The Missing Link

The implementation of priorities for research, development, and innovation

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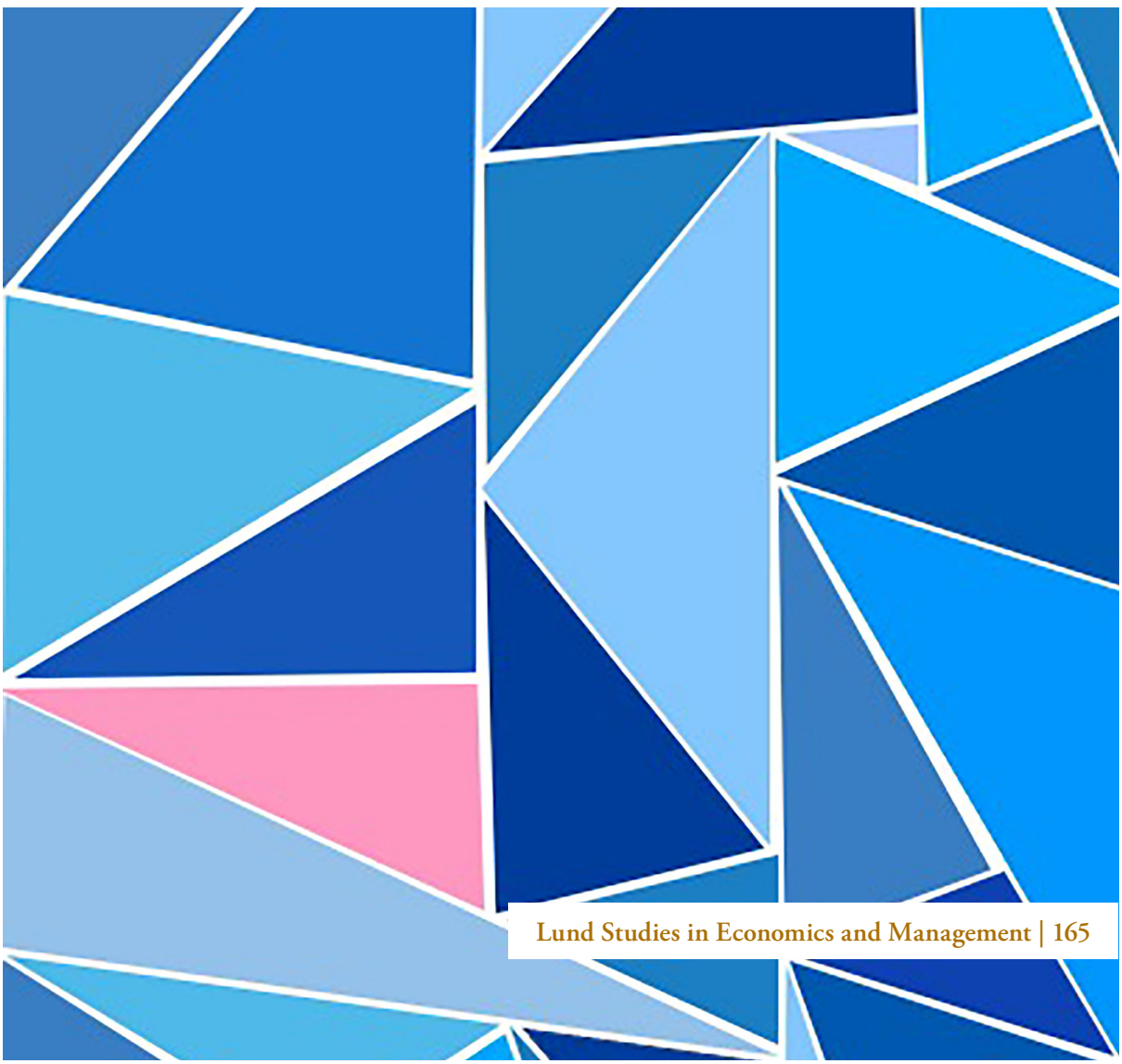
ERIK BRATTSTRÖM | DEPARTMENT OF BUSINESS ADMINISTRATION



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The Missing Link

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The implementation of priorities for research, development, and innovation

Erik Brattström

LUND
UNIVERSITY

DOCTORAL DISSERTATION

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Abstract:
The thesis explores the 'missing link' in the study of priority-setting for research, development, and innovation (RDI), namely the processes of implementing RDI priorities, and the consequences of these processes. It does so by focusing on how choices, actions, and motivations of implementers of RDI priorities established elsewhere in the policy system enact, or carry out, the priorities, resulting in new conditions for RDI production. Such conditions can be understood as concretizations of the broader, prioritized themes for RDI and ways of organizing RDI within the themes.

The methods, processes, and conditions involved in implementing priorities for RDI on the 'lower' levels of decision-making in science policy, such as the agency level, have hitherto received limited attention in science policy research in general, and research on priority-setting in particular. Yet, the tension between what policy-makers (at the top) assume RDI can yield (and how) and what implementers (at the bottom) are interested in and capable of delivering, is likely to emerge where broad RDI priorities are enacted by intermediaries such as funding agencies, industry, and research performers. However, we know little about how implementers of RDI priorities go about making priorities implementable and what that means for the emergence of new conditions for RDI production.

The results of the thesis suggest that priority-setting as enacted can be understood as a sequence of socially and cognitively motivated discretionary choices that stimulate creativity and socialization during the implementation of RDI priorities. The thesis refers to this as a 'socio-cognitive approach to the implementation of RDI priorities'. In their aggregated form, the discretionary choices, and the interactions they yield, shape new conditions for RDI production on content as well as form on the different levels of the policy system. This suggests that choices, interactions, and new condtions amount to a continuation of steering of RDI production after policy-decisions for RDI are made. It also raises some concerns about how discretion may undercut the legitimacy of RDI investments and negatively affect the 'optimal' trajectories of scientific fields (e.g. more significant discoveries and/or improved, complementary knowledge about observed phenomena, etc.). This begs the question if there is a need to govern discretion.

