The Systemic Nature of Research Impact

A Study Investigating Impact Generating Mechanisms and Systems

Geir Stølen

Master of Society, Science and Technology in Europe

TIK Centre for Technology, Innovation and Culture

Faculty of Social Sciences

UNIVERSITY OF OSLO

Spring 2020

The Systemic Nature of Research Impact

A Study Investigating Impact Generating Mechanisms and Systems

Master of Society, Science and Technology in Europe

Geir Stølen

May 2020

The Systemic Nature of Research Impact

Geir Stølen

http://www.duo.uio.no

Abstract

This thesis explores the systemic nature of research impact. The idea for the thesis origins from a connection between impact and innovation studies in terms of similarities between the two fields. The implication is that impact is a systemic phenomenon similar to the modern view on innovation systems.

The author suggests that impact should be understood as a system, and not just an effect of research. By connecting innovation to impact the project investigates the possibilities to use innovation systems approaches to understand how impact is generated. This is important and relevant to the current impact discussion as the amount of studies focusing on understanding impact generating mechanisms are rather lean.

The idea is tested in the thesis by using the technological innovation systems framework to analyze 15 impact cases from six Norwegian primary research institutes to see if important processes in terms of impact generation could be identified, and to learn if impact in fact is a systemic phenomenon.

The study found seven processes that can be understood as important for emergence of research impact. The influence these processes have on the system can either support or hamper impact generation.

Through the study structural system components were also identified, and a suggested foundation for development of a conceptual impact system framework is proposed.

Acknowledgements

Some say that life can give you lemons. When I first started working on this project, I never thought that life soon would give me a whole lemon tree. This thesis is dedicated to all the wonderful people that told me to eat or squeeze the lemons, to never give up, and get back finishing the project I once so enthusiastically started. Thank you all very much, your support has been appreciated. Lemon lemonade is on me!

I will also thank my supervisor Magnus Gulbrandsen for inspiration, good discussions, and ideas. I always got renewed motivation after leaving the office. I am sorry I was not around much towards the end as I needed to move away for a while, but all help has been very valuable and appreciated. Thank you.

A big hug goes to all my friends that I have gotten over the last couple of years. You made my student life so much easier. Thank you for all the fun and drama.

A huge thank you to my parents that supported and helped me through the project when I needed it the most. I am forever grateful.

Last but not least, a super huge thank you to my girl for sticking with me, through all the challenges no matter how annoying I was, especially towards the end of the project. Thank you for not throwing away my Rubik's cubes even though the clicking drove you nuts, and I am sorry for the lectures on CFOP and Roux. I know you do not really care. Thank you for all support, smiles, and for just being wonderfully weird. ¡Gracias, mi amor!

Kristiansand, May 2020

Geir

Table of Contents

Abbreviations

IPN - Infectious Pancreatic Necrosis

KVC – Knowledge Value Collectives

MRSA – Methicillin-Resistant Staphylococcus Aureus

NSI – National Systems of Innovation

PVM – Public Value Mapping

R&D – Research and Development

REF – Research Excellence Framework

RIS – Regional Innovation Systems

SI – Systems of Innovation

SIS – Sectoral Innovation Systems

TIS – Technological Innovation Systems

1 Introduction

1.1 Introduction and Research Questions

All over the world impact is highly debated among policy makers. Governments, research organizations and other agencies are now committed to measure the impact of research beyond academia (Adam et al., 2018). Impact has in terms of policy discussions become the new “big thing” to talk about. The European Commission (2018), for example, stresses the crucial role of impact assessment for possible success in the largest ever European Union research and innovation program, Horizon 2020 (European Commission, 2018). Though highly debated, impact evaluations are not without weaknesses. As a relative new concept impact measurement suffers from problems in terms of methodological challenges which has in some cases led to controversial results (Bornmann, 2017; Bornmann & Marx, 2014).

In order to face these challenges impact scholars have taken impact development to a new level. The more traditional linear understanding of the relationship between research and effect has been questioned, and new elements such as multiple dimensions, non-linear impact pathways and involvement of actors and networks has been introduced. As a result, multiple new approaches to impact assessment, often inspired by other disciplines such as innovation studies, has gained more attention in the literature (Joly et al., 2015). Not only has this contributed to an expansion of our understanding of research impact, but it can also be an important step towards the idea of an impact system. Bozeman and Sarewitz (2011), for example, argues that when research plays a significant role in achieving positive results it is in collaboration with a range of other determinants, and is rarely the most important one (Bozeman & Sarewitz, 2011). However, discussions regarding systems has acquired little attention in the impact literature.

A system can be understood as an expression to describe the connection between different components that serve a common purpose. For example, all components necessary for impact generation will form the basis of an impact system. Newer impact literature and approaches such as ASIRPA and SIAMPI (Joly et al., 2015; Molas-Gallart & Tang, 2011) support this view by assuming that impact is an effect created by a collaborative effort among a range of different components. From a systems perspective, impact cannot purely be understood as an isolated effect of research. The whole process from research to impact, including all determinants must be taken into account.

Discussions related to components and mechanisms that form the basis of a system are often to be found in newer literature, thus, my impression is that impact does not necessarily suffer from a lack of attention directed at a systemic view, but rather an unexploited form of expression or definition to explain the term. Therefore, I will argue that a systems perspective is not a new addition to impact, but rather a new view on recent approaches and literature.

Furthermore, a systems perspective creates a connection between impact and innovation studies through similarities in characteristics. In the modern innovation literature, there is a consent that innovation is a collective activity or a systemic phenomenon (Edquist, 2005; Fagerberg, 2005). From an innovation point of view, a system can be regarded as the determinants of innovation processes, and consists of all important factors that influence the development, diffusion and use of innovations (Edquist, 2005). In addition, though not always the case, research impact can be an effect of an innovation and arguably generated by an innovation system. Although recent literature does apply innovation characteristics to impact, there is still a lack of consensus on this matter. Nevertheless, by drawing theoretical parallels between processes related to innovation and impact generation, the resemblances appear as reasonably clear. It does not mean that impact and innovation should be understood as equals, but rather as two phenomenon's that share a resemblance in terms of determinants and processes by which they may occur. This can be resourceful as knowledge may be transferable between the two fields, enabling the use of decades worth of research from innovation studies, and can open up for a more extensive use of valuable knowledge and experience gained from innovation scholars.

Through comparison of different new impact approaches, more than often inspired by the field innovation studies, the literature does imply that impact is more than just an expression of the relationship between an "input" and an "output". One need to take into consideration the processes or activities that happens in the transaction between research and society, including actors involved. As we do not know what determinants to include or exclude, I will propose an idea of viewing impact as a system; all important factors that influence impact generation. The implication is that the system can be considered as the determinants of impact processes. The definition stems from Edquist (1997, p. 14) general definition of innovation systems and I will use it as a foundation to build further on the idea of viewing impact as a systemic phenomenon.

Therefore, I will in this thesis explore the systemic nature of research impact and examine how impact can be generated in an impact system, and further look at possibilities to influence its occurrence. I will draw inspiration from literature on innovation systems and approaches to study research impact from a systems perspective. On that basis I formed the following overall research question:

- What characterizes an impact system and under what circumstances does impact occur?

To answer this question, I will study impact systems based on impact cases from six Norwegian primary research institutes. With that in mind, I will address the overall research question by asking two more specific questions:

- What are the main components in an impact system?
- What kind of network structures and processes could explain the emergence of research impact?

1.2 Purpose and Relevance

The purpose of this thesis is to make a contribution to the discussion on what impact is, and how to better understand its occurrence. By building on the broad understanding of impact, emphasizing the important role of actors and networks in the impact process, my goal is not only to provide an opinion on this theoretical direction, but hopefully contribute to the theoretical development of the field by pushing forward the idea of a systems perspective. Though highly recognized in innovation studies, a systems perspective is more of a missing link in the impact literature regardless of a growing resemblance, as a result of theoretical development, between the two fields. Thus, creating relevance to this thesis by focusing on a theoretical direction that previously has been somewhat absent in the impact literature, but has recently gained increased attention.

1.3 Thesis Outline

The thesis continues in chapter two by introducing the theoretical foundation the project is based upon. In this chapter the concepts research impact and innovation will be introduced, followed by a discussion on using innovation approaches in the context of impact.

In chapter three I will present the theoretical framework, technological innovation system, that will be used for the analysis.

In chapter four I reflect on the methodology used in the thesis, including concerns about data collection, validity, and reliability.

The following chapter five provides an analysis of 15 impact cases from six Norwegian primary research institutes, and lastly, I will propose a reconstruction of the theoretical framework for use in the context of impact.

The last chapter will give a final discussion followed by concluding remarks, including weaknesses of this study.

2 Research Impact and Innovation

In this chapter I will clarify how impact research assessment has developed through time, from a linear to a broader view, and challenges often recognized in terms of assessment. Further, I will present some of the newer impact approaches, explain their features and the theoretical grounds they are based on. The purpose is to provide a description of how different theories are used to explain, understand and measure impact. In the end I will describe the concept innovation systems; considered to be the basis of the modern understanding of innovation. The intention is to give an explanation of all the theoretical content that will form the basis of this thesis, and on what ground ideas and theoretical framework are based on. The assumption is that impact share a lot of characteristics with innovation theory and that knowledge may be transferable. Thus, future development and understanding of impact may therefore benefit from experience and knowledge from decade’s worth of innovation research. This will be discussed further in section 2.3.

2.1 Impact of Science

Research has been evaluated for several decades, but it was first in the 1990s that the new modern term “impact” emerged (Bornmann, 2013). The term has its origin from policy debates in the United Kingdom and Australia (Williams & Grant, 2018), before being a worldwide phenomenon, and refers to broad long-term effects of research. Though a lack of a clear definition of the term it is normally tied to the assessment of cultural, social, environmental, and economic results of research (Bornmann, 2013).

According to Donovan (2007) early attempts to measure impact of research were based on the notion that the purpose of science was to support a country´s competitiveness and generation of wealth. As a result, impact were measured using metrics based on economic measures and a range of science, technology and innovation indicators (Donovan, 2007). Traditional methodologies neglect the upstream mechanisms that may generate research impact since they consider that “good things” will happen from quality research through a linear view, or model, of innovation (Bozeman, 2003; Joly et al., 2015). The linear view on innovation postulates that innovation starts with basic research, then adds applied research, and eventually ends with development, production and diffusion (Rosenberg, 1986), assuming that technology develop directly on the basis of scientific efforts, and further, to be materialized in new market products (Lundvall, Johnson, Andersen, & Dalum, 2002). The model has been very influential and widely disseminated, especially in the context of lobby for research funds, and expert economist advisors to policy makers. As a consequence, science policies carried a linear conception of innovation for many decades, including academics studying science and technology (Godin, 2006). Grounded in traditional production theory impact analysis are therefore often concentrated on the relations between inputs and outputs; the strength of the links between an observed change and a given research investment (Joly et al., 2015).

Approaches to research evaluations that are based on economy have many limitations, especially if the interest lies in measuring the impact of science on public values and social change. According to Bozeman and Sarewitz (2011) evaluations of this kind also tend to have a focus towards discrete products of research, which from a methodological view may be sensible as it promotes measurement, however, it also promotes a narrowness of view. They argue that if one is interested in the long-range capability to produce innovation, then simply counting results in terms of innovation products may not provide a good insight into the health and viability of scientific fields or a nations innovation system. In order to understand the capacity to produce innovation, then a focus on scientific and human capital, the integrated social networks and aggregate skills of scientists, and other non-economic approaches to evaluation will be required (Bozeman & Sarewitz, 2011).

2.1.1 Impact Evaluations: Towards a Broader Understanding

Research impact has more recently been interpreted as part of a social contract that exists between science and society, which implies that research must address pressing social issues (Donovan, 2007, 2011). Although most studies of research impact assessment has a focus on economic impact, other dimensions of impact such as organizational impact, cultural impact, social impact, political impact, environmental impact, and impact on health has obtained increased attention (Joly et al., 2015). As a result, the scope of research evaluations has since the 1990s become broader with the inclusion of societal dimensions. Impact has therefore been redefined to embrace broader social, environmental, cultural, and economic returns, and a mix of qualitative and quantitative methods has been developed to capture the outcomes (Bornmann, 2013; Donovan, 2011). For example, one of the most comprehensive evaluations of research impact, called Research Excellence Framework (REF), that assess the quality and impact of higher education institutions in the UK defines impact as: *an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia* (REF 02, 2011, p. 26). This definition of impact broadens the concept to not solely shed a light on economic effects of research but includes other effects on society as well (REF 02, 2011). Worth mentioning is that REF still mirrors somewhat of a linear view as it bases the evaluations on effects only beyond academia, and the focus of the evaluations are universities only. What happens in the transition between research and society are less prominent.

Though a broader view on impact can be positive as it enables measurement of research effects on the society, beyond economic effects, it also causes problems in terms of evaluation methods. According to Bozeman and Sarewitz (2011) a problem in most all approaches to research evaluations is that research often is only one factor in determining social outcomes and is rarely the most important one. When research plays a significant role in achieving desirable outcomes it is in collaboration with a range of other determinants. In these circumstances, it is almost impossible to explain the contribution of research (Bozeman & Sarewitz, 2011). Problems with causality, as it is not clear what impact can be attributed to what cause, is one of several common problems with impact assessment (Bornmann, 2013). Bozeman and Sarewitz (2011) argues that the effects are themselves often interwoven in ways that are difficult to understand and unravel (Bozeman & Sarewitz, 2011). Attribution is another problem, because impact can be complex, diffuse, and contingent, as it is not clear what part of impact should be attributed to certain research or to other inputs. Innovation and research and development (R&D) are also international by nature, which makes attribution almost impossible (Bornmann, 2013). As impact happens over time, temporality is another challenge because of the time lag between research and a particular impact, which further may cause attribution problems. (Spaapen & van Drooge, 2011). Premature impact measurement may also result in an overemphasis on research bringing short-term benefits. Lastly, one should also note that impact may not necessarily be positive or beneficial, and the same research may well lead to both positive and negative impacts (Bornmann, 2013).

While traditional methodologies has concentrated the analysis of the relations between inputs and outputs, and can be compared with the linear view on innovation (Bozeman, 2003), recent approaches has challenged this traditional perspective, and in addition turned the interest towards the understanding of impact-generating mechanisms (Joly et al., 2015). Like innovation, impact in society is no longer regarded as predominantly shaped by scientific and technological progress, but rather as a result of an iterative process of interaction between scientific and other social domains, technical experts, organizations, industry, government, and the public (Spaapen & van Drooge, 2011).

The Public Value Mapping (PVM) Project developed in the early 2000s, for example, challenged the traditional view by developing a conceptual tool for a systematically understanding of the multiple determinants of social outcomes, and the role of science as a part of the vast mesh of institutions, networks, and groups giving rise to social impacts (Bozeman, 2003). It moves away from the traditional view of public funding of research based on the argument of market failure because of the public good characteristic of science, and proposes an approach to assess what they call "public values" of science (Bozeman, 2003; Joly et al., 2015). Public values is the term Bozeman and Sarewitz (2011) use on the assessment of the impacts of a given research endeavor on the non-scientific, and non-economic goals of research (Bozeman & Sarewitz, 2011). The theory supporting PVM analysis is a mix-model of knowledge value and innovation, and that science outcomes are best understood in terms of what they call "knowledge value collectives" (KVC) and "knowledge value alliances", that arise to generate, develop, and use scientific research. The view recognizes that it is vital to understand research outcomes and the availability of scientific and technical human capital to produce research, but also emphasizes the importance in understanding other parties to the KVC including, for example, government and private funding agents, end users, equipment, wholesalers and other scientific resources. The premise is that science and scientists have little ability to provide social outcomes, apart from other social actors, and so forth (Bozeman, 2003). Science from this view is moved from an individual and small group activity to knowledge development and dissemination through the whole society, and in the end production of social outcomes. The focus is not on a single actor but on the dynamics of the broadest social group (Bozeman, 2003; Joly et al., 2015).

