm*) (Moore, 2007). Seetõttu võib üldistatult öelda, et selle kuristiku ületamine on riigipoolse sekkumise üks peamisi konkreetseid eesmärke innovatsiooni kiirema leviku toetamisel.

Ajalugu on aga näidanud, et innovatsioonil ei pruugi olla alati positiivne mõju. Paraku on senine innovatsioonialane teaduskirjandus olnud tugevalt innovatsiooni eelduslikult positiivselt käsitlev, ning mitmeid pikema perioodi vältel avalduvaid või kaudselt seotud negatiivseid tulemeid mitte arvesse võttes (ingl k. *pro-innovation bias*). Eeldades, et laiemalt seotud osapooli kaasates on võimalik neid negatiivseid (kõrval)mõjusid paremini ette näha, on innovatsiooni leviku kiirendamise meetodite teadmistest kasu ka võimalike ebasoovitavate innovatsioonide leviku aeglustamisel.

Innovatsiooniuringutes on uurimisobjektina pikalt domineerinud tooted ja tehnoloogiad, kuid seoses ärimudeli kontseptsiooni ja tööriistade (nt lõuendi) kiire levikuga just eelkõige praktikute seas, on lisandunud uurimusi ka ärimudeli leviku kohta. Pigem on need olnud siiski konkreetse ettevõtte kaasusi kirjeldavad kui laiemalt kasutatavat teooriat loovad. Samas on ärimudel üks olulisi komponente kliendi poolt vaadates tervikliku väärtuspakkumise tajumisel ning seega ka uue toote või tehnoloogia leviku kiiruse ja ulatuse kujunemisel.

Digitaalsete, sh platvormi loogikale üles ehitatud ärimudelite leviku kiiruse ühe olulise mõjurina on välja toodud usaldust. Usalduse kontseptsiooni ning selle praktilisi väljundeid on eelkõige just psühholoogide puhul uuritud samuti juba aastakümneid, kuid ettevõtete edukusega seostatavad usalduse-alased

uuringud on seda käsitletud peamiselt ülemuse-alluva vahelise suhte kontekstis. Usaldust kui konkurentsieelise allikat ning toote või tehnoloogia leviku ulatuse ja kiiruse mõjurit ei ole teadolevalt otseselt uuritud, samuti ka riigi rolli võimalikku usalduskrediidi pakkujana oma ettevõtetele.

Eeldades, et ühiskonnas on saavutatud kokkulepe milliste innovatsioonide levikut oleks vaja riigi poolt toetada, tuleb edasi leida selles sobivad meetmed, enamasti meetmete komplekt. Innovatsioonipoliitika sekkumismehhanismide kohta on rikkalik kirjandus samuti olemas, kuid võiks öelda, et tavapärases nn. tööriistakastis olevad nõudluse ja pakkumise toetamise mehhanismid jätvavad riigi rolliks kas info jagamise, raha jagamise, või üldise soosiva keskkonna loomise. Ka nõudlust toetavad mehhanismid nagu näiteks innovatsiooni soosivad hanked on olemuslikult siiski rahastamise meetmed. Vähe on teada kirjandust ja kaasuste analüüse juhtumite kohta, kus riik on eeltooduga võrreldes oluliselt pro-aktiivsem, kuni selleni välja, et võtab uue lahenduse turuletoojana sisuliselt iduettevõtjaga sarnase rolli.

Vaatamata mitmete innovatsioonide võimalikule positiivsele ühiskondlikule või keskkonnamõjule, ei suuda riik toetada neid kõiki. Ka peale esmase valiku tegemist oleks kogu nende turuletoomise ja laiemasse tarbimisse jõudmise protsessi otsetoetustega rahastamine väga kulukas. Seetõttu on riigipoolsete toetusmeetmete komplekti valikul oluline osata sihtida see õigele sihtgrupile ning võtta arvesse ka just selle sihtgrupi innovatsiooni kasutuselevõtu üle otsustamisel olulisi tegureid.

Lisaks on pakutud, et innovatsiooni leviku kiirendamiseks ja uuele lahendusele süsteemse riigipoolse toe pakkumiseks võiks kasutada nišše, mis strateegilise nišjuhtimise (Schot ja Geels, 2008) raamistiku kohaselt on ajutised soodustatud tingimused pakkumaks kaitset olemasolevate domineerivate lahenduste eest, toetamaks uue lahenduse lõplikku väljakujunemist läbi reaalsete kasutajakogemuste ning aitamaks uuel lahendusel leida sobivad seosed temaga otseselt seotud teiste valdkondadega (režiimidega). Nimetatud niššide raamistikku võiksid sobida ka eelnevalt mainitud pro-aktiivsed ja praktilist elluviimist sisaldavad riigipoolsed innovatsiooni levikut toetavad tegevused.