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Erik Brattström

LUND
UNIVERSITY

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School of Economics and Management
Lund University

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To Moni

Table of Contents

Acknowledgements 10
List of Papers 11

1. Introduction 12
1.1. An implementation perspective on priority-setting 13
1.2. Research aim and research questions 14
1.3. Outline of the thesis 16

2. Literature review 17
2.1. Priority-setting for research, development, and innovation 17
2.1.1. From laissez-faire processes of resource allocation to setting goals and selecting research programs: the proliferation of priority-setting 17
2.1.2. Rationales for priority-setting 18
2.1.3. Choosing priorities: some classic issues 20
2.1.4. Models of innovation and their relation to priority-setting 22
2.1.5. Contemporary priority-setting for RDI: functions, types, and methodologies 25
2.1.6. Priority-setting: trends and international comparisons 27
2.1.7. Systemic perspectives on priority-setting 29
2.2. Policy implementation 34
2.2.1. The top-down approach to studying policy implementation 35
2.2.2. The bottom-up approach to studying policy implementation 37
2.2.3. The synthesis approach to studying policy implementation 39
2.3. RDI priority-setting and implementation 43
2.3.1. The bottom-up/synthesis approach and implementation of functional/institutional RDI priorities 44

3. Research design 48
3.1. Case selection and material 48
3.1.1. Case study 1: From funding program to research results – Building capacity and governing interdisciplinarity in a Center of Excellence environment (articles 1 and 2) 49

3.1.2. Case study 2: From strategic sector priorities to funding programs and projects – The role of program officer discretion in the Swedish Energy Agency (article 3) 50
3.1.3. Case study 3: From government priorities to a strategic sector agenda for R&I – Conditions that facilitated choice and activities in building an R&I agenda for the Swedish food sector (article 4) 51
3.1.4. Material 52
3.2. Data collection 53
3.3. Data analysis 55
3.4. Reflections on the research design 57
4. Summary of papers 58
4.1. Paper 1: Center of excellence funding: Connecting organizational capacities and epistemic effects 58
4.2. Paper 2: Governing interdisciplinary cooperation in Centers of Excellence 59
4.3. Paper 3: Street-level priority-setting: The role of discretion in implementation of research, development, and innovation priorities 60
4.4. Paper 4: Facilitating collaborative priority-setting for research and innovation: a case from the food sector 61
5. Discussion 63
5.1. The relationship between discretionary choice, interactions, and new conditions for RDI production 65
5.1.1. Using funding conditions to build capacity for research 65
5.1.2. Exercising discretion to implement agency priorities into funding programs for energy relevant RDI 71
5.1.3. Making political objectives implementable by strategic R&I agenda-building 77
5.2. Specifying the contribution 81
5.2.1. A socio-cognitive approach to the implementation of RDI priorities 86
6. Conclusion 89
6.1. Reflections on the place of discretion in RDI priority-setting 89
6.1.1. A need to govern discretion? 90
6.1.2. Concluding remarks 94
7. References 96

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List of Papers

Paper I

Hellström, T., Jabrane, L., and Brattström, E. (2018). Center of excellence funding: Connecting organizational capacities and epistemic effects. *Research Evaluation*, *27*(2), 73-81.

Paper II

Hellström, T., Brattström, E., and Jabrane, L. (2018). Governing interdisciplinary cooperation in Centers of Excellence. *Studies in Higher Education*, *43*(10), 1763-1777.

Paper III

Brattström, E. and Hellström, T. (2019). Street-level priority-setting: The role of discretion in implementation of research, development, and innovation priorities. *Energy policy*, *127*, 240-247.

Paper IV

Brattström, E. (2021). Facilitating collaborative priority-setting for research and innovation: a case from the food sector. *Technology Analysis & Strategic Management*, *33*(7), 742-754.

1. Introduction

The subject of this thesis is Science Policy, or "the collective measures taken by a government in order, on the one hand, encourage the development of scientific and technical research and, on the other, to exploit the results of this research for general political objectives" (Salomon 1994, p. 39).

Since the end of the Second World War, science policy has transformed from embracing laissez-faire processes of resource allocation to setting goals and selecting research programs (e.g. Ziman 1994). The transformation has occurred in the context of an exponential growth of science and technology (de Solla Price 1965: Bornman and Mutz 2015), an expanding and resource demanding welfare state, and an increased competition for public funds between areas such as education, health, defense, the legal system, etc. Science policy competes with such policy areas for funds. However, and more importantly, science policy also runs across or is an integral part of other policy areas where research, development, and innovation (RDI) are considered instrumental in creating public value such as advances in pedagogy, improved drug treatments, or reduced crime rates. Priority-setting for R&D[1], and gradually also for innovation[2], has in this context emerged as a key instrument for planning, resource allocation, and orchestration/coordination of key actors in the innovation systems of most OECD countries (OECD 1991; Ziman 1984; Elzinga 2010; Rip and Nederhof 1986; Godinho and Caraça 2009). By setting priorities for RDI, governments try to make the most efficient use of scarce resources while at the same time attempting to improve the prospects of delivering on policy objectives such as improving quality of life, environmental sustainability, generating growth and wealth, addressing urgent societal challenges, etc.

The methods and processes by which national priorities for RDI are set, such as foresight and Delphi processes, are by now well-documented (e.g. Irvine and Martin 1984; Rip and van der Meulen 1997). However, science policy research in general, and research on priority-setting in particular have focused less on the methods,

[1] Research and development (R&D) can be understood to entail "creative and systematic work undertaken in order to increase the stock of knowledge […] and to devise new applications of available knowledge" (OECD 2015a, p. 28).

[2] According to the Oslo Manual (2005) an innovation can be defined as "implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (p. 46).

processes, and conditions involved in implementing priorities on the 'lower' levels of decision-making in science policy, such as the agency level (Hellström et al. 2017). Yet, at these lower levels, implementers are likely to confront challenges related to resolving tensions such as that between top-down policy preferences and bottom-up implementation capabilities. How implementers deal with such challenges is likely to affect the conditions and outcomes of RDI. This calls for an implementation perspective on priority-setting, which can facilitate a greater understanding of some of the factors that establish, or determine, the consequences of RDI priorities.