Another multi-dimensional approach to impact evaluation is The Payback Framework, originally developed to examine the impact of healthcare research. It consists of a logic model of the complete research process, and seven stages and two interfaces between the research system and the wider political, professional and economic environment. The model enables analyses of the story of a research idea, through the research process, into dissemination, and on towards its impact on society, and potentially reaching the final outcomes of health and economic benefits. The model considers different categories of benefits such as, knowledge benefits, benefits to future research, benefits from informing policy and product development, health and health sector benefits, and broader economic benefits. Though is not completely possible to tie benefits to specific stages of the model, it is possible to identify correlations that show where the categories of impacts are most likely to be found in the model. As mentioned above the Payback framework was originally developed to examine impact of healthcare research, but the framework can be, and has been applied to work in different other contexts, for example, impact of social sciences (Donovan & Hanney, 2011).

The Social Impact Assessment Methods for research and funding instruments through the study of productive interactions between science and society, SIAMPI, assumes that contact between researchers and non-academic stakeholders must have taken place for any kind of impact to occur (Joly et al., 2015; Molas-Gallart & Tang, 2011) When this contact leads to an effort by the stakeholder to engage with the research, it is referred to as "productive interactions". The research has had an impact if the productive interactions results in the stakeholder doing new things or doing things differently (Molas-Gallart & Tang, 2011). The interaction becomes productive because the stakeholders make efforts to use and apply the research result to generate impact. The idea and the recognition of the important role of stakeholders in the SIAMPI approach connects to the ideas of national innovation systems (NIS) in which science, government, industry and non-profit organizations interrelate in the context of socio-economic development (Spaapen & van Drooge, 2011). The approach has a focus on processes of interaction and can be used as a tool to identify how relevant research is conducted and the processes by which it is applied or not. By understanding the processes of research generation and application SIAMPI make the link between the research results and their effects, including an attempt to address problems with attribution. The approach also recognizes that productive interactions, and relevant research, may not lead to impact at all, and that impact may not necessarily generate a social benefit, but might as well have negative rather than positive effects (Molas-Gallart & Tang, 2011). Spaapen and van Drooge (2011) argues that by concentrating on productive interactions the focus moves from attribution to contribution of specific actors, productive interactions and the exchange of knowledge and expertise by the various stakeholders, and thus be able to identify contributions made in the process of impact generation (Spaapen & van Drooge, 2011).

The impact pathway approach are based on program-theory evaluation from the field of evaluation, and is a method for identification of different phases of impact generation, the flow of resources, and the progressive transformation of knowledge in outcomes and impacts (Douthwaite, Kuby, van de Fliert, & Schulz, 2003; Joly et al., 2015). Though the method may seem linear at first glance, Douthwaite et al. (2003) argues that the approach recognizes feedbacks and that it is not based on a linear progression from research to extension but an iterative learning process that adopts as it goes along (Douthwaite et al., 2003). Network of stakeholders can play central roles in the creation of research outputs as well as in diffusion and adoption processes, at different levels (Joly et al., 2015). The method highlights the crucial importance of the concept, or processes, of scaling-up and scaling-out. The idea behind these processes are that technological change is brought about by the formation and actions of networks of stakeholders in what is essentially a social process of communication and negotiation (Douthwaite et al., 2003).

One last approach to assess impact, highly influenced by the abovementioned approaches and methods, is the ASIRPA approach. Originally developed for analysis of impacts of public agricultural research in France, the ASIRPA approach can be used to capture the complexity of actor's contribution in innovation processes while identifying recurrent impact generation mechanisms across cases. Inspired by Actor Network Theory the approach is based on the notion of impact-generating mechanisms, an assumption that impact is multidimensional, and the involvement of actors and networks in the innovation process that plays a variety of roles at different stages over a non-linear impact pathway. The analysis is chronological and highlights the long time, multi-actor, and contextual dimensions of impact. Because of its temporality, ASIRPA is not limited to the steps right before the transfer of outputs, but accounts for all essential events in the path towards impacts. The pathway provides a graphical representation of the impact-generation steps, highlighting research work, the knowledge path outside the academic sphere, and it's processing and use by socio-economic actors. Because of the non-linear nature of the impact pathway, iterative and learning processes between the different steps on the pathway are allowed. The diversity of paths and iteration processes can be captured while standardizing description of the pathway within a limited number of identifiable phases; the identification and systematic analysis of common features across cases (Joly et al., 2015).

The approach uses the previous mentioned concept of contribution to indicate that impact is produced by networks and cannot be broken down to attribute shares to different actors. Highlighted in the literature is that it does not assume that characteristics of interactions processes between researchers and societal stakeholders can be used as a substitute for societal impact, but instead recognizes the need for a thorough analysis of the mechanisms of translation occurring at different stages and that impact characterization requires specific efforts. The ASIRPA approach is designed to identify five dimensions of societal impact: economic, environmental, social, health, and political impact. These can be referred to as "intermediate impacts" or "outcomes", and act as the first sphere of targeted end users. ASIRPA also provide a second degree of impact that involves wider sets of end users and can be referred to as "ultimate impacts", or just "impacts". These impacts are enabled by changes in adoption scale, in the diversity of effects, or in learning processes (Joly et al., 2015).

Trying to understand impact is not an easy task. From a broader perspective, with inclusion of non-linearity, we are not only trying to measure the effects of research, but also trying to explain and understand how research is used, and the relation between research and society. This makes impact quite a complex phenomenon, which in turn spike the interest from scholars with background from different fields of science, including the use of different approaches and methods. The ASIRPA (Joly et al., 2015) approach, mentioned above, draws for example theoretical influence from both science and technology studies and innovation. In other words, scholars' experiment with different methods, and draw influences from other disciplines in order to meet the challenges often recognized with impact assessment, and to find new tools to answer research questions.

As impact become more complex, it would make sense to draw influences from other disciplines that share similar complex problems. That is why innovation studies can be in particular an interesting field to draw inspiration from. This has already been done, as mentioned above, but I will argue that it is possible to take it even a step further. In approaches such as SIAMPI (Molas-Gallart & Tang, 2011; Spaapen & van Drooge, 2011) and ASIRPA (Joly et al., 2015) attention is directed towards the importance of actors and their role of contribution. The assumption is that impact is an effect that is produced by networks, and attention regarding research should be given to the processes by which it is applied or not; enabling the identification of contributions in the process of impact generation (Joly et al., 2015; Molas-Gallart & Tang, 2011). This new interpretation of impact shares strong resemblances with approaches on innovation systems, and the understanding of processes in which innovation occurs. The question is if impact can be a system as well, and if that can help us better understand how impact should be approached? If the resemblances between the two fields are strong enough and impact can be placed in a similar system, it may open up for the possibility of using innovation methods on impact or influence the creation of new impact frameworks.

Nevertheless, studying impact from an innovation point of view is quite interesting and will be further explored throughout this thesis, but first we need to get a better understanding of features that links these two concepts together. The next section will therefore explain the modern view on innovation systems and provide a brief historical review, of the birth, of the systems approach.

2.2 The Systems of Innovation Approach

The dominating insight in modern innovation literature is that innovation is a collective activity and take place in the context of a wider system (Edquist, 2005; Fagerberg, 2005). The modern view on innovation goes beyond the previous influential view on innovation, based on the linear model. Though the linear model was generally accepted throughout most of the period since the World War II, it has later been criticized for the lack, or complete absence, of so called "feedback-loops" in the different stages of the innovation process. Another problem with the model is that it views commercial R&D as applied science and generalizes a chain of causation that only holds for a minority of innovations. Even though scientific research may lead to innovation, the demand of innovations may also force creation of science, and innovation may even proceed independently of any interaction of science (Edquist & Hommen, 1999; Fagerberg, 2005; Kline & Rosenberg, 1986).

To address the problems of the linear-model, an alternative model of the innovation process called the "chained-linked model" was introduced. In this innovation model there is not one major path of activity, but five, and it is characterized by a central path starting with design rather than research and includes several feedback-loops (Edquist & Hommen, 1999; Kline & Rosenberg, 1986). The introduction of the chain-linked model was important because it gave a specific alternative to the linear model, and constituted an important step towards the idea of an innovation system (Lundvall et al., 2002).

As an extension of this more systems-oriented perspective of innovation, the systems of innovation (SI) approaches emerged (Edquist & Hommen, 1999). The expression national systems of innovation was, according to Edquist (2005), first used in published form in the late 1980s and gave birth to two major books, edited by Bengt Åke Lundvall (1992) and Richard Nelson (1993), on national systems of innovation. These books have been very influential in terms of development of the systems perspectives we embrace today and can be considered as part of their origin. As the books employ different approaches to study NSIs, they have also contributed to dividing innovation into two different directions, or schools of innovation (Edquist, 2005). On one side, Lundvall (1992) is theoretical oriented and analysis are focused around interactive learning, user-producer interaction and innovation. On the other side, Nelson (1993) places a larger emphasis on empirical case studies, rather than theory development (Edquist, 2005; Lundvall, 1992; Nelson, 1993).

Lundvall (1992) describes NSI with a distinction between a SI in the narrow sense and a SI in the broad sense. These two definitions may help clarify the difference between the two schools of innovation mentioned above. The narrow definition includes organizations and institutions involved in searching and exploring, such as universities, R&D departments and technological institutes. The broad definition stems from a theoretical perspective proposed by Lundvall (1992) and includes all parts and factors influencing the economic structure, institutional set-up affecting learning as well as searching and exploring, including the production, marketing and finance system that works as subsystems where learning takes place (Lundvall, 1992).

Nelson´s studies on NSI consisted of national studies, primarily descriptive, and are detailed studies of R&D organization structures and allocations over time. The main theoretical tools are often related to laws and economics, searching for answers on how different institutional set-ups can solve problems in terms of information and technical innovation. Thus, his studies of NSIs falls close to the narrow definition of SI. Lundvall´s broader approach recognizes that the organizations from the narrow view are embedded in a much larger socio-economic system in which political and cultural influence together with economic policies have an effect on the direction, scale and relative success of all innovative activities (Edquist, 2005; Lundvall, 1992; Nelson, 1993; Smith, 2000). More commonly Lundvall´s framework is known for conceptualizing innovation as learning, since innovation is regarded as novelty in the capabilities and knowledges which make up the technology. This school of innovation, also called the Aalborg school, understand the nature of learning on the basis of three concepts: interactive learning, the organized market, and the institutional framework (Lundvall, 1992; Smith, 2000).

Both schools define NSI in terms of determinants of, or factors influencing, innovation processes. However, they propose different definitions of the concept as they point out different determinants believed to be the most important ones for generation of innovation. What is noteworthy is that they use the same term but propose different definitions of the concept NSI, and as Edquist (2005) argues, reflects a lack of a generally accepted definition of the term (Edquist, 2005). No matter the schools they have both been very important and influential in the field of innovation studies.

A central find in more recent innovation literature is a more general definition of SI. Charles Edquist (2005) regards SI as the determinants of innovation processes, and consists of all important political, social, economic, organizational, institutional, and other factors that influence the development, diffusion and use of innovations (Edquist, 2005, p. 182). The premise is that all factors that influence innovation processes needs to be included in the definition. If not, one has to argue which potential factors that should be excluded and why. This is problematic as we probably do not know all the determinants of innovation in detail and excluding certain determinants may be dangerous as they might prove to be very important (Edquist, 1997, 2005).

Nevertheless, the SI approaches emphasizes interdependencies and non-linearity and recognizes the complex character of the innovation process. As of this complex nature, innovation processes occur over time, and firms normally do not innovate in isolation, but in collaboration with other organizations. Through these interactions' organizations gain, develop, and exchange various kinds of knowledge, information, and other resources. These activities creates relations between firms and organizations, and thus, innovative firms cannot be regarded as isolated and individual decision-making units (Edquist, 1997).

The overall function in an innovation system is to pursue innovation processes, in other words, develop, diffuse, and use innovations. The factors that influence the innovation process are called activities, and are the same as the determinants of the main function

(Edquist, 2005). The main components are organizations and institutions. Organizations are the actors and can be firms, venture capital organizations, universities, government ministries, research institutes etc. Institutions are what shapes the behavior of the firms, and regulate the interactions and relations between individuals, groups and organizations. Institutions can for example be laws, technical standards, social rules, or norms that influence relations between actors. It is important to note that institutions can differ considerable among different national SIs (Edquist, 1997, 2005).

2.2.1 Different Variants and Perspectives of Systems of Innovation

Innovation systems can be divided into different types or perspectives according to their geographical boundaries, industrial sector, or specific type of technological systems. These can be seen as variants of the generic SI-approach, and different variants coexists and complement each other (Edquist, 2005).

National systems of innovation (NSI) are located within the boundaries of a nation, and studies factors that influence innovative capabilities, learning and interactions among actors within a single country (Lundvall et al., 2002). Regional innovation systems (RIS) share similarities with NIS except the geographical location for analysis is reduced down to a region. The purpose of RIS are to study the innovative performance of a region, and the perspective emphasizes that geographical distance between actors has an effect on the innovative performance (Asheim & Gertler, 2005). Sectoral innovations systems (SIS) consist of a group of actors that develop and make a sector´s products, including generation and use of the sector´s technologies. SIS has a focus on agents, firms, interactions and processes regarding transformation of the system and competitive relationships among companies. SIS can have local, national and/or global boundaries depending on specific conditions, such as knowledge and knowledge transmission (Malerba, 2005; Malerba & Nelson, 2011). Lastly, to address certain weaknesses of NIS, the term technological systems was introduced. These systems were in the early stages defined as networks of agents interacting in a specific economic/industrial area under a particular institutional infrastructure involved in the generation, diffusion and utilization of technology (Carlsson & Stankiewicz, 1991). Through the years these thoughts have been developed further into what we today know as technological innovation systems (TIS). This variant is a socio-technical system that has an emphasis on development and diffusion of a particular technology. The components of a TIS are exclusively dedicated to the technology in focus, including all the components that influence the innovation process for that particular technology (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008).

The different SI perspectives may be seen as variants of a more generic version of SI and are existing under the premise that they coexist and complement each other. Which variant to use in a certain context will probably depend on the question one want to ask, and answers one seek to understand.

2.2.2 Systems of Innovation Approach: Challenges

The SI approach is widely used in academic circles around the world and can be a good tool in order to understand innovative performance, or in policy context to create guidelines supporting technological and other kinds of innovation. Nevertheless, the approach is not flawless, and it does suffer from certain weaknesses.

The SI approach has been associated with conceptual diffuseness. A typical example often mentioned in the literature is the term "institution" which is used in different senses by different authors. For example, it has been used in reference to both institutional rules as well as organizational actors. Another example on conceptual diffuseness, briefly mentioned earlier in this innovation section, is that the originators of the SI approach did not exactly indicate what should be included in the systems. In this case they did not specify the boundaries of the systems. The significance of such weaknesses is of course debatable, and scholars disagree on the seriousness. Nevertheless, it can be important in terms of communication, as Edquist (1997) argues, we cannot understand each other if we cannot clearly explain what we mean when using key concepts, and it is required for carrying out theoretically based empirical studies (Edquist, 1997).

On the other hand, all approaches that are new or under development will probably suffer from some sort of diffuseness. This is not necessarily a negative thing if we acknowledge the weaknesses as a step towards further development, which in turn may lead to additional research and insights into the operation of the approach (Edquist, 1997, 2005).

There is a lot more that could be said about strength and weaknesses of SI, and the approach is under constant development to face these challenges. However, disagreements are hard to avoid as scholars have different opinions on the significance of the weaknesses, how they should be addressed, and how the approach should be. Some would argue that the concept is overtheorized, while others will argue that it is undertheorized. In other words, innovation scholars are divided on these issues.