Dissertatsiooni koondatud kolm kaasust on nende toimumise ja üleskirjutamise ajal olnud kogu maailmas ka tehnoloogia ja ärimudeli kombinatsioonina uuendusmeelsed. Eriti on töö autorile valmistanud rõõmu, et siitsamast Eestist on niivõrd mitmes mõttes innovatsiooni valdkonna teaduskirjandusele materjali pakkuvaid kaasusi olnud võimalik leida. Järgnevalt on toodud dissertatsiooni ja üksikkaasuste kirjutamisel aluseks olnud uurimiseesmärgid ja -ülesanded.

Uurimiseesmärgid ja -ülesanded

Töö üldeesmärgiks on laiendada teadmisi riigi võimaliku rolli kohta radikaalsete innovatsioonide leviku võimaldaja ja kiirendajana. Riigi (originaalversioonis kasutatud terminit valitsus – ingl k *government*) all on silmas peetud riiki kui tervikut. Seega antud dissertatsioonis ei eristata keskvalitsuse, maakonna ja

kohaliku omavalitsuse taset ja ka mitte tööjaotust konkreetsete ministeeriumite vahel. See on oluline, kuid antud töös on võetud laiem strateegiline vaade. Seega, töö keskseks uurimisküsimuseks on:

RQ: Kuidas saab riik toetada ühiskonnale tervikuna positiivset mõju omavate radikaalsete innovatsioonide levikut?

Eesmärgi saavutamiseks on töö jaotatud viie uurimisülesande vahel:

Ülesanne 1: Luua kontseptuaalne raamistik, mis võimaldaks uurida riigi rolli radikaalsete innovatsioonide leviku kiirendamisel, sidudes selleks erinevate erialade ja ka akadeemiliste koolkondade teadmisi (sh innovatsiooni leviku üldised seaduspärad, innovatsioonipoliitika, strateegilise nišijuhtimise raamistik, usalduse käsitlus psühholoogias, jt)

Ülesanne 2: Koostada detailne ülevaade Eesti elektromobiilsuse programmi ELMO loomise motiividest ja elluviimisest.

Ülesanne 3: Uurida elektriautode lühirenditeenuse ELMO rent kui uue tehnoloogia ja uue ärimudeli kombinatsiooni pilootprojekti (ingl k *niche experiment*) varaste kasutajate sotsiaalmajanduslikku ja psühhograafilist profiili, mis aitaks riigipoolseid meetmeid paremini sihtida.

Ülesanne 4: Uurida usalduse rolli innovatsiooni leviku protsessi mõjutajana juhtumi korral, kus on globaalne akuutne vajadus uue lahenduse järgi. Lisaks näidata konkreetse kaasuse põhjal kuidas riik saab usalduse tekke protsessi mõjutada.

Ülesanne 5: Viimaks, võttes arvesse eelnevate ülesannete tulemusi, pakkuda välja soovitusi riigipoolseks meetmeteks ühiskonnale kasulike radikaalsete innovatsioonide leviku kiirendamisel.

Uurimismetoodika ja andmed

Dissertatsioonis on kasutatud erinevaid meetodeid, mis on olnud sobivaimad üksikartiklites toodud uurimisküsimustele vastuste leidmiseks, võttes arvesse ka saada olevate või kogutavate andmete analüüsi võimalusi ja -piiranguid.

Esmalt, töö kontseptuaalse raamistiku loomiseks on läbi töötatud valdkonna teaduskirjandus, minnes mitmel juhul (ja kui vähegi võimalik) tagasi koolkonna tekkimise, peamiste seaduspärade avastamise ja teooriate sõnastamise juurte juurde. Peamiste töös kesksel kohal olevate kontseptsioonide (innovatsioon, difusioon/levik, ärimudel, usaldus) kandvad seisukohad kehtivad ka tänapäeval. Näiteks, vaatamata sellele, et info hankimise kanalid on läbinud suure muutuse, siis info leviku roll difusiooni kiiruse mõjutajana ei ole palju muutunud. Valdkonna viimaste aastate teaduskirjandus on pigem varasematele teoreetilistele käsitlustele tuginevate uute kaasuste (võrdlev)analüüs. Välja pakutud uuemad teoreetilised lähenemised on tihti saanud ohtralt kolleegide kriitikat, seetõttu on käesoleva dissertatsiooni teoreetilise raamistiku puhul eelistatud kirjandust, mille puhul on akadeemiline kogukond jõudnud juba poolt ja vastuargumendid läbi vaielda.