1.1. An implementation perspective on priority-setting

In 1975, the political scientist Erwin Hargrove coined the term 'the missing link' to refer to implementation studies (or the lack thereof) in public policy research (Hargrove 1975). The missing link, or the study of the relationship between policy-making and its consequences has since the 1970s turned into what is now known as implementation research (e.g. Pressman and Wildavsky 1973; Sabatier and Mazmanian 1979; Lipsky 1980; Hjern and Porter 1981; Sabatier 1986; O'Toole 2000). However, it is only with a few exceptions that this strand of scholarship has been used in research on RDI priority-setting (one of the more recent exceptions being Hellström et al. 2017).

Broadly speaking, implementation research is concerned with "the development of systematic knowledge regarding what emerges, or is induced, as actors deal with a policy problem." (O'Toole 2000, p. 266). Researchers in this tradition typically explores the relationship between policy formation (i.e. formulation and design) and implementation, and how it can and should be studied. Implementation research tends to converge on the idea that while certain policy frames can be imposed from the top (e.g. themes/problems, rules, and potential solutions), one can also expect that implementers adjust policy to their immediate environmental conditions (e.g. Sabatier 1986; O'Toole 2000). Implementers make adjustments for various reasons; implementers typically possess deep knowledge about the local context of implementation, what typically works and what does not work in terms of policy solutions and interventions. This puts policy implementers in a good position to assess the feasibility of the policy but also to go one step farther and adjust the policy to the realities on the level of policy execution, or 'the floor'. Policy adjustment may also be a function of the implementers' interests, their ability to circumvent organizational obstacles ('navigate the system'), or their inclination to satisfy the employer's demands or clients' needs (e.g. Lipsky 1980). In a decentralized implementation system, one where the government relies on several intermediaries to realize/execute policy, central control over resources and how they are allocated

is typically low and as implementer discretion to make executive decisions is expected to be high (Tosun and Treib 2018).

Against this backdrop, an implementation perspective on RDI priority-setting appears extremely relevant. The tension between what policy-makers (at the top) assume RDI can yield (and how) and what implementers (at the bottom) are interested in and capable of delivering, is likely to emerge in the critical phases where broad RDI priorities are enacted by intermediaries such as funding agencies, industry, and research performers. The intermediaries are typically experts within their fields, both in terms of themes (e.g. health, energy, environment etc.) and operations (i.e. how things are carried out in the experts' organizations). Their choices and actions cannot typically be specified from the onset of the formal priority-setting process. Rather, choices and actions are likely to emerge during implementation and may significantly shape the conditions for RDI production. Such conditions, or 'de facto priorities', can be understood as concretizations of the broader, prioritized themes for RDI (e.g. improving transport efficiency) and ways of organizing RDI within the themes (e.g. various collaborative schemes).

Yet, we know little about how implementers of RDI priorities go about making the priorities implementable and what that means for the production of new RDI. Choices and actions may here be a function of the implementer's capabilities, interests and values, and the conditions under which he or she operates.

1.2. Research aim and research questions

The aim of the thesis is to improve our knowledge of how RDI priorities are converted into new conditions for RDI production. To achieve the aim, the thesis focuses on the implementation of priorities for RDI and specifically on how choices, actions, and motivations of implementers of RDI priorities established elsewhere in the policy system enact, or carry out the priorities, resulting in new conditions for RDI production. Implementers of RDI priorities are those who directly hold a public mandate to implement priorities, or indirectly via their organizational belonging (e.g. funding agency staff).

The main research question is:

- How do choices made by implementers of RDI priorities affect the way the RDI priorities are 'de facto' established and executed at various levels of the RDI system?

and more specifically,

- what are the choices, actions, and motivations that guide implementers during implementation and how do they relate to creating de facto priorities for RDI, that is new conditions for RDI production?

The empirical base for the thesis covers this process on three levels of implementation: 1) the level where national priorities for RDI are implemented into sector priorities/strategic RDI agendas (article 4); 2) the level where sector priorities for RDI are implemented into funding agency programs and projects (article 3), and; 3) the level where funding agency programs and projects are implemented into research processes and results (articles 1-2). The articles, on which the thesis builds, together cover a spectrum of RDI areas, viz. RDI in the food industry, in energy, and steering of basic science in terms of excellence funding.

The results of the thesis show that implementation activities that involve interactions between different types of expertise are critical in shaping new conditions for RDI production. A common feature of these critical interactions is that they typically have a social aspect, e.g. they involve persuasion/advocacy, relationship-building, and creating consensus. Critical interactions also tend to have a cognitive aspect. They stimulate creative activities among implementers such as assessments and problem-solving, knowledge-transfers, and mutual learning.

Furthermore, the thesis shows that several social and cognitive activities and decisions underlie discretionary choices of how to organize the interactions. A choice is discretionary in the sense that rather than being based on instructions 'from above'/the top, the implementers who make the choice typically base it on what they perceive to benefit effective implementation. The social aspect of discretionary choice appears when interactions are organized to stimulate socialization among implementers of different expertise. Another aspect of discretionary choice appeals to the cognitive, that is when the choice of how to structure interaction is motivated by what the implementer perceives to stimulate knowledge creation and creativity, such as mutual problem-solving between different experts. The discussion provided in chapter 5 will elaborate on the empirical relationship between discretionary choice, interactions, and new conditions for RDI production for each case of the thesis.

In summary, the results of the thesis suggest that 'priority-setting as enacted' can be understood as a sequence of socially and cognitively motivated discretionary choices that stimulate creativity and socialization during the implementation of RDI priorities. In their aggregated form, these choices, and the interactions they yield, amount to 'priority programming' and create conditions for RDI production on the different levels of the policy system. The thesis suggests that by focusing on choices and actions made by users, administrators, and research performers in the process of implementing priorities, a new empirical and theoretical focus comes into view – the 'priority-setting-implementation nexus', the study of which can lead to insights about some of the central social and cognitive factors that mediate between

political enunciation of RDI priorities and the point of delivery of RDI results. Such knowledge may provide a basis for learning for science policy-makers and managers of RDI priority implementation alike.