In regards of putting a label on SI, Edquist (2005) argues that SI is not a formal theory, in the sense of providing specific propositions regarding causal relations among variables, but should rather be labeled an approach or a conceptual framework because of the relative absence of well-established empirical regularities (Edquist, 1997, 2005).

2.3 Discussion

By reviewing the literature on both innovation and impact one can see that they do share some interesting similarities. This can be everything from the modern impact approaches that can be compared, or share features, with innovation systems approaches to discussions regarding a linear or non-linear understanding of impact and innovation. Though I will be careful putting too much into this argument, one may even recognize tendencies from historical challenges from the development of innovation systems, playing out in impact studies today. Nevertheless, I will argue that it is a sufficient amount of similarities between the two fields to ignore innovation as a possible useful source of information in terms of impact development.

It is important though, to make clear that impact is not innovation. In the impact literature the words impact, effect and innovation are sometimes used interchangeably, which can cause some confusion. Even though they share resemblances, and that innovation can generate impact, they are two different phenomena. In the case of using innovation methods to understand impact one need to take this into consideration and modify possible new frameworks or approaches accordingly if needed. As the modern view on innovation systems emphasizes non-linearity, one cannot from this view base impact on a linear understanding of the relationship between research and effect. The impact literature is somewhat divided on that discussion, which of course can be linked with the purpose of the assessment. However, newer impact approaches that try to understand what happens in between research and effect recognize that impact is a non-linear activity, in comparison to the more "input" and "output" related types of assessments. As of this one need be open for the idea that impact is a phenomenon that occurs as part of a network or a larger system, or as an alternative, an impact pathway that include so called "feedback loops".

With increased worldwide popularity in regards of impact evaluations, I will argue that it is time to learn walking before we run and give more attention towards studies of components and processes important for impact generation. Learning more about what impact is and how it occurs will be important for development of future evaluation methods, and solutions to current problems. I am not proposing that we should disregard more typical evaluations, but rather increase attention towards understanding the processes important to achieve impact goals. Some of the newer impact literature does recognize that impact is a very complex phenomenon, which process probably cannot be captured on the basis of a single form of causality. This indicates that impact may be an effect or process that take place in the context of a larger system, and mirror features more commonly known from innovation studies.

The question is what benefits impact can draw from a more systems-oriented perspective. As mentioned earlier impact suffers from various methodological problems which has led to controversial results. Challenges in terms of causation and attribution questions are also well known amongst scholars, as it is not clear what impact can be attributed to what cause, and it is not clear what part of impact should be attributed to certain research or input (Bornmann, 2013, 2017; Bornmann & Marx, 2014). Introduction of impact systems will not work as magical tool that will solve all problems but can provide us with new tools and ideas to study the inside of impact generating processes. The amount of impact literature that actually focuses on understanding what happens in the transition between research and society is surprisingly lean, which is a little odd as impact normally is tied to the relationship between the two. Therefore, claiming that impact is an effect of research on its own seems like a rather unlikely and modest conclusion. From a systems of innovation point of view this make sense, but I will argue that it is equally meaningful in the context impact as we do not yet have a lot of knowledge about the collaborative effort among determinants, and how these activities influence impact generation.

Though, newer approaches to impact assessment does enable analysis of processes concerning impact generation, they are not purely dedicated to the purpose. For example, the

ASIRPA approach which main purpose is to identify impacts can also be used to capture actor's contribution in the impact process including identification of common features across cases. The problem is that the framework is based on analysis of a substantial amount of standardized case studies in order to derive general conclusions, which makes the approach very comprehensive and resource intensive (Joly et al., 2015). This is familiar challenges concerning impact evaluations in general, including critic in regards of high costs and questions about the necessity of impact evaluations (Martin, 2011). Thus, more conceptual work may be needed as part of the methodological development. Though this can be potentially resource intensive as well, I will argue that conceptual work is important for the future of impact assessment in order to develop new and better impact approaches. Hopefully it will also contribute to, and influence, development of a new and accepted definition of impact and shed light on different ways of understanding the concept.

In the next section I will discuss the possibility to use innovation approaches as a tool to study impact or use it as basis for development of conceptual impact frameworks.

2.4 Study Impact using Innovation Approaches

As a systems perspective on impact is not a concept recognized in the literature, it does not exist any frameworks to analyze impact purely from that view. One can argue that ASIRPA can be related to system thinking but the framework is not grounded on a notion that impact is a system. That is why it might be beneficial to draw inspiration from innovation studies due to the similarities between the fields. The idea is to use innovation systems approaches as a foundation that can be helpful in identification of components and network structures that may work as building blocks for the impact system, and study processes and activities happening inside the system that could explain emergence of impact. I call it a foundation as it is not clear that innovation approaches can be used on impact without any modifications, and it can also form the basis for development of new impact frameworks.

In terms finding a foundational innovation framework, it is several to choose from, and not all are equally relevant. One can probably argue that, like innovation, it exists some sort of national impact system, or even a regional one, but that is not really the purpose of this thesis to discuss. The purpose of this thesis is trying to gain knowledge about factors that may be important for impact generation on the basis of a certain type of research. Therefore, what is needed is a framework that can help us understand what is happening inside an impact system and can help us identify important impact processes, including actors involved, that may support or hamper impact generation.

In this case we cannot view impact as a relationship between a certain research endeavor and effect, but rather view impact as a process. The impact analysis will then be focused on tracing an impact event back in time to identify processes that proved to have an effect on the final result, and study how these influenced the generation. By studying these processes through time and context it may also foster better answers to questions in regards of causality. This type of study is also important in the work of learning more about who the actors are and the activities they perform, and factors that can influence their behavior.

This thesis, with reference to the research question, is trying to identify network structures and processes that could explain the emergence of research impact in a system. One particular framework known from innovation studies came across as a very interesting alternative to answer this kind of question. The technological innovation systems framework is developed for analysis of a particular technology by evaluation of seven key processes. These processes are recognized as highly important for a well-functioning innovation system and has a direct effect on the technology in focus (Bergek et al., 2008; Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007). Typically the TIS framework is used as a basis for policy recommendations, nevertheless, Coenen and López (2010) argues that the framework has the potential to connect a micro-level theory of firm behavior with system dynamics which can provide important insights on the level of individual actors, strategies and behavior, including network activities and impact (Coenen & López, 2010).

Though the TIS framework is intended for innovation analysis it does share some characteristics with impact approaches such as ASIRPA. For example, the basis of both approaches is a technology, or some sort of knowledge, that moves along a non-linear pathway towards generation. Equally the approaches can be regarded as a chronological analysis, or a history event analysis, and share an emphasis on contributions of actors and networks over a longer period of time (Hekkert et al., 2007; Joly et al., 2015). Though the frameworks are not created for the same purpose they do share structural similarities which provide some support to the assumption that the TIS framework can work in the context of impact.

The main concern by using TIS on impact is that the framework is based on a set of pre-defined functions, or processes, intended for innovation analysis (Bergek et al., 2008; Hekkert et al., 2007). Though the idea is that impact is a system similar to innovation, it does not mean that the same processes will be prominent. However, Hekkert et al. (2007) argues that no innovation systems are the same, and structural patterns and processes will be different depending on the technology, and will change over time (Hekkert et al., 2007). That being said, by reviewing the impact literature I will argue that a sufficient amount of evidence does exist supporting an assumption that the pre-defined set of functions in the TIS framework will be of importance to an impact system as well. However, the purpose is to use TIS as a foundational framework that can be modified to be relevant for impact, thus development of new impact functions (key processes), or exclusion/modification of certain original functions, are most likely to happen.

If a functional framework can be used, or developed, as a tool for impact analysis it can contribute to a better understanding of where to intervene within the system to influence impact generation, which can be important in terms of policy recommendations and achievement of impact goals. In addition, if evidence support that system related activities are important to create effects of research, our understanding of impact as a systemic phenomenon can be further strengthen and influence researchers to study impact from this view.

Building further on the TIS framework I will in the following chapters explore if functional thinking is applicable to impact, and if it can strengthen the argument of considering impact as a system. In the next chapter I will start by explaining the TIS framework in more depth, and later test the framework up against impact evaluations of the Norwegian primary sector and try to identify if innovation systems functions appear to be of similar importance to impact.

3 Theoretical Framework

The TIS framework enables analysis of a particular technology by mapping key activities in innovation systems for the purpose to understand and explain how these systems change over time, including processes that support or hamper their development. I will use the TIS framework to analyze 15 impact cases. The purpose is to test the framework in the context of research impact and to investigate if innovation systems processes can be relevant to impact generation. If analysis indicates that the same processes are of importance to both fields, it can help defend an impact systems perspective, and increase incentives for development of a conceptual impact system framework.

In the following subsections a thorough explanation of the TIS framework will be provided, included a description of the proposed set of functions intended for use in the analysis, and small adjustments done to the framework to better fit the impact context.

3.1 Technological Innovation Systems

Traditional methods of NIS analysis have mainly focused on the understanding of the current structure of the innovation system. According to Hekkert et al. (2007), the emphasis on structure, and relevant indicators, is an effect of the complex nature of NIS and the vast amount of components it consists of. The consequence is that most empirical studies of NIS do not focus on the dynamics of the systems (Hekkert et al., 2007). Bergek et al. (2008), and Hekkert et al. (2007) argues that these traditional methods have proven to be insufficient (Bergek et al., 2008; Hekkert et al., 2007). As a result, policy makers have often experienced difficulties in extracting practical guidelines from studies of this kind. The TIS approach was developed to address these problems, and focus on generation, diffusion and utilization of a particular technology, or in other words, new products and processes related to a certain technological field or industry (Bergek et al., 2008; Jacobsson & Bergek, 2011). All the components in a TIS are exclusive to the technology in focus, including all components that influence the innovation process (Bergek et al., 2008). An important characteristic in TIS is that the complexity is reduced as the number of actors, networks, and relevant institutions are considerable smaller than in, for example, NIS. Therefore, an analysis of the dynamics of a system is possible. A TIS analysis can therefore be a good tool to evaluate the development of a particular technological field in terms of the processes and structures that support or hamper it (Hekkert et al., 2007).

Though the TIS approach has gained quite some attention over the recent years and widely used to study the emergence and growth of new technological fields and industries, it has been criticized for a number of issues and suggestions for improvement have been made by innovation scholars (Markard, Hekkert, & Jacobsson, 2015). Markard et al. (2015) point out six areas of criticism often mentioned: TIS context, system delineations, transitions, spatial aspects, politics and policy recommendation. In the article it is discussed what the TIS framework can embrace and what is beyond its capacity, including suggestions for further improvement of the approach, and how to work around possible problems. Though they acknowledge that the approach needs further improvement, they still expect the TIS framework to maintain and strengthen its position as one of the key frameworks in the field of innovation studies (Markard et al., 2015). The criticism regarding TIS was taking into account before settling on a theoretical framework but for the purpose served in this thesis the above-mentioned issues was not believed to cause any problems.

3.2 TIS Functions

The most prominent feature in the TIS framework is that it allows the analysts to study the behavior of the system, and interactions between actors and networks, by evaluating seven key processes labeled as “functions”. These functions are according to the literature highly important for well performing innovation systems and have a direct and immediate impact on the development, diffusion and use of particular technologies (Bergek et al., 2008; Hekkert et al., 2007). Though different innovation systems may have similar components, it does not mean that they are functioning the same way. Different TIS will likely have different functional patterns, that is a description of how each function is currently filled in the system, and they will probably change over time. Thus, the concept does not imply that a pattern is either optimal or repeated (Bergek et al., 2008). The analytical framework can help contribute to the understanding of the complex nature of the emergence and growth of new industries and analysis of factors that may hamper these processes (Markard et al., 2015).

3.3 Proposed Set of Functions

The development of the TIS framework is an ongoing process, thus different lists of functions can be found in different versions of the approach. The set of functions have been refined and revised several times on the basis of empirical studies and application, including literature studies and discussions amongst researchers (Bergek et al., 2008). By reviewing TIS literature, differences found between the most recent set of functions were rather small, and often just a matter of braiding two functions together or adding an extra function by splitting a function into two, providing extra focus towards certain activities believed to be of importance to the TIS.

The proposed set of functions in this assignment is based on a set of functions described in Hekkert et al. (2007). The reason for choosing this list over others is a function concerning knowledge diffusion through networks, an activity often mentioned in the literature as important for impact generation. For example, the SIAMPI (Spaapen & van Drooge, 2011) approach assume that exchange of information between researchers and non-academic stakeholders must have taken place for any impact to occur (Spaapen & van Drooge, 2011). On that basis it may from an analytical point of view be of interest to include knowledge diffusion as a separate function to give it more attention, whereas in other TIS approaches this process is considered to be a part of another function labeled knowledge development. The remaining functions are more or less the same in the different versions found in newer literature.

In the following the seven functions used for analysis in this thesis will be described.

3.3.1 Function 1: Entrepreneurial Activities

Evolvement of a TIS take place under considerable uncertainty in terms of technologies, markets and applications, and uncertainty is a fundamental feature of technological and industrial development. This is not limited to the development of a TIS but is a characteristic of later phases as well. In order to reduce this uncertainty entrepreneurial experimentation and activity is essential (Bergek et al., 2008). The entrepreneur’s role in a TIS is to turn the potential of new knowledge, networks, and markets into concrete actions to generate and take advantage of new business opportunities. Entrepreneurs can be either new entrants or incumbent companies who diversify their business strategies to take advantage of new developments (Hekkert et al., 2007). Entrepreneurial activity is risky and many will fail, others will succeed and a social learning process will unfold (Bergek et al., 2008). Through experimentation many forms of learning take place and knowledge can be collected about the functioning of the technology under different circumstances. This enables the possibility to evaluate reactions of consumers, government, competitors, and suppliers (Hekkert et al., 2007). A TIS without entrepreneurial experimentation will according to Bergek et al. (2008) stagnate.

For evaluation of this function the analyst can, for example, map the number of new entrants, the number of diversification activities of incumbent actors, and experimentation with new technology (Hekkert et al., 2007).

3.3.2 Function 2: Knowledge Development

Knowledge is according to Lundvall (1992) the most fundamental resource in the modern economy (Lundvall, 1992). Knowledge development and R&D are therefore prerequisite within the innovation system, and are considered by Bergek et al. (2008) and Hekkert et al. (2007) to be placed at the heart of a TIS (Bergek et al., 2008; Hekkert et al., 2007). This function encapsulates the breadth and depth of the of the current knowledge base of the TIS, and changes that occur over time. Knowledge can be distinguished between different types such as technological, scientific, production, market, logistics and design knowledge, and different sources of knowledge, for example R&D, learning from new applications, productions etc. (Bergek et al., 2008).

The function encompasses “learning by searching” and “learning by doing”, and Hekkert et al. (2007) highlights three typical indicators to assess this function: 1) R&D projects, 2) investments in R&D, and 3) patents (Hekkert et al., 2007).

3.3.3 Function 3: Knowledge Diffusion through Networks

The most important activity in networks are according Carlsson and Stankiewicz (1991) the exchange of information (Carlsson & Stankiewicz, 1991). Hekkert et al. (2007) points out that this is important in strict R&D settings, but especially in a heterogeneous context where R&D meets government, market, and competitors. They argue that policy decisions should be consistent with the latest technological insights, while at the same time R&D agendas should be affected by changing norms and values. As of this, they regard network activity as a precondition to "learning by interacting", and when user producer networks are concerned, it can also be regarded as "learning by using" (Hekkert et al., 2007).

Function 3 can be analyzed by measuring, for example, the number of conferences and workshops devoted to a specific technology topic, and by mapping network size and intensity over time (Hekkert et al., 2007).