Eraldiseisvatel empiirilistel kaasustel oli igal oma eraldiseisev eesmärk ja uurimisküsimused, samuti vastav metoodika:

Artikkel I: Õppides elektromobiilsuse eluslaborist: Eesti ELMO programmi kogemused

Kaasusanalüüs vaatab süvitsi Eesti elektromobiilsuse tekkeloo sisse, alates peamistest motiividest selle ellu kutsumiseks kuni riigipoolsete meetmete kombinatsioonini, mida kasutati selle loomisel ja toetamisel. Kuna antud pilootprojektiis said kokku väga mitmed valdkonnad ja osapooled, ja programm ise koosnes mitmest alam-projektist, siis on autor ka lähtunud süsteemsest perspektiivist (Churchman, 1968). Diskussiooni aluseks on kasutatud sel perioodil laialt kasutatud eluslabori (ingl k. *living lab*) lähenemist (Nyström and Leminen, 2011) ning elektromobiilsust ennast vaadatud kui nišši strateegilise nišijuhtimise (ingl k. *strategic niche management*) kontseptsiooni (Kemp *et al.*, 1998, Schot and Geels, 2008) kohaselt.

Artikkel II: Kes on elektriautode lühirendi kasutajad? Eesti ELMO Rent kahe esimese tegevusaasta kaasus

Artikli aluseks on andmed kõigi ELMO Rent teenuse kahe esimese aasta kasutajate kohta, mis sai võimalikuks kuna kasutajaks registreerimisel oli küsitud ka inimese isikukood. Need andmed on omakorda kombineeritud viimase Rahva- ja eluruumide loenduse andmetega. Andmed on seotud ning seejärel anonüümiseeritud, tagades uurijale väga detailse andmestiku, mis samas ei riiva uuritavate andmete kaitsega seotud õigusi. Tegelike klientide andmete kasutamise võimalus annab sellele uuringule olulise eelise võrreldes varasemate, küsitlustel põhinevate uuringutega. Saadud andmestiku peal on läbi viidud ökonomeetriline analüüs, mille tulemuste tõlgendamisel on omakorda abiks olnud ka esimese artikli kirjutamisel kogutud materjalid.

Artikkel III: Usaldusepõhise konkurentsieelise saavutamise vaksineerimissertifikaadi platvormi näitel

Kolmandas artiklis on uuritud digitaalse vaksineerimissertifikaadi loomise võimalust kasutades platvormipõhise ärimudeli väärtuspakkumise loogikat ning kaasaegseid detsentraliseeritud andmete juhtimise mudeleid ja tehnoloogiaid. Artikli keskseks kontseptsiooniks on usaldus, selle loomine, hoidmine ja selle olemasolu kui innovaatilise lahenduse leviku võimaldaja ja kiirendaja. Kuigi antud kaasuse puhul tuli esmane initsiatiiv erasektorist, siis selle globaalseks rakendamiseks vajaliku rahvusvahelise kogukonna usalduse tekitamisel on riigil kande roll.

Dissertatsiooni tulemuste mõtestamisel ja järelduste tegemisel on eeltoodud kolme kaasust omakorda võrreldud strateegilise nišijuhtimise raamistikus. Lisaks pilootprojektide loomise ja nende riigipoolsele toetamise motivatsioonile on välja toodud harvaesinevalt pro-aktiivne ja tugevalt selle praktilisse elluviimisse panustav roll, kus riik või selle allorganisatsioon võtab endale sisuliselt iduettevõtja ülesanded. Diskussioon hõlmab ka mõningast kriitikat, kus strateeg-

gilise nišijuhtimise põhimõtetest lähtuvalt oleks võinud riigi tegevus olla läbi-mõeldum ja just eriti pikemat ajalist perspektiivi ja laiemat ühiskondlikku kasu arvestades tulemuslikum.