1.3. Outline of the thesis

The thesis is structured in the following way. In the next chapter, a literature review will be presented (chapter 2). The chapter also makes up the conceptual framework for the thesis. It is followed by the research design of the thesis (chapter 3), a summary of the articles (chapter 4), and the discussion (chapter 5). The final chapter includes a conclusion and raise some implications for policy (chapter 6).

2. Literature review

2.1. Priority-setting for research, development, and innovation

The first part of the literature review (section 2.1.) focuses on priority-setting for research, development, and innovation (RDI). The section provides a brief account of how priority-setting has emerged as an instrument of science policy planning. Science policy has a long tradition of attempting to steer RDI towards goals of social and economic relevance, and increasingly also towards organizational ways by which such goals are assumed to be best achieved. The thesis raises some of the classic issues pertaining to priority-setting found in the science policy literature as well as provides accounts about priority-setting in a contemporary science policy context. The latter includes outlining the types and functions of priority-setting and describing some trends in priority-setting across time and countries. Finally, the section raises some ideas of how priority-setting can be understood from a systemic or process-oriented approach, that is, how priority-setting may depend on several interacting factors such as actors, organizational structures, hierarchies, incentive structures, and external circumstances/pressures.

2.1.1. From laissez-faire processes of resource allocation to setting goals and selecting research programs: the proliferation of priority-setting

Since the beginning of the scientific revolution in the mid-16th Century, science has gone from being an activity of the few to a key institution of the modern state. De Solla Price (1965) demonstrated that between the mid-17th Century and the 1960s, science and technology grew at an exponential rate. He found that the size of manpower (researchers and engineers) and the number of universities had doubled every 50 years, that the number of important discoveries and students/1000 population had doubled every 20 years, and that academic journals had doubled in numbers every 15 years. By the 1960s, the growth rate of researchers and scientific institutions in the United States was faster than the general population growth rate and that of nonscientific institutions (de Solla Price 1965). For countries like the US, the increased costs associated with science and technology placed new demands

on selectivity in terms of what would be funded by the state in order to get the most bang for the taxpayer's buck. Selectivity in this context is related to choices between how to allocate scarce resources across fields of basic and applied science, as well as to whom resources should be allocated, e.g. industry, institutes, universities, etc. Bornman and Mutz (2015) provide updated support for de Solla Price's growth thesis. By rough estimations, the annual growth rate of global scientific output[3] between the end of the Second World War (WWII) and 2010 may have been up to 8-9 per cent. This is equivalent to a doubling of global scientific output every nine years (Bornmann and Mutz 2015).

Because of the fast growth of the scientific enterprise, this sector continues to absorb large portions of national budgets. Consequently, demands for selective funding and planning in science and technology have only increased since the writings of de Solla Price in the 1960s. In fact, it is by now well-recognized that science policy has transformed since the end of WWII from embracing laissez-faire processes of resource allocation to setting goals and selecting research programs (e.g. Ziman 1984). Priority-setting has emerged as a key science policy instrument for planning and selection in the post-WWII era. In recognition of this, OECD published a special report in 1990 on priority-setting. It concluded that priority-setting is a cornerstone in framing strategic objectives for science and technology in OECD member states. Similarly, Elzinga (2010) refers to priority-setting/resource allocation to R&D as "one of science policy's most classical components" and Ziman (1984) to it as science policy's basic building block, in the sense that priority-setting constitutes a stage in a science policy cycle. This cycle can be understood to include the stage of priority-setting, implementation, and evaluation. Since at least the 1970s and 80s, science policy has increasingly focused priority-setting on innovation as an addition to the traditional orientation towards R&D.

2.1.2. Rationales for priority-setting

The two aims of science policy (to stimulate knowledge creation and to exploit that knowledge in support of policy objectives) are inextricably linked in the sense that government spending on RDI is typically justified on the basis that RDI will generate valued returns to the public (and to policy-makers) such as improved quality of life, national security, increased economic growth and wealth creation, etc. As a complement to the policy rationale that investments in RDI will generate value for the nation-state, the last two decades have seen an increased international political consensus that RDI is key in addressing global, or grand, societal challenges. Grand challenges include poverty and inequalities, climate change and energy, global security, etc. (e.g. Lund declaration 2009). For example, by signing the Addis Ababa Action Agenda (2015) – the framework for funding and

[3] Measured by the number of cited references in scientific publications (peer reviewed)

implementing Agenda 2030 – United Nations (UN) member states committed to integrating science, technology, and innovation strategies into national strategies for sustainable development and to increase investments in research and technology. The actual Agenda 2030 include goals and sub-goals related to investments that directly have a bearing on national science policies (e.g. goal 9 and 17).

In addition to justifying public investments in RDI on the grounds that the investments will create public value, resource allocation from national budgets to RDI is also justified on the basis that RDI outcomes can be rationally planned and executed (e.g. Shils 1968; Sarewitz and Pielke Jr. 2007). Planning/rational decision-making for RDI assumes that 'facilitating linkages' between investments and the desired outcomes of such investments can be identified and created. Such linkages may for instance be science policy instruments (e.g. rules and regulations) and funding programs, collaborations, research instruments etc. Linkages can also be understood as the actors operating at the lower levels of policy-making, be they firm managers, funding agency staff, and research leaders in the universities. Here, investments and outcomes can be assumed to be linked by actors' interests and ideas, creativity and problem-solving capabilities, and everyday organizational choices.