3.3.4 Function 4: Guidance of the Search

According to Hekkert et al. (2007) guidance of the search refers to those activities within the innovation system that can positively affect the visibility and clarity of specific wants among technology users. They argue that guidance of the search is important as resources are almost always limited, and when various technological options exists specific foci will be chosen for further investments. Without this selection, resources will be scarce for individual options. For example, if knowledge creation is regarded as the creation of technological variety, this function represents the selection process. The function can also be important from a social perspective, for example, changing preferences in society can influence R&D priorities and thus the direction of technological change (Hekkert et al., 2007). In the development phase of a TIS the function may also be important as organizations have to choose to enter it, which will not happen unless there are sufficient incentives and/or pressure to be encouraged to do so (Bergek et al., 2008). For example, announcement of a new government goal may create a certain degree of legitimacy for development of a new technology and stimulate resource mobilization for the development. Guidance of the search is not just a matter of government influence, other system components such as industry and/or market can also fulfill this function. One last factor to include in this function is expectation, as it can converge on a specific topic and generate a momentum for change in a specific direction (Hekkert et al., 2007).

Analyses of guidance of the search can be done by mapping specific targets set by industries or governments regarding the use of a specific technology and by mapping the number of articles in professional journals that raise expectations about new technological developments (Hekkert et al., 2007).

3.3.5 Function 5: Market Entrance and Formation

Market formation is especially important for an emerging TIS or one under transformation. Under these phases markets may not exist, or they may be significantly underdeveloped (Bergek et al., 2008). A TIS need a place to form and develop, and new technologies often experience difficulty to compete with incumbent technologies. Creation of protective spaces where new technology can nurture and grow can be highly important to secure further development and diffusion (Geels, 2002; Hekkert et al., 2007; Kemp, Schot, & Hoogma, 1998). Hekkert et al. (2007) argues that formation of temporary niche markets, an environment where actors can learn about the new technology and develop expectations, for specific applications of a technology may be one possibility to tackle this challenge. Another possible solution they point out is to create a competitive advantage by favorable tax regimes or minimal consumption quotes (Hekkert et al., 2007).

According to Bergek et al. (2008) market formation normally goes through three phases. The early phases are where the markets need to evolve, and where the TIS can find its place to form. This leads to what they call the "bridging market", which allows for volumes to increase, and for an enlargement in the TIS in terms of number of actors. Lastly, mass markets may evolve, often several decades after the formation of the initial market (Bergek et al., 2008).

For the purpose of impact analysis, I chose to slightly change the name of this function from "market formation" to "market entrance and formation". I did this to prevent confusion as impact does not necessarily occur on the basis of new research. Impact can be generated from research that were conducted 30 years ago, thus, a market may already exist, and the challenge will be to enter it rather than forming a new one. The original function does support market entrance, but it is not that clear in the literature.

This function can be analyzed by mapping the introduction of niche markets, specific tax regimes for new technologies (Hekkert et al., 2007), and assessment of what phase the market is in, who the users are and the design of their purchasing processes, whether the demand profile has been clearly articulated and by whom, and if there are institutional stimuli for market formation or if institutional change is needed (Bergek et al., 2008).

3.3.6 Function 6: Resources Mobilization

Resource mobilization, both human and financial, is an essential activity within all innovation systems (Bergek et al., 2008; Carlsson & Stankiewicz, 1991; Edquist, 2005; Hekkert et al., 2007; Lundvall, 1992). Allocation of sufficient resources is necessary to make knowledge production possible for specific technologies (Hekkert et al., 2007). Bergek et al. (2008) argues that it is important to understand to which extent a TIS is able to mobilize competence and human capital through education in specific scientific and technological fields, as well as in finance, entrepreneurship, management and complementary assets (Bergek et al., 2008).

Example of activities in terms of this function can be long term R&D programs set up by government or industry to develop specific technological knowledge, or funds made available enabling testing of new technologies (Hekkert et al., 2007).

According to Hekkert et al. (2007) this function can be difficult to analyze by means of specific indicators over time. A better method for analysis of this function may be to identify, through interviews, whether or not actors perceive access to sufficient resources as problematic (Hekkert et al., 2007).

3.3.7 Function 7: Creation of Legitimacy/Counteract Resistance to Change

A large challenge for a new technology is to become part of, or overthrow, the incumbent technology (Hekkert et al., 2007). Therefore, a new technology needs to be considered appropriate and desirable by relevant actors. This is important in order to mobilize resources, to create a demand, and for actors in the new TIS to acquire political strength (Bergek et al., 2008). One problem is that parties with different interests will often oppose to the new technology. In these circumstances, advocacy coalitions can function as a catalyst, and place the new technology on the agenda, and lobby for resources and favorable tax regimes. By doing so they may create legitimacy for the new technology. These coalitions, if successful, will grow in size and influence, and may end up powerful enough to influence a change of interests in opposing forces. However, the scale and success of the coalitions are dependent on available resources and future expectations associated with the new technology (Hekkert et al., 2007).

Analysis of this function can be conducted by mapping the rise and growth of interest groups and their lobby (Hekkert et al., 2007), and other various relevant actors and stakeholders, including activities within the system that may increase this legitimacy (Bergek et al., 2008).

Summary

In this chapter the TIS framework has been introduced with inclusion of a proposed set of functions. This framework will be used in the analysis later in this thesis. In the following chapter I will discuss methodological concerns in regards of this study.

4 Methodology

One of the major challenges concerning impact evaluations are temporality as it can take several years, or even decades, for research to have an effect. Collecting data of the whole progression from research to impact, including analysis, would therefore be an unrealistic task for a thesis of this scope, as the data material would be of unmanageable size and the time frame for analysis to short. I therefore decided to limit the workload by using empirical content from already finished impact evaluations and cases. In terms of limiting the scope of the thesis I decided to focus my study on the relationship between research and effect, a decision taken on the basis of a felt lack of attention to this important topic in the literature.

In the preparatory work to this assignment I spent months searching for literature, reading and learning about the concept research impact assessment. It did not come as a surprise that the main attention in the literature was identification of impacts, but I was astonished by the absence of more in-depth research or analysis related to the transition between research and effect. I do have to emphasize that it is not a lack of article discussions regarding impact generating mechanisms, but rather a scarcity of research with a main purpose of examining generation processes. As this type of research can provide us with valuable knowledge on different types of interventions that can be important to influence the development of impact, I found it hard to understand why it has not acquired more attention. In addition, it was difficult to find a consensus in the literature on what an impact process really is, and its significance in regards of impact generation.

After reviewing a lot of impact literature, I started to see a connection between impact and innovation studies on the basis of similarities in the literature. This further led to an idea of viewing impact as system and not just an effect of research. By viewing impact as a system, it would imply that the system as a whole would be responsible for the impact generation. The question that arose was, what is an impact system? As of the similarities found between impact and innovation in the literature, I decided to use the definition of a system from innovation studies as a basis description of an impact system. In its simplest form an impact system will then be regarded as all the determinants of impact processes. The reason for choosing this definition of a system is because it does not exclude any determinants, which make sense as we do not know what to include or exclude. However, it does add more complexity to the system.

The main components in an innovation system are organizations (actors) and institutions (laws, technical standards, norms etc.). Their behavior inside the system is called activities (Edquist, 2005). After reviewing a lot of impact literature, I found a reasonable amount of evidence to support an early prediction that the same main components would be found in an impact system as well, and I wanted to learn more about how these components and their activities influence the generation of research impact. On that basis I formed an overall research question: *What characterizes an impact system, and under what circumstances does impact occur?*

I thought it was a good starting point for further investigation of impact systems as of the poor coverage in the literature. As it is a rather open question of formed to more specific questions to address to overall research question. Nevertheless, my goal was to gain a deeper understanding of processes, including human events and contextual conditions, in which research develops into impact. Thus, a qualitative research design and method seemed to be the most sensible choice (Yin, 2010, pp. 7-9).

In the following sections I will discuss methodological choices taken in terms of data collection and analysis. I will start by discussing case studies as a method, and clarify choices taken and procedures followed in terms of data collection. Further, actions in regards of coding and data analysis will be clarified, followed by a discussion in relation to the reliability and validity of this project, and lastly, thoughts around ethical concerns.

4.1.1 Case Study

According to Yin (2014) a case study is a research method for an in depth investigation of a contemporary phenomenon within its real world context, in particular when the boundaries between the phenomenon and the context are not clearly evident. In other words, one wish to understand a real-world case based on an assumption that important contextual conditions relevant to the case are likely involved. (Yin, 2014, p. 16).

In terms of choosing the right research approach for this assignment, I compared three main approaches: experiments, surveys and case studies. In experiment cases the experiment is created by the researcher and influencing factors can be controlled and manipulated. As the processes I wished to study could not be manipulated nor isolated this approach was excluded

(Given, 2008; Yin, 2014). Whereas larger surveys tend to focus on causal research goals, case studies tend to be directed towards more descriptive goals. It does not mean that case study research is not concerned about causation but are more focused towards descriptive-interpretive elements. Furthermore, case studies often seeks to understand specific mechanisms and pathways between causes and effects rather than revealing the average strength of a factor that causes an effect (Given, 2008, pp. 68-69). As the latter argument resembled what I wished to accomplish, a case study strengthened its position as the most suitable choice of method.

According to Yin (2014) case studies are preferred when examining contemporary events, where relevant behavior cannot be manipulated, and when the research questions are mainly focused on “how” and “why” questions, or alternatively an exploratory “what” question in which a case study in addition to other methods can be used. If this corresponds with the study in focus, which it does in this thesis, a case study may be the favored approach (Yin, 2014, pp. 9-12).

In addition, Given (2008) argues that case studies have a strong comparative advantage with respect to the “depth” of the analysis; understood as empirical completeness and natural wholeness, or conceptual richness and theoretical consistency. In contrast, larger surveys would have an advantage in terms of “breadth” of the propositions which is an important argument in contexts where there are many similar cases, or where a homogeneous population of cases is assumed (Given, 2008, p. 69). As my study seeks more “depth” than “breadth”, a case study seemed to be the preferred method in such situation. In the end a decision was taken on the basis of my research questions, and comparison of the different approaches, and the research method of choice fell on case studies.

4.1.2 Data Collection

According to Yin (2014), a major strength of case study data collection is the opportunity to use multiple sources of evidence, a feature he refer to as triangulation. Multiple sources of evidence enable multiple measures, and cross-reference analysis, of the same phenomenon. The main sources for data collection are interviews, direct and participant observation, documentation, archival records, and physical artefacts. Case study findings or conclusions are therefore likely to be more convincing and accurate if they are based on several different sources. Thus, triangulation can help strengthen the construct validity of a case study (Yin, 2014, pp. 106, 119-122).

As impact of research can be an ongoing process lasting for years, I could not observe this process myself. In addition, my research questions have exploratory characteristics that seeks depth and detailed information about the impact process. In the beginning of this project interviews were up to discussion as a primary source of information, which would also strengthen the triangulation. However, while investigating possible impact cases and relevant informants I quickly understood what a major challenge this would become, considering the scope of this thesis. As it can take decades before research generate effects on society, collecting informants that could provide relevant information throughout the whole process was believed to be too resource intensive for a project of this size.

Though it could possibly weaken the validity as of lesser triangulation, interviews were ruled out as a source of information. Instead I chose to use documents as the main data source, using multiple impact cases collected from a larger impact study executed by the Research Council of Norway.

In the following section I will discuss procedures in relation to my process of collecting data through documents.

4.1.3 Collecting Data through Documents

Documentary information is relevant in most case studies and can be of a variety of formats such as newspaper articles, letters, formal studies, written reports etc. In case study research documents are most often recognized as an important source of information to corroborate and augment evidence from other sources (Yin, 2014, p. 107). However, Green and Thorogood (2004, p. 155) argues that it is not always necessary to collect new primary data for research, and using existing documents can be an efficient use of resources for many qualitative questions. The efficiency gains of re-analysis of primary data from other studies can be particularly important for smaller student projects where time and resources are limited for new data collection (Green & Thorogood, 2004, p. 162). The latter was the main challenge in terms of data collection for this thesis as of the temporality problem in regards of impact studies mentioned in the beginning of this chapter, thus, using data from other studies seemed liked the most sensible approach.

As with other data collection methods documentation has certain strengths and weaknesses as a source of evidence. On the one hand, it is a stable and specific source that can be reviewed repeatedly. It is also a broad source that can cover a long span of time, many events, and many settings (Yin, 2014, p. 106). The breadth of the source was in particular important for this thesis. On the other hand, it can be a difficult source to find, and access may not always be available. Likewise interviews one also need to be aware of possible bias from the author, and biased selectivity (Yin, 2014, p. 106).

While collecting the data I tried as best as possible to locate evidence that would be most relevant in order to answer the research questions. At the same time, I kept in mind the possibility of biased selectivity meaning that I subconsciously would pick out evidence that would provide results supporting personal thoughts opposed to relevance, correctness, and variety. As of this I remined myself through the data collection process that me as a researcher could influence the choice of evidence, and further color the results. Another challenge is that not all research is good research and by basing your own research on poor results from other studies, it could end with questionable conclusions. Therefore, I critically reviewed the case studies, methods used, and results of the evidence that would provide the data for my analysis.

Collecting Data from Primary Research Institutes in Norway

The analysis in this thesis are based upon data from a report published in 2018 that presents evaluation of seven primary research institutes in Norway. The evaluation was carried out by a Nordic panel of nine experts and was a part of a series of evaluations of Norwegian research institute groups, initiated and organized by the Research council of Norway. As part of this report the research institutions was asked to deliver their own examples of impact on society from their research. This where done through a fixed template with of a maximum of two pages. The method was partly inspired by the British Research Excellence Framework (REF), however, the Norwegian variant is on an experimental stadium but had already been used in two evaluations from the Research council of Norway (Norges forskningsråd, 2018a). It was delivered 55 impact cases from the primary research institutes. These were collected and put in to a single document as an attachment to the main report (Norges forskningsråd, 2018b). Together, the main report and the attached document with impact cases will serve as the main data source for the analysis in this thesis.

One of the main reasons for choosing this data source is that it is public available. It means that everyone has access to the data used in this thesis, and the study may therefore be replicated by others or tested for biases and errors. Another reason is availability as it was not easy to find interview transcripts or other documentation from impact cases involving people telling their story of the impact process. This is of course one of the drawbacks from not conducting own interviews as a data collecting tool. On the other side, by using impact cases found in the documents a larger number of cases can be cross case analyzed looking for similarities in the results, and the resources needed for the data collection is at a manageable level.

On the critical side of this method I did sometimes experience challenges in terms of finding more specific data I was looking for. The template used in the report from Norges forskningsråd (2018b) to collect the impact cases is not the best if one wish to learn how effects are created as the question are quite few, and none are related to generation of impacts. The method used seems to focus more on finding and proving impacts, and what type of impact the research contributed to. As of this I had to use the main report and the attached impact cases in conjunction with each other. The main report provided technical facts such as financing, networking, and how the institutes are structured. The impact cases gave more personal stories from the institutes on the impacts of specific research. How I processed and used the data and challenges I experienced analyzing it will be described in the next section.

4.1.4 Data Analysis and Coding

I started the analyzing process by reflecting over why I was doing this and what answers I was looking for. I did this as I was about to use an analytical tool, the TIS framework, that is not purposely created for impact analysis and the data material was not originally created for the purpose of being analyzed this way. A typically way of use the TIS framework is to create a narrative from the source material and analyze the story from start to finish (Hekkert et al., 2007). This method needs a substantial amount of data material, which as mentioned earlier was hard to find in the context of impact. In order to successfully use the TIS functions approach to analyze causal relationships between system components, activities and key functions that may support or hamper impact, one first need to know if these functions will be of importance in the context of impact. This is also related to the research question. On these grounds, I decided to focus my analysis towards identifying key functions in the impact cases, and if possible, analyze the relationships and influences between the functions within the cases.

After planning how I would approach the analysis I started the process of coding. Coding is an important step of the data analysis and can be referred to as the process of identification, arrangement, and systematization of ideas, concepts and categories uncovered in the data material. Source material can then be broken down into smaller shares so that the large amount of data will be more comprehensible and useful as evidence. The procedure begins with identification of potentially interesting events, features, phrases, behaviors or processes. These may then be reworked into a smaller number of categories, relationships and patterns enabling the possibility to tell a story or communicate conclusions (Given, 2008, p. 85).