Töö tulemuste kokkuvõte

Riigi sekkumine radikaalselt uuenduslike tehnoloogiate ja ärimudelite leviku kiirendamiseks on õigustatud lahenduste puhul, mis võiksid olla kasulikud ühis-konnale tervikuna. Enamasti vajavad need kaitset turu- ja süsteemsete tõrgete eest. Lisaks levinud poliitikainstrumentidele, sh otsesed nõudluse ja pakkumise toetamise meetmed, on riigil võimalus soovitud innovatsiooni levikut toetada ka pro-aktiivse ja praktilise tegevusega, mille kohta töösse kaasatud artiklid ka näiteid toovad.

Töö peamised tulemused võib kokku võtta järgnevalt:

- Valitsus võib mängida kriitilist rolli radikaalselt uuenduslike lahenduste leviku kiirendamisel. See on eriti oluline juhtudel, kus kasusaajaks on ühis-kond tervikuna ja kui innovatsioonist saadava kasu maksimeerimiseks on vajalik rahvusvaheline koostöö.
- Valitsusepoolse toetuse kavandamisel ja elluviimisel peaks hoolega jälgima, et see oleks vastavuses konkreetselt hetkel probleemse difusiooni protsessi etapiga ja potentsiaalse kasutusele võtjaga, keda sellega soovitakse mõju-tada. Riigipoolse toetuse komplektis võib olla kitsamalt sihitud meetmeid, sh võib eesmärk varieeruda üldisest teadlikkuse tõstmisest kuni sihitult usal-duse loomiseni potentsiaalsete kasutajate seas ja laiemalt ühiskonnas.
- Radikaalselt uuenduslikud lahendused on enamasti mõjutatud samaaegselt mitme domineeriva režiimi poolt ning seetõttu on nende leviku kiirenda-miseks vaja ka süsteemset lähenemist. Sagedane 'muna või kana' dilemma tekitab raskeid valikuid, sest kõige korruga toetamiseks ressursse ei jätku. Platvormipõhiste ärimudelite puhul näiteks tuleb valida strateegiliselt oluline osapool, keda enamasti alguses subsideeritakse, et anda tõuge esmasele kiirele kasvule. Kõigi nende meetmete puhul ei tohi aga unustada, et toetus saab olla vaid ajutine ja seetõttu on toetusmeetmete kavandamisel võrdselt oluline ka planeerida toetamise lõpetamine, selliselt, et uus lahendus suudaks iseseisvalt, ilma toeta olla jätkusuutlik.
- Kui valitsus soovib saavutada soovitud radikaalse innovatsiooni leviku kiirendamisel suuremat efekti, siis peaks ta oma toetusmeetmete komplektis kasutama ka eksperimenteerimist sisaldavaid võtteid, nt nišše (vastavalt strateegilise nišijuhtimise põhimõtetele), et selle käigus uut lahendust sama-aegselt kaitsta välismõjude eest ja toetada. Toodud näidete varal võiks riik aga kaaluda veelgi aktiivsema ja praktilisema rolli võtmist, millega ajutiselt täita sisuliselt iduettevõtja rolli kohas, kus erakapitali jaoks on riskid veel liiga suured.

Doktoritöö panus teoriasse

Käesolev dissertatsioon haakub mitmete valdkondadega ning seetõttu saab vaadata ka panust erinevate koolkondade ja ka erialade vaates. Aeg näitab, milline neist suurimat kõlapinda saab.

Innovatsioonipoliitika vaates on töö peamine panus laiemas lahtimõtestamises milline võiks olla riigi roll innovatsiooni leviku mõjutajana, eelkõige selliste radikaalsete innovatsioonide, mis praeguse teadmise juures oleksid kasulikud ühiskonnale tervikuna. Võttes kasutusele pro-aktiivsemaid lähenemisi ja kombineerides eksperimentides nii tehnoloogiaid, ärimudeleid kui sekkumismeetmeid, saab luua uutele lahendustele piiratud ajaks tervikliku toetuskeskkonna (nišši). Olulise õppimiskohana on välja toodud oht ära unustada toetamise lõpetamise planeerimist. Niššist väljumise kavandamine on samavõrd oluline, mõnikord võib olla ka võtmetähtsusega kogu eksperimendi õnnestumises.