With increased expectations on RDI's ability to address societal challenges (e.g. Lund declaration 2009) and improve economic performance and its embeddedness in what has become known as the national system of innovation (e.g. Lundvall 1992), the number of actors who have a stake in policy-making for RDI and RDI priority-setting has grown. For example, most OECD countries have experienced growth in sectoral agencies, research performers, knowledge intense firms, and civil society organizations (e.g. cancer associations). From being the task of science policy-makers at the level of central government and/or a limited number of research councils, actors like those above actively participate in making RDI investment decisions. This has created some challenges for policy coherence. In an international comparison of priority-setting, Gassler et al. (2004) observe that actors at the operational levels, such as individual funding agencies, technology transfer institutions, private sector firms, and universities, may formulate and pursue their priorities and strategies more or less disconnected from science policy bills and strategies at the national policy level. Some reasons for the incongruence they claim, relate to different timings of RDI priority-setting. Government, funding agencies, firms, and research performers may simply work on different priority-setting cycles. Observations like these suggest that for governments, a larger issue is how to efficiently divide labor between key stakeholders (including itself) while at the same time ensuring policy coherence. Decentralization of this sort has only emphasized the need for priority-setting, now with the additional expectations on priority-setting as an instrument for orchestration/coordination of key actors in the innovation system (e.g. Rip and Nederhof 1986; Godinho and Caraça 2009).

To summarize, RDI priority-setting has become a key instrument for the planning and selection in science policy. On the one hand, and as raised already in the introduction to the thesis, scarcity of resources/increased competition for funds (with associated pressures for accountability) is one likely factor behind the demand. Another is the growing need for coordination between policy areas and key actors in the innovation system where priority-setting is perceived as an instrument for such coordination/orchestration. On the other hand, priority-setting has been facilitated by the notions that RDI investments can create public value and that RDI is amenable to planning/rational decision-making. The general factors motivating priority-setting, divided up as demands and opportunities, are presented in table 1 below.

Table 1. General factors motivating priority-setting for RDI

Demand factors	Opportunity factors
Scarcity of public resources	Public value can be created from RDI investments
Increased complexities associated with national innovation systems and responding to societal challenges call for coordination between actors in the innovation system	RDI is amenable to planning/rational decision-making

The next section focuses on some of the traditional issues of RDI priority-setting in greater detail, such as criteria for choice and how choice relates to some basic tensions in priority-setting.

2.1.3. Choosing priorities: some classic issues

Although RDI priorities may be justified in terms of how they promote public interests, a traditional point of contestation concerns how public interest is best supported by priority-setting. When policy-makers have identified policy objectives for RDI, on what basis, or according to which standards/criteria should policy-makers base their investment decisions? How should they compare possible areas of investments to make the most efficient use of taxpayers' money? And, how should they choose the actor who executes the investment decisions?

One of the first persons to attempt to create a meta-discourse of choice/priority-setting was Alan Weinberg, a nuclear physicist and the then director of the Oak Ridge National Laboratory (Hellström and Jacob 2012). In the early 1960s, Weinberg published a series of papers on choice in science in the scientific journal *Minerva* (Weinberg 1963, 1964). In his papers, he explicated and argued for a set of criteria for the allocation of limited public resources to basic science (e.g. molecular biology), applied sciences (e.g. nuclear energy research), and a mix of basic and applied sciences (e.g. behavioral sciences). In his first paper, Weinberg

(1963) referred to two types of choice. The first, scientific choice, concerned choosing between diverse fields of science such as high-energy physics and oceanography. The second type of choice concerned the kind of institution that would receive funding from the government (e.g. universities, national laboratories, or industry). Weinberg called the latter institutional choice. Weinberg was clear to point out that choice occurs on several levels. Scientific choice was the concern of the researchers and research directors. By contrast, institutional choice was made by government administrators. Together, according to Weinberg, the two types of choices determined science policy as a whole.

Weinberg never developed criteria for institutional choice. In contrast, to guide scientific choice Weinberg developed two sets of criteria, viz. internal criteria and external criteria. Internal criteria measured the efficiency of the conduct of scientific activity within a field. Here, allocators of funds should assess the scientific field in terms of its ripeness for exploitation and the level of competence of the researchers in the field. External criteria on the other hand measured the usefulness of a field to other fields, technological advancement, and society more generally. As such, external criteria according to Weinberg were criteria of utility. Of the two sets of criteria, Weinberg argued that the external ones were more important. The rationale underlying his position was that the social needs of society were more important than science as an end in itself.

Weinberg's proposal of criteria for scientific choice reignited a debate between several scholars and practitioners. The larger issue of the debate related to how science, and in particular basic science, ought to be governed – by the researchers themselves or centrally by the government. Weinberg's proposals resonated with earlier visions of the role of government in setting the direction for science. For example, John Desmond Bernal, a renowned physicist and active member of the Communist Party of Great Britain, had in 1939 proposed the vision that support for science should be determined by its prospects of being useful to society. In contrast to Bernal (and Weinberg after him), Michael Polanyi (1962/2000), a professor in chemistry and social sciences, philosopher, as well as liberal of his time, argued that the results from intellectual competition among researchers, not government choice, must set the priorities. Polanyi's position in the debate echoed the position laid out by the then director of the US Office of Scientific Research and Development, Vannevar Bush, in the 1945 report *Science – the Endless Frontier*. The report was commissioned by President Franklin D. Roosevelt and influenced the US government's science policy in the immediate aftermath of WWII and the following two decades (Pielke Jr. 2010). In short, Polanyi like Bush before him suggested that when government-sponsored researchers are allowed to pursue truth freely, efficient social outcomes would follow. The two governance modes pitch political planning and the autonomy of researchers against one another and illustrate one of the basic tensions in science policy, sometimes referred to as the 'internalist' stance (e.g. Polanyi) and the 'externalist' stance (e.g. Bernal).

2.1.4. Models of innovation and their relation to priority-setting

Despite their many differences, Bush and Polanyi, Bernal and Weinberg, and their respective supporters converge on the notion of the relationship between research, development, and innovation as 'linear'. To the former two, socio-economic objectives such as innovations are predicted to follow when researchers pursue scientific discoveries freely. Discovery would then feed into 'subsequent stages' such as applied research, development, and finally social utilization/commercialization (see fig. 1). By now, it is widely held that how this 'supply-side'/'science-push' model conceptualizes the relationship between research, technological development, and innovation lacks empirical support. Hence, the model serves as a poor foundation for priority-setting (e.g. Kline 1985; Godin 2017).