As my goal was to identify TIS functions in the impact cases, I started by labeling each function with the letter F and a number 1 to 7, F1 to F7, in correspondence with the TIS framework. Then I read through the cases and if a certain function was identified I marked the function number in the text. I constantly kept rechecking the TIS framework as a guidance on what specific factors to look for in order to identify the different functions. The function was only marked if it was clear from the text that it was an activity or process. If a specific case did not provide enough information to create some sort of narrative, or simply did not describe what happened in between research and effect it was put aside as not usable. This also include cases that did not prove any impacts; cases based on research that had not yet generated impact but could possibly create impact in the future.

When that was done, the cases were broken down to smaller summaries containing the functions and if possible, written down as a narrative. If a specific process in the impact case seemed to be of importance for generation, but did not correspond with a function in TIS, it was marked aside a possible “new function”. The intention was to see if this particular process would appear in other cases as well. When all the cases were broken down to summaries, I cross checked them with the main report to see if there was additional information to be found. I did not use any information from the report unless it was perfectly clear that this information was related to the specific case I was working on. This was done in order to prevent that information was taken out of context.

In the process of coding and analyzing, it is important to check and recheck the accuracy of the data, assure that the analysis is as thorough and complete as possible, and continually acknowledge unwanted biases imposed by own values and ideas (Yin, 2010, p. 177). I tried as best to my ability to follow these guidelines throughout both of these processes.

When I had worked through the 55 impact cases, I selected 15 for further investigation. These cases were selected on the basis of providing the most detailed description of the impact process. I also chose this number as I have to follow certain guidelines in terms of the scope of this thesis. After the selection process ended, I started analyzing the data. Through the analysis I went through the identified functions and compered their appearance among the cases to see if certain functions where more prominent than others, or if certain functions were not mentioned at all, including looking for possible new functions especially important for impact. Further I would look for activities among actors and see if this could influence the functions. Lastly and most importantly, see if the functions had an influence on each other and if some or all of these processes together as a system could explain the emergence of research impact. Through this process I also identified structural components found in the impact system. The knowledge gained from the analysis formed the basis of the final conclusion.

4.2 Reliability and Validity

The research quality is dependent on reliability and validity in the research design and process. This is important to ensure trustworthiness and to clarify thoughts, ideas, and work that have influenced the research process (Yin, 2014, pp. 45-49). In the following I will discuss different considerations taken into account through the progression of this thesis.

4.2.1 Reliability

Reliability is a term to describe to what extent others can replicate research results, and draw the same conclusions, by following the same procedures on the same study. The goal of reliability is to minimize errors and biases (Yin, 2014, pp. 48-49), which can be challenging as the research process can be influenced by own subjectivity and decision making.

Nevertheless, the reliability can be strengthen through transparency, which can be referred to as the explicitness of the method used, and how clearly they are outlined for the reader (Green & Thorogood, 2004, p. 192).

In order secure transparency researchers need to provide a thorough description of the steps taken in conducting their research, including an honest and clear explanation of the actual procedures used for analyzing the data (Given, 2008, p. 795; Green & Thorogood, 2004, p. 192). All data need to be available for inspection so that others should be able to scrutinize the work and the evidence used to support findings and conclusions (Yin, 2010, p. 19).

I have tried to secure reliability by providing a description of the development of my research questions and design, and further show transparency by explaining my choice of method in regards of data collection. All analyzed data material used in this thesis is publicly available and download links can be found in the reference list. This secures openness around the data material that conclusions were drawn from and enables replication of the study. I have shared reflections of what I consider as strengths and weaknesses in relation to my approaches, and other challenges that occurred working on this project. I have also been open about how I have worked around the problems and how it possible could affect the results. In terms of data analysis, I have clarified how it was collected, coded, and how the data was analyzed.

Reflexivity

Reflexivity is a researcher's awareness of how he or she may influence a study; a researcher's recognition of being a part of the process of producing and interpret data, and a conscious reflection on that process (Green & Thorogood, 2004, pp. 194-195; Yin, 2010, p. 11). In a perfect situation, it means that potential biases or individual coloring of the data collection and the analysis would be nonexistent. However, as humans we are not aware of all the subconscious ways in which our assumptions shape our approaches to research (Green & Thorogood, 2004, pp. 194-195; Yin, 2010).

In order to face reflexivity challenges some precautions were taken. As it is impossible to totally remove subjectivity, including influences from reading literature in preparation for this assignment, I focused on reminding myself that reflexivity threats exist and made reflections on possible measures to avoid them. In addition, I have tried to account for the interplay between my presence, the research context and the data produced. As previously mentioned, I have been open in terms of methodology and steps taken in data collection and analysis, including openness around decisions made. I have explained theoretical concepts and assumptions, and the way in which they shape this thesis. As the idea behind this project originated from interdisciplinary theoretical content I tried as best to my ability describing the thought processes that formed the basis of the thesis, and how the theoretical content was used to create the idea of viewing impact as a system.

4.2.2 Validity

According to Yin (2010) validity can be referred to as a quality control of a study and its findings. To secure validity, data need to be properly collected and interpreted so that the conclusions accurately reflect and represent the real world that was studied (Yin, 2010, p. 78). The term is often differentiated into two categories: internal validity and external validity (Given, 2008, p. 714).

Internal validity refers to what degree the researchers conclusions correctly portray the data collected, and the relevance of the data collection in regards to the research questions (Bloor & Wood, 2006, p. 148; Given, 2008, p. 714; Yin, 2014, p. 47). To gain validity, the researcher must be able to justify why the study should be considered credible and legitimate. This means clarification of any interpretation and analytical decisions made, which is important in order to ensure the reader that conclusions were not taken on the grounds of subjective interpretations (Green & Thorogood, 2004, p. 192). I have tried to be as clear as possible in the description of what is data and what are interpretations, including explanations on what formed the basis of any assumptions or conclusions. Through the thesis I have also tried to highlight alternative views and perspectives through rival explanations, or rival thinking, and being a constant sceptic to my own work. This imply rejecting own original interpretations on behalf of a rival ones if the alternative seem to be more plausible (Yin, 2010, p. 80).

Yin (2014, pp. 46-47) also emphasizes the importance of identifying correct operational measures for the concepts being studied, referred to as construct validity. To encounter this challenge, I have through the preceding chapters tried to be clear in regards to operationalization of the research questions, and identification of analytical tools appropriate to answer them (Yin, 2014, pp. 46-47).

4.2.3 Generalizability

Generalizability is often referred to as external validity, and refers to what extent findings from a study applies to a wider population or to different contexts (Bloor & Wood, 2006, p. 93; Green & Thorogood, 2004, p. 197). Generalizability is emphasized differently in quantitative and qualitative studies. For instance, in a sample survey random sampling allows generalizability on the basis that the study sample is likely to be statistically representative of the larger population of interest. Findings can therefore be extrapolated to that population (Green & Thorogood, 2004, p. 197). In qualitative work, study participants are rarely randomly sampled this way and the sampling units, are not cases, and will be to small in number to serve as an adequately sized sample to represent the larger population. Consequently, statistical generalization is not that relevant for generalizing case study findings (Green & Thorogood, 2004, p. 197; Yin, 2014, p. 40). Rather than aiming for statistical generalization qualitative research often seeks to produce concepts that are theoretical generalizable (Bloor & Wood, 2006, p. 93).

What this imply in terms of my study is that I can use it to shed empirical light about certain theoretical concepts or principles, and confirm or contrast emergent theory (Bloor & Wood, 2006, p. 93; Yin, 2014, p. 40). As this assignment only investigates a small number of cases it is not possible to discuss its transferability to other cases, but it ought to provide an opportunity to suggest theoretical refinements or supplements.

4.3 Ethical Concerns

All data material used in the thesis is of public domain and does not pose any concerns in terms of confidentiality or handling of sensitive information. I still gave it a high priority, and throughout the whole project I have followed the guidelines provided by the University of Oslo in regards of ethical concerns.

5 Analysis and Reconstruction of the TIS Framework in the Context of Impact

In this chapter I will analyze the collected data material using the TIS framework. The goal is to identify structural components that form the basis of the impact system and to see if TIS functions can be found in the context of impact, if the functions can be understood as important for impact generation, and if the functions influence each other. All tied to the research question.

The first part of the analysis consists of 15 impact cases, from six primary research institutes, that has been broken down into smaller summaries, and if possible written as a narrative. If a function is identified it is marked in the text as an "F" followed by the correct function number from one to seven. Function number five "market entrance and formation" will for example be displayed as (F5). The purpose of this part is to see if innovation systems functions can be mapped in the context of impact, and the possibility to identify possible causal relationships between the functions. It also enables a review of how I mapped the functions that will form the basis of part two of this analysis.

The analysis does not attempt to identify impacts, as the purpose is to learn about impact generation rather den identification. Nevertheless, one criterion set for using a particular case in the analysis was that the research it is based on should have contributed to some sort of tracible impact, though that is grounded on a subjective consideration from my part.

The second part of this chapter consist of an analysis of each of the functions in the TIS framework in the context of impact. In this part the functions will be analyzed separately based on findings from part one. The purpose is to discuss the relevance of each function and if certain functions seem to have a specific influence on other functions, and if the function seem to be of importance for impact generation.

5.1 Part 1: Impact Cases

Writing summaries of the cases and identify functions turned out to be more challenging than anticipated. The method used in the original report to collect the impact cases did not specify very clearly how to write or what to include in the case. Therefore, the cases in terms of details and design is very different from each other, making it difficult at times to extract useful information. Though the cases were not collected for use in this thesis, I still think it could have been done better.

The consequence is that it sometimes was hard to decide if a function should be marked or not as it was not always clear in the case document what triggered activation of a particular function. For example, if research results were legitimized by the government (F7) who then spread the knowledge to the public causing a change in behavior, the question would be who influenced the government and how? Did someone convince the government to accept the research, or did they simply just stumble upon the results by a coincidence? Thus, it was a challenge mapping the functions correctly, not knowing the story behind the activity. In such situation the impact could be a matter of pure luck, or matter of an intricate process to create acceptance for the research. Keep this in mind reading the following case summaries if a function seems to be missing or marked incorrectly

Despite the challenges, the functions were marked on the basis of all information that proved activation of a particular function. In the following sections I present 15 impact cases, from six Norwegian primary research institutes, broken down into smaller TIS analyzed summaries. The cases are organized according to what institute they belong to.

5.1.1 The Veterinarian Institute

The veterinarian institute is a public biomedical contingency- and research institute under the Royal Norwegian Ministry of Agriculture and Food, and deliver research, diagnostic and consulting services (Norges forskningsråd, 2018a, p. 78). Five out of six cases were selected for analysis, and collected from Norges forskningsråd (2018b, pp. 11-28).

Algae toxins

Algae produces toxins that can be a concern in terms of food poisoning (shellfish poisoning). Because of this concern and the need for a solution to the problem an opportunity (F4) arose to conduct research (F2) on this matter and enter the aquaculture market (F5). The R&D conducted by the veterinarian institute was made possible as of knowledge diffusion through networks (F3), a cooperation between national and international research institutes that helped provide material, resources (F6) and communicate results (F3). Through knowledge exchange (F3) the research has influenced the European Union, who also legitimized (F7) the research, and changed research regulations in terms of testing on mice. The research from the veterinarian institute was an important prerequisite for the change in regulations. This affected the aquaculture market (F5) in terms of research methods, and the amount of animals used in possible painful tests was reduced drastically in Europe and New Zealand. Through knowledge diffusion (F3), new methods and standards developed from the original research has been adopted by different actors in the market (F5) and contributed to the impact of their research.

Infectious salmon anemia

In this particular case no narrative were provided, but certain connections between functions were found.

Infectious salmon anemia in farmed salmon was first described by the veterinarian institute in 1988, an ILA-virus was isolated 1995 and characterized in 1997. The study started based on diagnostic material delivered (F3) the veterinarian institute, and R&D processes (F2) has since then been going on for decades. As the virus causes huge challenges in the fish industry, a demand for research (F4) was created and the research could easily enter the market (F5). The results influenced the government (F7) to introduce general standards in terms of hygiene in fish farms, and specific ILA standards, to reduce transmission of viruses. The results were a dramatic reduction of ILA cases. As the virus is a continuous problem that causes enormous financial losses, the research project (F2) is therefore a constant process, keeping the window open (F4) to continue the R&D, legitimized by the government (F7) that use the knowledge provided (F3) to fight the virus in order to maintain a healthy fish industry. As the virus has caused problems in several other countries as well ILA has become an international notifiable disease through regulations from World Organization for Animal Health, providing opportunities (F4) for the research to be used internationally. The veterinarian institute is appointed the role being a reference laboratory, and to conduct R&D work (F2). This also generated international effects of the research. As a result, the research has become part of a large network of knowledge diffusion (F3).

Development of effective tools for diagnostic and surveillance of crayfish plague

The veterinarian institute has through research developed efficient molecular tools for crayfish plague diagnostic and eDNA-based infection tracking in water. After the plague hit Norway in 1971 it has overt time caused problems in many river systems (F4). The institute assisted the government with disease clarification and advises (F3) which further led to R&D activity (F2) as the current available methods for diagnosis were weak. However, in the years from 1971 – 2004 the institute were not able to give a correct diagnosis. In 2005 the institute strengthen their R&D work (F2) in this area of research. The results were a fast and specific method for detection and quantifying crayfish plague, tested and validated internationally and in Norway (F2, F3). The last ten years the institute has leaded or participated in research (F2) resulting in 15 international articles (F3) on crayfish and crayfish plague, and ten articles (F3) for the government. The impact from this research is difficult to put in numbers, but through knowledge diffusion (F3) it has influenced governmental decisions and the research has been featured in the European Commission "Science for Environment Policy".

Methicillin-Resistant Staphylococcus aureus CC398 in Humans and Pigs in Norway: A "One Health" Perspective on Introduction and Transmission

Methicillin-resistant staphylococcus aureus (MRSA) can cause infections in animals and humans, and some types can be established and spread in livestock population. Norway has a unique surveillance and control strategy for MRSA in livestock. This strategy opened up a basis (F4) for a cooperative study (F2) between veterinarian and human medicine academic communities, government, and Norwegian and Danish reference laboratories (F6, F7). The results have been of major importance in terms of optimize advises, guidelines (F3) for prevention of introduction and diffusion of MRSA to pigs and other livestock, including devices for surveillance. The study has influenced the government (F7) that together with academic societies have influenced change of behavior in the agriculture market (F5) to prevent that livestock-MRSA is spread within agriculture and from pigs to humans. Through knowledge diffusion (F3) the research has gotten attention from professionals, politicians, and Norwegian and international medias.

Prion research

Research on prion diseases in animals conducted by the veterinarian institute the last 20 years has given good results and had effects in terms of ways of handling the diseases and positive economic effects for industry and state administration.

In 1998 the institute discovered a new type of scrapie in sheep. This version of the disease, called Nor98, turned out to be different from the common version and use of current available diagnostic tests proved to be problematic due to discrepancy between results. Through research (F2) and exchange of research results (F3), one producer (F1) of diagnostic tests were able to develop a test that could separate Nor98 from the common version. This test is today one of the most used internationally. The institute contributed in several European projects as well (F3), and the disease is well characterized. Because of the research on scrapie the institute was quickly able to diagnose chronic wasting disease in a reindeer in to 2016, and shortly after in two moose. Results from the examination showed that the disease were different in moose than in reindeer. Governmental institutions understood that it was a demand for new knowledge on the topic (F4), and the veterinarian institute was then asked to start research (F2) on chronic wasting disease. This could be done because of knowledge gained from previous research on scrapie. This R&D project is an ongoing process and results are not totally clear yet. Through research from the veterinarian institute (F2), and diffusion of knowledge (F3), new standards for handling Nor98 has been implemented in Norway as well as the European Union (F7).