Innovatsiooni leviku kirjandusele, mis on samuti väga pikaajaline ja rikkalik, on seos kaudne. Kui innovatsiooni leviku kirjandus käsitleb peamiselt tehnoloogiaid või tooteid, siis antud töös on nende kõrval paralleelselt olulisteks ka ärimudelid, sh platvormipõhised ärimudelid. Valitud kaasused näitavad, et innovatsioonipoliitika kavandamisel peaks neid vaatama koos, sest hästi planeerides võivad nad omakorda üksteise levikut võimendada. Seega siit tuleneb omakorda ka panus ärimodelite innovatsiooni teoriasse. Lisaks on töös analüüsitud tege like kasutajate sotsiaal-majanduslikke ja psühhograafilisi andmeid ning näidatud varaste kasutajagruppide erinevusi varasemate, peamiselt küsitlusandmete-põhiste uuringutega. Kolmanda aspektina väärrib välja toomist erinevus esimese proovimiskorra ja edasise kasutusintensiivsuse vahel. Püsikasutajaks saamise teekonnal riigi tuge vajavaid etappe on töös kirjeldatud innovatsiooni leviku protsessi loogika põhiselt, mida arvesse võttes oleks otstarbekas ka riigipoolseid sekkumismeetmeid planeerida.

Kahe eelnimetatud valdkonna omavaheline sidumine on samuti omakorda oluline, sest seni on need suuresti arenenud omavahel vähe seotud teadlaste koolkonnas. Üks põhjuseid siinjuures võib olla, et innovatsiooni leviku kirjandus ja teoreetilised raamistikud lähtuvad kas innovatsiooni enda või ettevõtja vaatest, samas innovatsioonipoliitika kirjandus lähtub riigi vaatest.

Kui innovatsiooni levikut mõjutavad mitmed faktorid, mida on mitmete aastakümnete jooksul põhjalikult uuritud, siis kolmandas kaasuses on spetsiifiliselt välja toodud usalduse roll. Usalduse rolli on ettevõtetemajanduses seni vaadatud peamiselt inimeste vaheliste suhete kontekstis, nt ülemuse-alluva vahel. Usaldus on aga oluline faktor kõigi innovatsioonide levikul, eriti aga ärimodeli innovatsiooni levikul ja platvormipõhiste ärimodelite puhul võib see olla võtmetähtsusega. Vähesed senised kirjutised sel teemal on praktikult-praktikule suunatud väljaannetes, mitte teaduskirjanduses.

Käesoleva töö oluline panus on nende valdkondade ja vaatepunktide kokku toomine, sest seni palju rõhutatud vajadus holistilise, süsteemse ja erinevaid poliitikainstrumente kasutava innovatsioonipoliitika järele jääb muidu üld-sõnaliseks. Samuti ei ole riigipoolne sekkumine tõhus kui ei teadvustata selgelt

kus asuvad innovatsiooni leviku protsessis pudelikaelad, ning mis on nende algpõhjused.

Tööst järeldeb ka vajadus õppida paremini ette nägema innovatsioonide kaudseid mõjusid ja ettekavatsemata tagajärgi. Kui me õpime efektiivsemalt innovatsiooni toetama, kuid samal ajal laiem ja pikaajalise mõju prognoosimise oskus ei parane, siis on suur oht, et toetust saavad innovatsiooni, mis ühiskonna kui terviku vaatest pigem ei peaks seda saama.

Kokkuvõttes võib nentida, et vaatluse all onud uudsete lahenduste levik ei oleks olnud nii kiire kui riik oleks jäänud nende toetamisel vaid traditsioonilise innovatsioonipoliitika meetmete kasutamise juurde. Loodetavasti pakuvad nendest pilootprojektidest saadud kogemused inspiratsiooni ka tulevikus riigi rolli innovatsiooni leviku kiirendamisel laiemalt käsitlema ja nii Eestis kui mujal julgemalt eksperimenteerima.

Peamised piirangud töö tulemuste kasutamisel

Ajalugu on näidanud, et vahel võivad innovatsiooni kaudsed ja pikaajalised mõjud olla väga raskesti prognoositavad ning üldse mitte iga innovatsioon ei ole ühiskonna kui terviku vaatest positiivne. Vaatamata sellele on innovatsioonialane teaduskirjandus olnud pikalt kallutatud innovatsiooni positiivsete käsitluste suunas. Sama võib öelda ka poliitikakujundajate ja ettevõtjate osas. Abiks võiks siinkohal olla muuhulgas ka töös käsitletud kollektiivselt, erinevaid ühiskonna gruppe kaasates soovitatavate trajektooride ja sihtide seadmine. Kuid siiski tuleb arvestada, et ka käesolevas töös käsitletud uuenduslike lahenduste kaastuste puhul ei pruugi me suuta kõiki mõjusid ette näha.

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