Figure 1. A supply-side version of the linear model of innovation

While still alluding to linearity, a revised version of the model conceived the process as one where political demands achieve desired socio-economic objectives by prioritizing the 'right science' (see fig. 2). This model resonates with the position of Bernal and Weinberg. However, some suggest that this 'demand-side'/'demand-pull' model of priority-setting too is insufficiently supported by empirical observations (e.g. Irvine and Martin 1984).

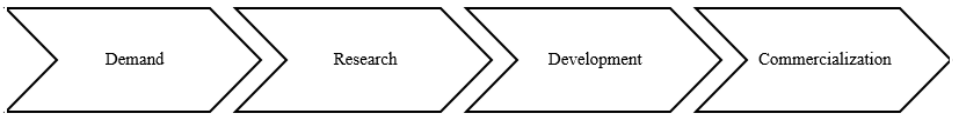

Figure 2. A demand-side version of the linear model of innovation

Casual observation suggests that most OECD countries, implicitly or explicitly base national priority-setting on the demand-side model. Since the model places urgent public needs at the fore, such as economic growth, sustainability, and public health, and proposes that science can contribute to satisfying the needs, it provides a neat political justification for investing public resources into research and technological development. However, placing a demand factor before science may be problematic. First, satisfying demand may prove difficult if science policy-makers do not take into account, or are able to accurately assess, scientific supply, that is,

what researchers, engineers, and innovators have the capacity to deliver within reasonable timeframes, or at all (Sarewitz and Pielke Jr. 2007; Chalmers et al. 2014). Reconciling demand with supply may be particularly challenging for science policy-makers since knowledge about research frontiers and research processes may be opaque from a lay perspective (Hellström and Jacob 2012).

Secondly, policy problems are not necessarily research problems and may not appeal to researchers or even be easily translated into research problems (e.g. Elzinga 1986). Even when translation is deemed feasible by researchers, science policy priority-setters still face the challenge of how to manage tensions between public value creation and the creation of valued outcomes for the research community. Outcomes valued by the research community may for instance include discoveries and methodological advances, training/capacity-building of junior and senior researchers, and career advancements. The latter may hinge on researchers' opportunities to publish novel work in high-impact journals and get that work cited. However, a policy priority aimed at creating public value by solving a policy problem does not necessarily stimulate these types of values internal to science (Elzinga 1986).

The issues above aside, the demand-side model as a guidance for priority-setting is further challenged by uncertainties associated with knowledge production. Results depend on the researchers' problem-solving abilities and his/her propensities to adapt to new circumstances (Pickering 1995). This may involve hands-on activities of manipulating materials and conditions to make experimentation work (Hacking 1983). Production of new knowledge can thus be understood to include significant amounts of tinkering. Tinkering in this context denotes how researchers, throughout a research process of trial-and-error construct scientific facts by managing, modifying, and re-modifying an assemblage of opportunities, material resources, standard procedures, and collaborators (Knorr-Cetina 1981). Additionally, research results/discoveries may simply be consequences of 'happy accidents', i.e. serendipitous events that proceed scientific breakthroughs (e.g. Ziman 1984; Yaqub 2018). This lends further support to the notion of results as highly unpredictable and difficult to plan/anticipate.

In recognition of uncertainties such as those described above, picking the winners through priority-setting i.e. selecting the scientific fields or technological areas for investments that will successfully meet social and political demand, has been described as a lottery (Irvine and Martin 1984). And even where scientific results with prospects of being socially relevant exist, the uptake of the results into the economy depends on several types of support structures and interactions between key actors in an innovation system, e.g. availability of complementary funds, technology, and workable market niches (e.g. Lundvall 1992). Empirical studies have repeatedly demonstrated that successful innovations with a science-base, depend on complex, difficult-to-predict interactions between several actors in the innovation system and usually take several years, if not decades, to materialize (e.g.

Irvine and Martin 1984; Mazzucato 2013). In fact, even in hindsight, the pathways from scientific results to socio-economic impacts may for methodological reasons be difficult to uncover (Hughes and Martin 2012).

Complexities like those are reflected in a model of innovation developed by Kline and Rosenberg (1986). They suggest that the relationship between research and socio-economic outcomes is best captured by 'the chain-linked model'. The model conceptualizes the relationship between needs/demands, R&D, and innovation/economic performance as being interactive rather than linear in the sense that innovation processes involve feedback loops between several actors and stages of an innovation process. Actors include researchers (academic and non-academic), administrators, policy-makers, and end-users. One of the central insights provided by the chain-linked model is that chains of causation run in both directions, that is from science to economic performance and from economic performance to science (Rosenberg 1982). Accordingly, technology may be a consequence of basic discovery. But the opposite also applies, i.e. that new, scientific knowledge may emerge from technological problem-solving. For example, the science of bacteriology emerged from how problems of fermentation and purifications were dealt with in the French wine industry (Rosenberg 1982). Louis Pasteur, the person who discovered how to protect wine from bacterial contamination, later used the new knowledge about how micro-organisms behaved in beverages to create a range of public goods such as the process of pasteurization and antiseptic methods in surgery (Stokes 1997).