5.1.2 Nofima AS

Nofima is an independent business-oriented institute. Their objective is to contribute with research-based knowledge with commercial potential for development of the food industry (Norges forskningsråd, 2018a, p. 70). Five out of nine cases were selected for analysis, and data were collected from Norges forskningsråd (2018b, pp. 124-147)

New packaging technology using carbon dioxide -emitter

Nofima has for many years conducted research on optimized packaging solutions for food, related to material, packaging methods, and storage. The research (F2) on carbon dioxide - emitter started in the beginning of the 2000s made possible (F4), through projects financed (F6) by Forskningsrådet and Fondet for Forskningsavgift på Landbruksprodukter, and a PhD. project. The research was verified through a “Forny” Project in cooperation with Vartdal Plastindustri (F1). The concept is that a little moisture absorber that lies beneath the food is added components that produce carbon dioxide gas when getting in contact with fluids, thus, hamper bacterial growth and contribute to increased shelf life. Through the research Nofima and Vartdal Plastindustri AS have gained a considerable amount of knowledge tied to the emitter, production, composition and sizing. This is because the emitter needs to be customized dependent on the product, product amount, type of packaging and method, and gas composition. The research did prove that the shelf life of fish and meat increases with use of the emitter, and Vartdal Plastindustri sold in 2016, mainly in Norway, 1,2 million emitters. Further, they plan to expand globally, and have done an agreement with Cellcomb AB (F1) in Sweden tied to production and sale.

As a side note, this case also illustrates a possible formation of an innovation system which demonstrates the close relationship between impact- and innovation systems. Nevertheless, time will tell if they will succeed, however, it can be difficult and challenging to enter the market (F5) as the product requires changes at the manufactures. On the other hand, the product contributes to reduced package size, meaning more packages per transport, reduction in climate gas emission, and more efficient transport which can have an effect on the other functions which in turn may help a system to form.

Processes in the food industry based on on-line near infrared interactance imaging

In the meat industry the economic margins are small, and because of that it is important to utilize raw material as best as possible. One of the main products are batches of trimming. The price of the product is set based on the fat content. Low fat content gives a better price and having control on the fat content in the batches are important for stability in quality and profitability. As of this it has for many years been a demand for a method that can measure the fat content in meat that is transported on a conveyer belt.

The need for a solution opened up an opportunity (F4) for Nofima in cooperation with Sintef ICT to develop (F2) a new optical measurement system based on multispectral near infrared interactance imaging. They also developed (F2) methods to reduce noise tied to variations in the meat. The latter work was a part of an innovation project called Meat vision (F6). The method was first developed for a Spanish company (F1) to measure cases with pork meat, the work got published (F3), and the instrument commercialized by TOMRA Sorting Solutions (F1). Another R&D project (F2) from Norges Forskningråd (F6), MeatAutoSort, was started as a follow-up project. Through this project the method became much more accurate. The success of the research came as a result of good cooperative work between the research institutes Sintef ICT and Nofima, and the instrument supplier TOMRA Sorting solutions (F1, F3). The technology has been accepted by the market (F5) and the system has been sold globally. Another effect of the success is that the food industry has started several R&D (F2) projects to further develop the technology.

Functional feed for farmed salmon and preventive fish health

Nofima has for the last decades been central in the development of so-called functional feed preventing virus disease in farmed salmon. Virus disease is one of the most serious health threats in farmed salmon and is the costliest challenge in the industry because of a lack of effective vaccines against the viruses. This opened an opportunity (F4) to conduct research (F2) on controlled nutrition to modulate the salmon's immune system, and to influence growth and restitution under and after the disease. Nofimas research strengthened a hypothesis that one can control the fish health through nutrition. The results (F3) gave birth to new R&D (F2) projects for developing feed against virus diseases. Nofima has been an important actor in the development of this type of feed for two of the largest feed companies (F1), through documentation (F3) of the feeds effect on the immune system and heart condition. They have also developed (F2) models for infection which has be an important basis for testing the feed under controlled environments. As this type of feed can be considered a competitive advantage, with inclusion of increased profitability, for the feed companies, the research had no problem being accepted by the market (F5). The research has contributed to decreased costs and losses, and increased profitability for the salmon farms.

Effective QTL tied to IPN-resistance

Nofima was a participant in the work of finding genetic markers connected to a gene controlling salmons resistant against the virus disease infectious pancreatic necrosis (IPN).

On the basis of a study from Scotland (F3) that opened up an opportunity (F4) to conduct further research, Nofima initiated a project studying genetic markers tied to IPN. The project was financed (F6) by AquaGen (F1) and HAVBRUKS-programmet from Norges forskningsråd. The R&D project helped approve and map an effective QTL (genetic locus) for IPN resistance in Atlantic salmon, which provided a tool for marker assisted selection. Nofima designed an infection test (F2) with input (F3) from AquaGen (F1), and testing were conducted by VESO (F2). Through the research they found a QTL that results in a direct use of marker assisted selection providing large effects.

The R&D project resulted in a reduction, 75% in 2013, of IPN outbreaks in the sea and hatcheries. This in turn effects the market (F5), by use of research results, through reduced losses and costs. AquaGen also increased their income from sales of QTL-roe as a direct result of the project.

Cold pre-cocked meals

The first cold pre-cocked meals were introduced to the Norwegian market in 1996, and since then the product has generated a turnover above two billion NOK annually. Through research projects Nofima has been an important contributor on the development of the product.

The sous vide technology was known from the restaurant industry but had to be customized for the Norwegian market. The market (F5) sought after traditional Norwegian dinners that had not yet been produced with the sous vide technology. The reason was that the heat treatment required to use the sous vide technology can be problematic especially on fish as it is more sensitive to heat than meat and vegetables. The market demand for traditional Norwegian dinners created an opportunity (F4) to start R&D projects (F2) to develop the sous vide technology further, and Nofima have since then had active national and European R&D projects (F2) working on the technology. Development of cooled pre-cocked meals for the Norwegian market (F5) has required interdisciplinary knowledge from different networks (F3), including industry actors (F1) that were willing to implement and test the technology.

The research has contributed to better products in terms of taste, shelf life, and nutrition. In an analyzing project it was proved that sous vide meals from Fjordland had a nutritional content closely equivalent to home cocked meals. Through the project new knowledge (F2) has been created and shared (F3) with the users and the industry to better utilize meat from animals, better use of resources, lower environmental impact, and lower priced and environmentally friendly products for the consumers.

5.1.3 NIBIO

NIBIO is one of the largest research institutes in Norway. The institute has a central role in development of the Norwegian bioeconomy. The research is mainly focused towards food safety, sustainable resource management, innovation and value creation (Norges forskningsråd, 2018a, p. 62). Only two cases from NIBIO were selected for analyses as their cases either lacked details or the cases were most focused on a description of the research. The cases can be found in Norges forskningsråd (2018b, pp. 75-109).

Area estimation of land

Area estimation of land was a nation-wide study of land resources. Through mapping of 1100 "stamps", systematically spread over Norway, the program quantified the value of pasture resources, and was developed over a period of ten years and delivers current statistics and reports.

The research (F2) was enabled (F4) by governmental financing (F6) through different projects and use of basic grant to finance (F6) a PhD fellowship tied to the project. As the research provided knowledge to government agencies with good results it has generated new opportunities (F4), and a spin-off project was initiated by another governmental agency to develop (F2) similar methods to be used in their agency.

The program has provided data for knowledge-based decision making, which is mirrored in regional planning- and strategic documents and new measures to increase the use of rangeland.

Nanoparticles and environment

NIBIO has for the past decade studied nanoparticles and environment to consider if human made nanoparticles can cause a threat to health and environment, and to apply nanotechnology to serve the environment. This activity has generated several R&D projects (F2) and a substantial income for the institute, including establishment as a leading national research institute within this type of technology. NIBIO has through this work established a wide network of collaborators (F3) and earned international status. Their research has been used as a knowledge base (F3) of the environment agency, Standard Norge, and the European Food Safety Authority. This has in turn generated new R&D projects (F2) for the institute from Forskningsrådet and the European Union, and lastly, work assignments from commercial actors to test toxicity in products that has been sold in the Norwegian market.

5.1.4 SINTEF Fiskeri og Havbruk AS

SINTEF Fiskeri og Havbruk AS is a business-oriented institute that is a part of the SINTEF-group. The main role of the institute is to provide industry knowledge and technological competence to the seafood industry. Their most important task is to be an independent R&D partner for the Norwegian fishing and aquaculture industry (Norges forskningsråd, 2018a, p. 74). One case was selected from Norges forskningsråd (2018b, pp. 110-122)

Protection against sea lice using shielding skirts

Research at the institute has contributed to development of products to protect farmed salmon against sea lice. In short, the product is a type of shielding skirt placed horizontally around the cages separating water from the outside and inside of the skirt. This prevent lice from getting in touch with the salmon on the inside. Results proved that the shielding skirt had good effect.

There is no story line to be found in this case on the processes between research and product. However, some functions can be identified. As sea lice is a large problem for salmon farmers the market (F5) was in a demand for a solution to the problem, which opened up the possibility (F4) for R&D projects (F2). The institute developed the products for the industry which probably created a knowledge diffusion network (F3), though it is not perfectly clear through the case. What is clear is that the research was taken in use by producers (F1), Botngaard AS was mentioned in the case file, that turned the research in to products and further sold to the users. The case also mentioned that one of the effects from the research is increased turnover for suppliers of the products, which imply that knowledge of the research has been diffused (F3).

In terms of societal impact of the research it has contributed to products that can help control lice which is a threat especially for wild salmon.

5.1.5 Havforskningsinstituttet

Havforskningsinstituttet is one of the largest marine research institutes in Europe. Their main activities are research, consulting, and surveillance (Norges forskningsråd, 2018a, p. 56). Only one of 16 cases were selected for analyses. The reason is that a lot of the cases described technology that could have an impact rather than had an impact, and some of the technology was still on the stages of testing, thus, I did not consider them to be impact cases. The selected, and the other cases can be found in Norges forskningsråd (2018b, pp. 29-67)

Knowledge and technology to avoid death in pelagic fish

In Norway it is illegal to throw out dead or dying fish in the ocean. Havforskningsinstituttet has provided new knowledge in regards of mortality in pelagic fish species after pursing and slipping from a purse seine, influencing the authorities to change the regulations in regards of this type of activity.

Release, or "slipping", of unwanted fish caught in a purse seine has been, and is partly today, a regular method for regulation of the catch using purse seines to fish mackerel and herring. Unintentional deaths caused by this method was proposed as a possible problem in the 1970s after large quantities of dead mackerel was caught in a bottom trawl west of the British islands. On that basis, Havforskningsinstituttet saw a need and opportunity (F4) to study (F2) how pelagic fish species reacts to pursing in seines. The research showed that mackerel was in particular sensitive to pursing, and over a certain density almost all mackerel would die after slipping. Herring is also vulnerable to pursing but not as much as mackerel. Through knowledge diffusion (F3), regulations in terms of fishing with seines were changed, and new technological development (F2) was generated as a result. This influenced the market (F5) as all vessels operating in Norwegian waters had to adjust to meet the new regulations, and controlling authorities had to introduce new surveillance methods. After the regulations were changed in Norway, the results (F3) influenced the European Union to use the Norwegian regulations as a template for implementation of "landing obligations", thus, research conducted by Havforskningsinstituttet has formed the basis for international regulations for fishing with seines.

5.1.6 NIFES

NIFES conduct research on nutrition for fish, and how consumption of fish and seafood can influence our health (Norges forskningsråd, 2018a, p. 67). One of two cases were selected from Norges forskningsråd (2018b, pp. 69-74).

Surveillance of unwanted pollutants in Norwegian seafood

In 2013 several medias questioned to what extent pregnant females, and females in fertile age, should eat fat fish, including farmed salmon. This was based on report from the Norwegian Scientific Committee for Food Safety that expressed caution towards females in fertile age recommending a restricted intake of fat fish of two meals per week. The data basis for the report was the amount of pollutants in fish until 2004 which triggered a need (F4) for revision, and NIFES delivered updated analytical figures (F2). The results were delivered the Norwegian Food Safety Authority who made a revised report removing the restrictions based on the research results (F3). The research concluded, published (F3) by the Norwegian Scientific Committee for Food Safety, that the health benefits from eating fish outweighed the risk as the pollutant in fish had been significantly reduced the past ten to twelve years.

An interesting point in the case is that research from NIFES and the Norwegian Directorate for Health and Social Affairs showed that pregnant women eat under half of the recommended amount of fish. This could be an effect, or impact, of previous recommendations to reduce the intake of fish. If that is the case it shows how powerful knowledge diffusion (F3) can be on users.

5.1.7 Thoughts on Part 1

In this first part of the analysis I have tried to identify TIS functions from 15 impact cases. This process turned out to be quite challenging as mentioned in the start of this chapter. In the end I did find the information extracted from the cases sufficient enough to continue the analysis in part two based on the purpose of this thesis.

In the following part, I will analyze each of the TIS functions based on the findings from part one.

5.2 Part 2: TIS Functions in the Context of Impact

In this section I will analyze all the TIS functions based on data from part one. The purpose is to discuss the relevance of each function in terms of impact generation and shortly discuss challenges in regards of mapping the functions in the context of impact.

5.2.1 Entrepreneurial Activities (F1)

I did not have too much faith in this function when I first started the work on this thesis, and it only appeared in four of the impact cases above, which is not necessarily much to draw a conclusion from. However, I would not rule this function out quite yet. It seems like this is a function that could possibly have an important role in some specific situations where the effect of the research stems from some sort of product. In all the cases where this function was identified the research turned into a product, and the entrepreneurs either used the research results to produce a product for sale or recognized a potential in a product that would be worth selling to the user market. The product in all these cases was what caused the impact, which implies that the producer and the seller (F1) had a role in causing the effects.

The challenge is how to identify entrepreneurial activities from regular research users, or actors that is just a part of the R&D team. I will suggest three situations to look for: First, if an actor is hired by researches to provide knowledge, technology, or similar without using the research on their own behalf, I would consider them as part of F2 or F3. Second, if an actor is the end user of the research, product, or service, I will consider the actor to be a part of the user market. That is because they are not a link in the chain, but rather existing at the end of it. It does not mean that they are not important to impact generation, but they are not contributing to entrepreneurial activity. Third, if an actor inspires research, or use research, knowledge, or technology in order to produce or sell a product on their own behalf, I will consider them an entrepreneur (F1). This is because they are a link in the chain, and has seen the potential in the research, and turned that into a business opportunity. They are not the end user but provide a product or service to the user market.

Though this function were not mentioned in many of the impact cases, I will argue that entrepreneurial activities can be considered an important process in an impact system and can influence the generation of research impact. This function can also be considered a structural function and the entrepreneurs can perform other functions as well. In the cases from part one the mentioned entrepreneurs also performed functions like knowledge development (F2), knowledge diffusion (F3), and resource mobilization (F6). This shows that the function can have relations with, and influence on, other functions as well.

As an end note I will say that due to a lack of details found in the cases in terms of this function it is hard to determine causes that can trigger this function to blossom.

5.2.2 Knowledge Development (F2)

It is no surprise that knowledge development is identified in all cases as it is the basis of all research, thus, a very important process in an impact system. However, there is important things to discuss in terms of this function. Some would possibly argue that this function is unnecessary as most impact studies today focus on impact after academia which could be understood as processes happening after this function. The thing is that knowledge development can be an ongoing process lasting for a long time, and through time this process can influence other functions. In many of the impact cases the original research went through several rounds of development, often influenced by knowledge diffusion through networks (F3) or other functions, before the research provided any results.