As suggested above, a central question/issue pertaining to the development of modern science policy is to what extent external goals can and should be internalized in science in terms of guiding or steering the direction of longer-term programs for knowledge production and more short-term applications. Some argue that science's amenability to external steering depends upon which maturity phase the specific field is in. For example, Gernot Böhme, Wolfgang van den Daele, and Wolfgang Krohn argue that by trying to exploit premature fields, external goals may disrupt science's natural, or 'optimal' trajectory (e.g. Böhme et al. 1976). To avoid such disruption, Böhme and his co-authors argue that external goals and relevance criteria should not be introduced when a scientific field is still immature, i.e. when the development of theory is in an initial stage. The 'finalization thesis' thus argues that a field needs to have achieved a certain level of maturity before its results and theories can lend themselves to application. Elzinga (1986) suggests that potential disruption of the development of a scientific field by external interference is not limited to the early development stage of a field. According to Elzinga, the autonomy of science should therefore be upheld also at the stages where scientific fields have matured. He considers external interference situations where researchers no longer have the authority to define research problems, choose methods, accept or reject hypotheses, or publish results without external interference and censorship (Elzinga 1986). Elzinga suggests that in the case where the autonomy of research

communities is subjected to external priorities so-called *epistemic drift* may occur. Epistemic drift refers to how administrative, business, and policy preferences and interests influence the researchers' selection of research problems and replace scientific quality criteria. In practical terms, this means that the quality of research is assessed in relation to policy frames by political or bureaucratic institutions instead of by the collegial system in academia. Against this background, Rip (1981, 1997) suggests that science policy-makers should take into account how external aims for science affect disciplines', or fields', natural, or 'optimal' trajectories. In short, policy-makers should know more about the social and cognitive dynamics internal to science before making decisions.

Having raised some of the classic issues pertaining to choice in priority-setting and models of innovation and their implications for priority-setting, the literature review will now focus on the more contemporary aspects of RDI priority-setting. It will cover the functions of RDI priority-setting in contemporary science policy, address some of the trends in priority-setting over time and across countries, and describe how priority-setting can be viewed from a perspective that takes the many complexities associated with stakeholder diversity and local conditions for prioritizing into account.

2.1.5. Contemporary priority-setting for RDI: functions, types, and methodologies

As noted earlier, priority-setting may function as an instrument by which governments coordinate action and actors involved in science policy (Godinho and Caraça 2009). For example, priorities may function to create coherence between objectives of policy-makers and those of researchers (Rip and Nederhof 1986). In recent years, it has been noted that RDI priority-setting also involves more than simply picking fields of science to achieve social or technological outcomes. RDI priority-setting may be a way for policy-makers to highlight special issues for attention (Stewart 1995). Its function includes producing rationales and discourses for national science and technology policy and signalling shifts in political goals (Barré 2008).

In the broader sense, an RDI priority in science policy may be defined as "any activity that receives special attention and thus special treatment [by the government] as regards funds and/or other incentives" (OECD 1991, p. 22). OECD (1991) distinguishes between thematic, mission-oriented, and structural or functional priorities (hereinafter: functional priorities). The first type – thematic priorities – traditionally refers to scientific disciplines (e.g. physics), research fields (e.g. biomedical research), or specific technologies (e.g. artificial intelligence). The second type – mission-oriented priorities – typically concerns technological or societal challenges. Putting a human being on the moon is an example of the former.

Improving global public health or addressing climate change are typical cases of the latter. Functional priorities, as a third type of priority, address perceived inefficiencies in the innovation system. A priority in this sense may for example be for governments and their agencies to focus resources on training and renewal of the research base, increase support to small- and medium-sized firms (by for example grants, loans, fiscal incentives etc.), or to stimulate industry-university collaboration and/or international RDI collaboration (OECD 1991, 2009). OECD (1991) observes that functional priorities increasingly have been added to complement thematic priorities. One of the reasons for the shift relates to a growing awareness of how socio-economic value creation depends on effective interactions between key actors in the innovation system (e.g. Lundvall 1992). Recent work has implied that 'institutional priorities' constitute a significant aspect of functional priorities. For example, Hellström and Jacob (2012) suggest that policy-makers may choose institutional conditions for RDI on behalf of the research communities. Framed this way, an institutional priority may be understood to formulate desired organizational structures for knowledge production, be it how researchers organize and manage research centers/programs and projects.

Attempts to structure priority-setting and create common visions for the future among science policy actors (government, industry, academia, civil society) have stimulated the development of specific priority-setting methodologies such as forecasting and foresight. The former – forecasting – was a prominent methodology for priority-setting in the 1960s and 1970s. Forecasting is based on the notion that the general direction of the future can be predicted. In contrast, foresight as a method for priority-setting is less rigorous but still pursues a systematic approach to looking into the future of science and technology (Martin 2010).

Foresight as a method of selecting amongst scientific fields and technological areas for investment has since the 1980s gained popularity amongst policy-makers, industry, and researchers. Instead of attempting to predict or project the future (cf. forecasting), foresight exercises build on the notion that there are several possible futures, and that the decisions of today contribute to determining which future scenario will materialize in the longer term. Foresight exercises are thus considered formative measures applied to set priorities (Irvine and Martin 1984; Martin 1995). Based on an analysis of the objectives of 50 foresight exercises described in the European Foresight Monitoring Network (EFMN) database, Georghiou and Cassinga Harper (2011) argue that foresight as a means for RDI priority-setting has three distinct roles. The authors refer to the first as a corrective role where foresight in priority-setting is an instrument to address shortcomings and systemic failures and policy lock-ins. According to the second – the disruptive role – foresight serves to change the status quo by harnessing opportunities of crises or breakthrough events. The creative role is a third one whose purpose is to stimulate environments where new networks and structures can grow and evolve.

2.1.6. Priority-setting: trends and international comparisons

Gassler et al. (2007) provide an in-depth account of how national RDI priority-setting has evolved in some OECD countries[4] since WWII. The authors identify some overlapping trends, or 'paradigms', (see fig. 3.). Each paradigm can be understood from a thematic dimension (type of priorities), an institutional dimension (how and by whom the national priorities are set/chosen), and a legitimatory dimension (how priority-setters rationalize processes and choice of priorities). The first priority-setting paradigm/trend emerged in the 1940/the 50s and concerned government-driven missions oriented towards large-scale technologies (e.g. defense, nuclear energy, and aerospace). Here, specialized institutions typically implemented the priority processes (e.g. nuclear research centers). The authors refer to this as the old or classic mission-oriented approach. In the 1960s, a new paradigm emerged in which priority-setting focused on key, civil industrial technologies (e.g. ICT, biotech, and new materials). Institutional choice for organizing priority-setting referred to national technology programs that implemented forecast and/or foresight exercises. Following this paradigm was a shift in focus in the 1980s towards improving the general capacity of the innovation system by, for example, focusing on industry-academia collaboration, facilitating conditions for business start-ups, etc. Gassler and his co-authors refer to this as the systemic approach. In this context, public agencies emerged as important formulators and coordinators of priorities. The latest paradigm can according to the authors be understood to have a new mission orientation where priorities concern societal challenges such as environmental sustainability, demographic change, public health, etc. In this context, priorities are set by integrating several societal groups and areas of policy. Gassler and his co-authors' account of paradigmatic shifts in national priority-setting roughly corresponds to a change from thematic to functional priorities (and institutional ones), from a centralized approach to setting priorities (top-down) to one that includes a diversity of stakeholders (bottom-up), and from institutions to programs as the dominant means to organize and implement priorities.