For example, imagining that during a R&D project (F2) the knowledge network (F3) communicates expectations to the market (F5), triggering F4, which activates entrepreneurial activity (F1). In this kind of case the entrepreneur (F1) might have discovered a business opportunity based on the current state of the R&D project and may choose to join the system at an early stage to be the first to grab the business opportunity, or influence the R&D (F2) to their advantage. Another example could be activation of F3 to create legitimacy (F7) and lobby for more resources at the R&D stage. Point being, it may be possible to influence other functions during the R&D process. This could be a factor that may help research generate impact later in the process and may be a process to study closer.

A challenge with this function is that the cases often described multiple R&D projects within the same case. Therefore, it can be difficult to identify what research actually contributed to the final impact.

As findings from the impact cases showed that other functions such as F3, F4 and F5 can activate, or potentially be activated by, knowledge development, I will argue that this function is very important in an impact system even though impact studies often focus their attention to activities after academia. In order to fully understand processes in the system after academia, one also need to learn if the functions could possibly have been influenced before and during R&D activities and if this is an activity that should be given more attention.

5.2.3 Knowledge Diffusion through Networks (F3)

Knowledge diffusion through networks is one of the most important functions in the impact system. From the impact cases one can see that it is an important function both before and after R&D. In several cases it served its purpose as a data collection activity that inspired the start of R&D projects. At the same time, the cases proved that it is an important function in terms of diffusion of research results. Examples from some of the impact cases are diffusion to the user market, Norwegian government, and the European Union; an activity of often connected with legitimation of the research (F7). Other cases showed that this function has contributed to formation of larger knowledge networks and creation of collaborative R&D projects.

In sum of all the cases it seems like knowledge diffusion through networks would be important to all impact systems, and that the function can have some sort of relationship with, and influence on, all the other functions. It can also be tied to the SIAMPI-method mentioned in the theory chapter. In this method it is argued that interactions between academic and non-academic stakeholders are necessary in order to generate impact. Though the function in this section also cover interactions between academics I will argue that it finds support in the SIAMPI-method of being a very important function in an impact system, and for impact generation.

5.2.4 Guidance of the Search (F4)

This function was identified in 14 out of 15 cases and is clearly an important function for an impact system. In the literature I sometimes find this function to be a bit unclear in terms of what it actually does. In the context of impact, I refer to this function as activities within the system that communicates specific wants or challenges among possible research users, including exchange of ideas between, producers, users, and other actors that can open up opportunities that trigger activity in the other functions.

As of this the function can be activated both before and after R&D and has the ability to influence, or be influenced by, other functions. In most of the cases the function was activated before R&D as of specific wants or problems in the user market or industry, but a couple of exceptions were found. In the case about infectious salmon anemia the research results enabled opportunities to cause international impact as infectious salmon anemia is a worldwide problem, which shows that guidance of the search can be activated multiple times in the same impact system. Another example is the area estimation of land case where the research results gave birth to a spin-off project based on ideas from the original research to develop methods for other purposes. This may be considered a bit too creative use of the function as the spin of can be regarded as a new system or a different case, but it only shows how difficult impacts analysis can be as it is hard to determine what research started the impact process.

Nevertheless, the cases proved that guidance of the search is a function that can influence impact generation in an impact system.

5.2.5 Market Entrance and Formation (F5)

Market entrance and formation is another important function in an impact system and was identified in most of the cases. Just to clarify, no functions were marked in the summaries unless it was mentioned in the case document. By reviewing the cases were this function was not identified I will still argue based on the cases as a whole that a market did exist, it was just not mentioned by words in the case document. Nevertheless, the analysis indicates that a market is not only important in terms of use and diffusion of the research, it can also be an important catalyst to trigger activity in other functions as well. In many cases guidance of the search was triggered by F5, and in other cases had strong relationships with F2 and F3. Through F2 and F3 the market can learn about the research and choose to accept it or not, which could trigger F4. On the other hand, in other cases it seemed like the market communicated knowledge through F3, influencing activity in F2 and F1.

The function can probably have other important roles in the system as well, but the impact cases did not provide a lot of information in regards of the market, thus, I cannot describe market activities deeper without it being speculations or by taking information out of context.

5.2.6 Resources Mobilization (F6)

Resources mobilization is a necessary function in any impact system. Both human and financial resources will be of importance in all activities in the system. Only six of the cases mentioned this function, all connected to knowledge development (F2), but it does not mean that resources mobilization was not of importance to the other cases as well.

In the TIS framework it is emphasized that this function can be difficult to map, and interviews may best the best solution for identification of this function.

To elaborate further on this function I needed to find some data from the main report from Norges forskningsråd (2018a). In total, 70% of the institutes R&D expenses are financed by public funds. This may be a reason why financial resources were not mentioned in more of the impact cases, apart from R&D projects financed by other actors. The report also mentioned that the authorities have the possibility to influence the financial situation of the institutes. This implies that function F7, creation of legitimacy/counteract resistance to change, may be an important function in terms of lobby for resources (F6) though it was not mentioned in any of the cases. Lastly, according to the report the institutes have a good flow of qualified human resources.

Though the impact cases did not focus too much on this function I will argue that availability of resources is a necessity in all impact systems. This also includes studies of impact after academia as resources may be needed to diffuse research results.

5.2.7 Creation of Legitimacy/Counteract Resistance to Change (F7)

This was a challenging function to analyze as the impact cases were not detailed enough to know the extent of this function activities in the impact process. The function was identified in four cases based on that certain activities played a role in convincing authorities to use research results causing changes in regulations, methods or standards to the incumbent technology or knowledge.

Though the function did not appear in many of the cases it may still have been active in other cases as well. This is because certain activities connected with F7 can sometimes be a bit more hidden and one need to dig a little deeper to find information. Nevertheless, as the function have the potential to positively influence, for example, F4, F5 and F6, I will not rule it out of the impact system.

5.2.8 Thoughts on Part 2

In part two I discussed the relevance of all the functions in the context of impact based on the analysis in part one. Though all the functions proved to have an influence on the impact system it was challenging to find activities or other factors that had a triggering effect on the functions. This is of course a result of the impact cases not being detailed enough, but it would have been interesting to learn more about causal relationships among the functions in the system as well. Nevertheless, I do think that some of the functions need to be slightly customized to better fit the impact context, but that will be discussed further in the following sections.

5.3 The TIS Framework in the Context of Impact

Based on results from the analysis I will in this section propose a reconstruction of the TIS framework. This is a slightly modified version intended for impact analysis, but it can also form a foundation for future conceptual impact system frameworks.

5.3.1 Impact System Components

The reconstruction of the framework is built upon a systems perspective and impact is therefor considered a systemic phenomenon. As a system consists of certain structural components, we need to establish what these are in the context of impact.

The impact cases showed that processes in regards of impact generation involves multiple actors. Examples from the impact cases are, research institutions, firms, governmental agencies, international organizations etc. These actors are responsible for the activities in the system as well of being one of the main structural components. The actors in the system does not necessarily have the same goals, but they do often have relationships with each other in the form of networks. Network activity was mentioned in the analysis as one of the most important processes in terms of impact generation. The networks can fulfill different roles in the system, though knowledge diffusion proved to be one of the most important ones.

The last component is not that obvious looking back at the impact cases, but it is found in the innovation framework and is called institutions, a word borrowed from innovation studies. Some of the impact cases did for example mention changes in regulations, and this is a type of institution that could influence the system. Other examples can be laws or norms, nevertheless, all systems are under the influence of some kinds of institutions.

This leaves us with three main structural components in an impact system; actors, networks and institutions. The structural components perform activities that can influence the system, and the main goal of a system is to create, diffuse and use research. If the system succeed, impact may be generated. All the system components found in the impact cases correspond with the TIS framework.

In the next section I will propose a set of key processes.

5.3.2 Key Processes in Impact Systems

One of the main purposes of this thesis has been to identify important processes that can explain emergence of research impact. Based on similarities between innovation and impact I tested if TIS processes could be of importance to impact as well. Through analysis of the 15 impact cases I found that all the TIS functions were activated in the impact system. This proves that processes important for creation of innovation can also be central in the process of impact generation. As the impact cases did not in detail describe all activities happening in the impact process, the importance of certain relationships between the functions was hard to identify. Therefore, the functions should be explored and studied further in the context of impact to learn more about their role in the system, including customization of the functions content.

The purpose of an impact function analysis is to describe what is actually going on in the impact system, in terms of the key processes, by creating a functional pattern; a description of how each function is filled in the system. This process resembles what I did in part one of the analysis. On that basis one can identify mechanisms that either support or hamper development of the system, or a desired functional pattern. If the system develops nicely impact may be generated, if not, we can identify the blocking mechanisms and try to influence them in such way that the system can continue to develop.

In the context of impact, I will propose a set of six functions from the TIS framework for further investigation. These functions exist in a dynamic impact system together with the main structural components as illustrated in fig.1.

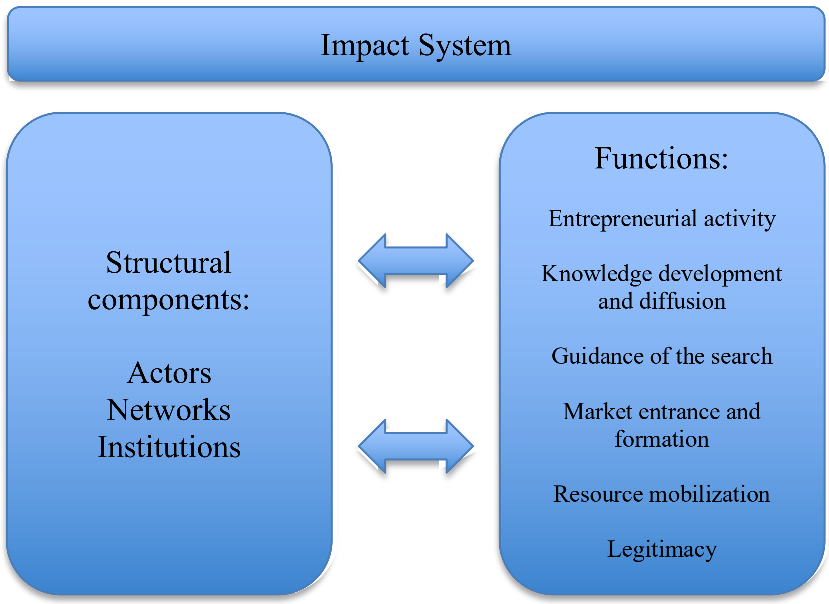

Fig.1. Impact system components and functions.
Source: developed by the author.

Detailed description of the functions can be found in chapter three in this thesis, theoretical framework, but I will suggest further development of the functions content in regards of impact. To be noted, some of the functions names have been slightly altered in the impact version.

As can be seen in fig.1., the functions two and three from the theoretical framework in chapter three are merged down into one function. The content of the function will be a combination of the two other functions, knowledge development and knowledge diffusion. This version of the function is collected from Bergek et al. (2008). The reason for combining the functions is that in the context of impact, knowledge development and knowledge diffusion proved through the impact cases to be very closely related activities that often happened in conjunction with each other. Another reason is that impact analysis is often targeted at processes that happens after R&D, thus, in a strictly R&D state of mind the function loses some of its significance. However, knowledge development is still important in other forms, for example, learning about the market or industry. Therefore, one cannot remove the function from the system. In terms of deciding if R&D activity should be a part of the analysis is up to the researcher.

To be noted, entrepreneurial activity is a function that may be discussable. In the impact cases where this function was identified, the system could be viewed as an innovation system. In those cases, one could argue that the impact was created by an innovation system, not an impact system. But I think it is reasonable to consider that it could be dependent on the purpose of the analysis. If the focus is on the innovation it is an innovation system, but if the target is the effect the innovation has on society it can be regarded as an impact system. Nevertheless, the systems will be the same, but the execution, breadth and depth, of the analysis may be different. I do think it is a function that need to be examined further through tests in order to decide its final destiny.

The final six impact system functions with inclution of a short content description can be found in table 1.

Table 1.

Functions	Content
Entrepreneurial activity	Extent of actors that experiment with knowledge, processes, products, etc.
Knowledge development and diffusion	Most important function. Refers to learning processes and diffusion of knowledge.
Guidance of the search	Incentives for actors to enter or exit the system.
Market entrance and formation	The place where demand for the system output exist (impact). Need to be entered or created.
Resource mobilization	Refers to investment in social, human or financial capital.
Legitimacy	Acceptance of the research by incumbent actors, and compliance with relevant institutions.

Source: Bergek et al. (2008)

5.3.3 Impact System Functions: Summary

In the last couple of sections I have taken experiences gained from using the TIS framework to analyze impact cases and promoted a reconstruction of the framework to fit the context of impact systems. As the impact version is more or less similar to the innovation version one might ask, why not use the original framework? The answer is that the framework is not perfect. In order to fully apply functional thinking into the context of impact the framework need to be further developed. What I have tried to do is provide a foundation that can be developed further on the basis of functions that through analysis in this thesis has proved to have an active role in impact generating processes.

More on my experiences using the TIS framework in the context of impact and discussion about the future of impact studies follows in the next chapter.

6 Discussion and Concluding Remarks

Throughout this thesis I have explored det idea of viewing research impact as a systemic phenomenon. In this section I will reflect on the experiences gained from working on this thesis. I will start by discussing my thoughts on using the TIS framework in the context of impact, and then share some thoughts about the future of impact studies. In the end I will conclude this thesis and reflect on the weaknesses of this study.

6.1 TIS framework: Suitable for Impact?

The framework used in this thesis to identify components and processes important to impact generation is the TIS framework known from innovation studies. As the basis for using the framework was only similarities found between impact an innovation in the literature, it was not perfectly clear if the framework would be transferable between the fields.

Through testing of the framework on the impact cases it proved to be suitable for impact analysis, and innovation system functions were identified in the context of impact. The similarities between the two fields proved to be strong enough enabling transferability of approaches. All seven TIS functions were identified and understood as important for the impact system. The challenge, or weakness, of the analysis is lack of information on relationships between the functions, but that is a consequence of little details provided in the impact cases and not a problem in terms of the framework. Despite the challenges, the framework did enable identification of certain influencing factors between the functions.

Based on results in this thesis I would conclude that the TIS framework can explain impact generating mechanism, but it does require a good and thorough data material to release its full potential. The scheme of analysis on the other hand seems to work great in the context of impact. The framework is not perfect, but I will recommend testing it further on impact to possibly create an impact version, as mentioned in the last chapter. This is because through more in-depth studies one might find that certain functions need to be altered or new functions need to be included. This is especially important for activities happening after R&D as the impact cases were not very specific on that matter. The reason is probably that the cases were written by the research institutes, and their area of interests lies in the research they conducted. To fully utilize the possibilities of the TIS framework more data sources from the system will be needed to map the complete system activity. The data collection process will therefore be quite resource intensive and the framework is probably best suited for larger studies where available time and resources are sufficient.

Is the TIS-framework better than other current impact approaches? That depends on what answers one wish to find. It is worth mentioning that the framework is not a tool to identify impacts. It is a tool to learn about what is going on inside the impact system and detect processes that can support or hamper impact development. This can help extract practical guidelines from impact studies to influence policy decisions and to reach impact goals.

The framework also consider impact as a system which is unique in the field of impact but can at the same time coexist and compliment the current impact approaches. The results from the analysis also corresponds with content from other impact approaches such as ASIRPA and SIAMPI as well, which may help legitimize further development.

6.2 The Future of Impact Studies

The field of impact studies are under constant development. New approaches develop, new definitions are suggested, and new articles are constantly published. All having a meaning about impact. The question is, what lurks in the future of impact studies? The answer to that question will probably be very different depending on who you ask. If the direction suggested in this thesis is followed the future is systems, but what consequences can we expect from implementation of a systems perspective and why is it relevant to the impact discussion?

With the introduction of a systemic view, impact will move away from simply being an effect of research towards being the whole process in which effects are generated. Consequently, this may cause a discussion regarding if the term "impact of research" is the best way to describe such processes, as the research loses some of its significance. It does not mean that research is no longer important to impact generation, but rather that it need to be considered as one of many determinants. Thus, it can be deceptive to imply that impact is an effect of research on its own.

I do not think that "impact of research", or "research impact", necessarily are wrong terms to describe effects of research. It is rather the definition of the word "impact" that needs a revision. Evidence from this thesis suggest that impact generation is a process with involvement of many actors that performs all kinds of different activities, and the combined effort of all the determinants are what causes impact in the end. Through a systems perspective we can understand impact as a process, instead of just an effect. The definition of the word impact can then be changed to contain all important processes and determinants important for generation of societal effects of research. The word "effect" probably needs to be redefined as well. Nevertheless, the word impact will get a new meaning, thus, affecting the way we understand the concept, how we should study it, and how to set impact goals. This without questioning the expression "research impact".

A systems perspective can therefore be an important step forward in the process of forming a new and accepted definition of the term and provide new analytical tools to study impact generation.

The question is, do we really need another impact framework, or another definition, as impact is already quite complex and confusing? The purpose of this thesis is not to ad complexity, it is actually to reduce it. A systems perspective is without doubt a complex concept. However, the problem with impact is that there is no consensus in terms of what impact actually means, or how it should be studied. Therefore, it exists multiple definitions and different frameworks, all explaining impact in a slightly different way. Often these are developed on the basis of the research field they represent which is not wrong as it suits the purpose. The problem is that it is not a collective development of impact as a field based on the same grounds. What I am suggesting with the introduction of impact systems is that impact can be developed in collaboration if we can agree upon the system as a valid platform for further development. Research impact will still be an extremely complex phenomenon, scholars will still disagree with each other and have discussions, but at least they are working on the same problem which is understanding the impact system. New approaches and frameworks can then be developed for different analyzing purposes based on the same foundation, and the studies can complement each other.

A systems perspective will not be accepted in the field of impact studies unless it proves to be a valid approach. I think that based on results from this thesis a systems perspective can be useful to learn more about factors that influence impact generation and enables development of new methods. What need to be communicated is that impact is more than just an effect, and that it is a lot of value in learning how to influence it. Impact has previously been valued in terms of the relationship between an investment in research and an expected outcome, knowledge about systems can help secure or better that outcome. Therefore, we must give more attention to activities and processes happening inside the system in order to explain how effects are generated. This must be placed on the agenda of decision and policy makers to secure resources for this type of research. With reference to the impact system functions, we need activity in the “legitimacy” function in order to influence the “resource mobilization” function. Nevertheless, the future of impact will be a combination of knowledge development and knowledge diffusion to create awareness and legitimacy to new possibilities.

In terms of impact development, it might be necessary to draw inspiration from other fields to build knowledge and conceptual ideas. In the next section I will shortly discuss the benefits of extracting information from innovation studies.

6.2.1 Drawing Influences from Innovation Studies?

Impact is relatively new research field compared to other fields and development is therefore still in an early phase. As there is no accepted definition of impact it opens up the possibility to be creative and explore its complexity by drawing influences from other research areas.

Throughout this project I have drawn inspiration from innovation studies to form the idea of impact systems, and test if innovation approaches can be relevant for use on impact. The use of concepts from innovation studies can be found in other impact approaches as well, and support findings from this thesis. The reason innovation is relevant is because of the similarities between the two fields discussed earlier in this thesis. What impact can benefit from this connection is the extensive amount of research and knowledge available from innovation research. This can be everything from literature on concepts, frameworks, research results, theories, etc. Not all of this will be relevant for impact but because of the similarities, the knowledge available from decade’s worth of innovation research can be used as inspiration or as a foundation to impact development.

Results from this thesis has showed that there is a strong connection between innovation and impact, and that system components and processes for generation of innovation is relevant for impact as well. On that basis I will recommend continuing investigation of the connection between impact and innovation to further explore possible useful knowledge that can benefit the development of impact studies in the future.

6.3 Concluding Remarks

6.3.1 Research Questions

Through this thesis I have explored the systemic nature of research impact. The purpose has been to learn about how impact occurs and to explore the idea of impact as a systemic phenomenon. I started this project by forming the overall research question: *What characterizes an impact system and under what circumstances does impact occur?* To address this question, I asked two more specific questions and now I will reflect on the answers this project has provided.

What Are the Main Components in an Impact System?

This question is related to the first part of the overall research question. Based on findings from this thesis the main components in an impact system are actors, networks and institutions. These three components form the structure, or the foundation, of the impact system. As no systems are the same, the structural components can be different depending on the system.

The impact system is characterized by large networks of actors, influenced by institutions, that perform activities inside the system that can support or hamper impact generation. The actors may not have the same goal, but they contribute to the main goal of the system, which is creation, diffusion and use of research. Through this activity impact may occur if the system develops successfully.

The results also show that effects of research do not occur in isolation, but together with a range of other determinants.

What Kind of Network Structures and Processes Could Explain the Emergence of Research Impact?

This question is related to the second part of the overall research question. In order to answer this question seven key processes, or "functions", where tested on impact cases to learn if these could explain the emergence of research impact. All the seven processes were found to be of importance in terms impact generation. These processes can either support or hamper impact generation, thus, also contribute to explain emergence of research impact. The seven key processes were in the end merged down to six impact processes and are: entrepreneurial activity, knowledge development and diffusion, guidance of the search, market entrance and formation, resource mobilization, and legitimacy.

The key processes can be recognized as activities performed by the structural networks which proved to be the same as the main components. As mentioned above, no impact systems are the same, and the type of processes existing in the system may therefore vary. In terms of impact generation, the important factor is that the dynamics between the present functions are working properly and are not hampering the development.

Through the analysis I also tried to identify possible other processes not covered by the theoretical framework, but the results were negative. However, other processes that can explain emergence of impact may still exists and be discovered in other studies.

Summary

Impact systems are characterized by actors, networks and institutions that exist in a dynamic relationship where they perform different activities. The impact system can be influenced by six key processes, or functions, that can change the performance of the system. If the system succeeds to develop, and the functions are working correctly, impact can be generated as a result.

6.3.2 Weaknesses of this Study

No studies are without weaknesses and this one is no exception. The major weakness in this study is the data material. The collected data material are impact cases with origin in another research project. The weakness is the lack of detail in the cases, especially prominent in activities happening after R&D. Worth mentioning is that they did vary substantially in terms of content so only the most detailed ones were chosen as data material. The consequences are that it was difficult to find detailed information about the causal relationships between the functions which would have been interesting to investigate as it could provide more information about the significance of each function in the impact system, and activities they performed in that process. It would also provide more valid results.

As impact is a rather new field of study it was challenging to find suitable data material from other studies, especially since generation processes has not been the area of attention. Therefore, one has to settle with what is available unless you collect your own data material which of course is the best solution. The problem is that collecting data to a study like this will be very resource intensive and be far over the scope of a thesis of this kind.

For future research I will recommend collecting own data material if the resources are available, and further focus a lot more on detailed information after R&D and study the relationship between the functions in more depth.

Lastly, all the cases in this study had positive impact results. Therefore, it was not possible to learn about processes that hamper impact generation and how to possibly reverse the failure. In the future, if possible, I will suggest to also study cases where research did not result in expected effects.

References

Adam, P., Ovseiko, P. V., Grant, J., Graham, K. E. A., Boukhris, O. F., Dowd, A.-M., . . . Chorzempa, H. (2018). ISRIA statement: ten-point guidelines for an effective process of research impact assessment. *Health Research Policy and Systems, 16*(1), 8. doi:https://doi.org/10.1186/s12961-018-0281-5

Asheim, B. T., & Gertler, M. S. (2005). The Geography of Innovation: Regional Innovation Systems. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation*: Oxford University Press.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy, 37*(3), 407-429. doi:https://doi.org/10.1016/j.respol.2007.12.003

Bloor, M., & Wood, F. (2006). *Keywords in qualitative methods: A vocabulary of research concepts*: Sage.

Bornmann, L. (2013). What is societal impact of research and how can it be assessed? a literature survey. *Journal of the American Society for Information Science and Technology, 64*(2), 217-233. doi:https://doi.org/10.1002/asi.22803

Bornmann, L. (2017). Measuring impact in research evaluations: a thorough discussion of methods for, effects of and problems with impact measurements. *Higher Education, 73*(5), 775-787. doi:https://doi.org/10.1007/s10734-016-9995-x

Bornmann, L., & Marx, W. (2014). How should the societal impact of research be generated and measured? A proposal for a simple and practicable approach to allow interdisciplinary comparisons. *Scientometrics, 98*(1), 211-219. doi:https://doi.org/10.1007/s11192-013-1020-x

Bozeman, B. (2003). Public value mapping of science outcomes: theory and method. *Knowledge flows and knowledge collectives: Understanding the role of science and technology policies in development, 2*, 3-48.

Bozeman, B., & Sarewitz, D. (2011). Public Value Mapping and Science Policy Evaluation. *Minerva, 49*(1), 1-23. doi:https://doi.org/10.1007/s11024-011-9161-7

Carlsson, B., & Stankiewicz, R. (1991). On the nature, function and composition of technological systems. *Journal of Evolutionary Economics, 1*(2), 93-118. doi:10.1007/bf01224915

Coenen, L., & López, F. J. D. (2010). Comparing systems approaches to innovation and technological change for sustainable and competitive economies: an explorative study into conceptual commonalities, differences and complementarities. *Journal of Cleaner Production, 18*(12), 1149-1160. doi:https://doi.org/10.1016/j.jclepro.2010.04.003

Donovan, C. (2007). The qualitative future of research evaluation. *Science and Public Policy, 34*(8), 585-597. doi:10.3152/030234207X256538

Donovan, C. (2011). State of the art in assessing research impact: introduction to a special issue. *Research Evaluation, 20*(3), 175-179. doi:10.3152/095820211X13118583635918

Donovan, C., & Hanney, S. (2011). The 'Payback Framework' explained. *Research Evaluation, 20*(3), 181-183. doi:10.3152/095820211X13118583635756

Douthwaite, B., Kuby, T., van de Fliert, E., & Schulz, S. (2003). Impact pathway evaluation: an approach for achieving and attributing impact in complex systems. *Agricultural Systems, 78*(2), 243-265. doi:https://doi.org/10.1016/S0308-521X(03)00128-8

Edquist, C. (1997). *Systems of Innovation Approaches - Their Emergence and Characteristics*.

Edquist, C. (2005). Systems of Innovation: Perspectives and Challenges. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation*: Oxford University Press.

Edquist, C., & Hommen, L. (1999). Systems of innovation: theory and policy for the demand side 1. This article is based on work from the project "Innovation Systems and European Integration (ISE)", funded by Targeted Socio-Economic Research, DG XII, European Commission, Contract No. SOE1-CT95-1004 (DG 12-SOLS). In particular, the article draws upon work originally produced as part of ISE subproject 3.2.2, "Public Technology Procurement as an Innovation Policy Instrument".1. *Technology in Society, 21*(1), 63-79. doi:https://doi.org/10.1016/S0160-791X(98)00037-2

European Commission. (2018). *COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS - Horizon 2020 interim evaluation: maximising the impact of EU research and innovation* Retrieved from https://ec.europa.eu/transparency/regdoc/rep/1/2018/EN/COM-2018-2-F1-EN-MAIN-PART-1.PDF

Fagerberg, J. (2005). Innovation: A Guide to the Literature. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation*: Oxford University Press.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy, 31*(8), 1257-1274. doi:https://doi.org/10.1016/S0048-7333(02)00062-8

Given, L. M. (2008). *The Sage encyclopedia of qualitative research methods*: Sage publications.

Godin, B. (2006). The Linear Model of Innovation: The Historical Construction of an Analytical Framework. *Science, Technology, & Human Values, 31*(6), 639-667. doi:10.1177/0162243906291865

Green, J., & Thorogood, N. (2004). *Qualitative methods for health research*: SAGE Publications.

Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. H. M. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change, 74*(4), 413-432. doi:https://doi.org/10.1016/j.techfore.2006.03.002

Jacobsson, S., & Bergek, A. (2011). Innovation system analyses and sustainability transitions: Contributions and suggestions for research. *Environmental Innovation and Societal Transitions, 1*(1), 41-57. doi:https://doi.org/10.1016/j.eist.2011.04.006

Joly, P.-B., Gaunand, A., Colinet, L., Larédo, P., Lemarié, S., & Matt, M. (2015). ASIRPA: A comprehensive theory-based approach to assessing the societal impacts of a research organization. *Research Evaluation, 24*(4), 440-453. doi:https://doi.org/10.1093/reseval/rvv015

Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis & Strategic Management, 10*(2), 175-198. doi:10.1080/09537329808524310

Kline, S. J., & Rosenberg, N. (1986). An Overview of Innovation. In R. Landau & N. Rosenberg (Eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (pp. 640). Washington, DC: The National Academies Press.

Lundvall, B. Å. (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*: Pinter Publishers.

Lundvall, B. Å., Johnson, B., Andersen, E. S., & Dalum, B. (2002). National systems of production, innovation and competence building. *Research Policy, 31*(2), 213-231. doi:https://doi.org/10.1016/S0048-7333(01)00137-8

Malerba, F. (2005). Sectoral Systems: How and Why Innovation Differs across Sectors. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation*: Oxford University Press.

Malerba, F., & Nelson, R. (2011). Learning and catching up in different sectoral systems: evidence from six industries. *Industrial and Corporate Change, 20*(6), 1645-1675. doi:10.1093/icc/dtr062

Markard, J., Hekkert, M., & Jacobsson, S. (2015). The technological innovation systems framework: Response to six criticisms. *Environmental Innovation and Societal Transitions, 16*, 76-86. doi:https://doi.org/10.1016/j.eist.2015.07.006

Martin, B. R. (2011). The Research Excellence Framework and the 'impact agenda': are we creating a Frankenstein monster? *Research Evaluation, 20*(3), 247-254. doi:https://doi.org/10.3152/095820211X13118583635693

Molas-Gallart, J., & Tang, P. (2011). Tracing 'productive interactions' to identify social impacts: an example from the social sciences. *Research Evaluation, 20*(3), 219-226. doi:https://doi.org/10.3152/095820211X12941371876706

Nelson, R. R. (1993). *National innovation systems: a comparative analysis*: Oxford University Press on Demand.

Norges forskningsråd. (2018a). *Evaluering av primærnæringsinstituttene - Hovedrapport*. Retrieved from https://www.forskningsradet.no/siteassets/publikasjoner/1254035862139.pdf

Norges forskningsråd. (2018b). Evaluering av primærnæringsinstituttene - Samfunnseffekter av instituttenes forskning.

REF 02. (2011). *Assessment framework and guidance on submissions*. Retrieved from http://www.ref.ac.uk/2014/media/ref/content/pub/assessmentframeworkandguidanceonsubmissions/GOS%20including%20addendum.pdf

Rosenberg, N. (1986). The Impact of Technological Innovation: A Historical View. In R. Landau & N. Rosenberg (Eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (pp. 640). Washington, DC: The National Academies Press.

Smith, K. (2000). Innovation as a Systemic Phenomenon: Rethinking the Role of Policy. *Enterprise and innovation management studies, 1*(1), 73-102. doi:10.1080/146324400363536

Spaapen, J., & van Drooge, L. (2011). Introducing 'productive interactions' in social impact assessment. *Research Evaluation, 20*(3), 211-218. doi:https://doi.org/10.3152/095820211X12941371876742

Williams, K., & Grant, J. (2018). A comparative review of how the policy and procedures to assess research impact evolved in Australia and the UK. *Research Evaluation, 27*(2), 93-105. doi:https://doi.org/10.1093/reseval/rvx042

Yin, R. K. (2010). *Qualitative Research from Start to Finish*: Guilford Publications.

Yin, R. K. (2014). *Case Study Research: Design and Methods*: SAGE Publications.