[4] The countries included in the analysis are Germany, Finland, France, the U.K., Ireland, Japan, Canada, Korea, New Zealand, the Netherlands and the United States.

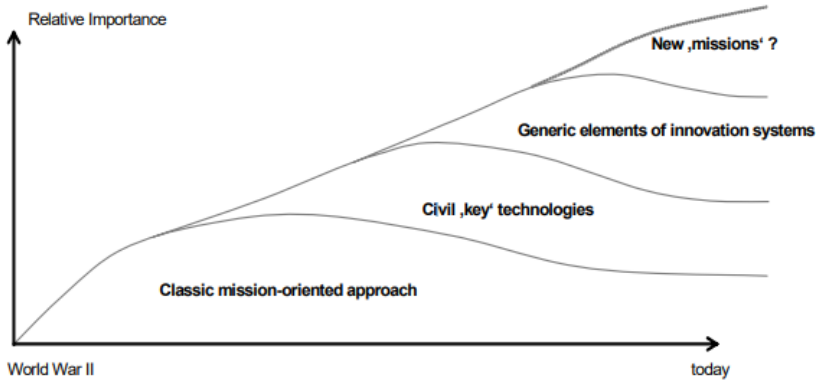

Figure 3. Priority-setting trends, running in parallel since WWII. Source: Gassler et al. 2007.

In an attempt to discern international patterns in priority processes, the Swedish Research Council (2008) conducted an international comparison of agency-coordinated processes for priority-setting across ten countries[5] and 19 research funding agencies. The Swedish Research Council observed a high level of conformity in terms of prioritized themes and ways of setting priorities. Priorities were mainly set bottom-up by extensive consultation with stakeholders followed by preparatory work by expert panels within the agencies, and final decisions by executive boards/boards of directors. The report also observed that international research agendas, such as the EU framework programs, harmonized thematic priorities across member states. According to the report, countries perceived themselves in a better position to compete for EU funding by aligning national priorities with EU priorities.

However, other international comparisons suggest that countries differ in terms of the thematic orientation of RDI priorities. For example, Godinho and Caraça (2009) compared the research focus of 27 OECD countries, including Russia. They did so by analyzing publication patterns. The analysis revealed two major patterns. Countries either concentrated resources on engineering and technology or on health-related research themes. Higher-income countries with a stronger presence of the pharmaceutical industry, demographic ageing biases, and generous pension systems typically focused on the latter theme. Godinho and Caraça also observed that larger countries tended to prioritize research that targeted specific applications within the two major themes of health (e.g. the UK, France, the US) and engineering and technology (e.g. South Korea and Russia). Smaller countries on the other hand typically favored blue-sky research, here understood as basic research.

[5] The countries are Sweden, Finland, Denmark, Norway, United Kingdom, the Netherlands, Switzerland, Austria, Canada, and USA.

Studies focusing specifically on processes for prioritizing have also noted differences across countries. In a report commissioned by the Austrian Research and Technology Development, Gassler et al. (2004) compared priority-setting across six countries (Canada, Ireland, South Korea, Netherlands, New Zealand, and the United Kingdom). The authors suggest that the surveyed countries can be placed on a spectrum ranging from centralized to decentralized approaches to priority-setting. On one extreme, they find South Korea that applies a centralized/top-down approach to setting priorities where the government is involved in formulated priority themes (e.g. key technologies) on several levels ranging from the national level to the programmatic level. On the other end of the spectrum, where priority-setting is decentralized, Gassler et al. (2004) place countries such as the United Kingdom and the Netherlands. Decentralized priority-setting should here be understood as the absence of top-down governmental steering/formulation of RDI priorities and strategies at the lower levels of science policy-making. They also observe that where priority-setting is decentralized, research councils and research institutes are typically niched thematically and larger in numbers. Research councils may for instance reflect certain disciplines and research institutes may be dedicated to specific technology areas. Gassler et al. (2004) refer to this as the institutionalization of priorities. In this context, governments tend mainly to set functional priorities, that is, the type of priorities assumed to support the RDI system rather than to steer RDI towards specific themes.

Another way to distinguish between countries in terms of how priorities are set is to analyze priority-setting in terms of how formal or informal it is. In a report on priority processes for public RDI in the energy area, the Swedish Agency for Growth Policy Analysis (2014) concluded that some industrialized countries had formalized procedures for setting priorities. These were characterized by clear and transparent routines. This was for example the case in Canada, Switzerland, and South Korea. Informal procedures, on the other hand, were noticeable in countries such as Japan, Denmark, and the United Kingdom (also, the US to some extent). Informal procedures should here be understood as government officials or senior administrators on the agency level using their networks to collect and act upon signals from academia and the industrial sector as well as personal and agency-level preferences.

2.1.7. Systemic perspectives on priority-setting

This last section of the literature review will highlight some of the ways in which we can understand priority-setting from a systemic perspective. Accordingly, priority-setting may depend on several interacting factors such as actors, organizational structures, hierarchies, incentive structures, and external circumstances/pressures.

Georghiou and Cassinga Harper (2011) suggest that a systemic perspective is important when setting priorities. They argue that priorities may not fully take into account interdependencies with other thematic fields. For example, information and communication technologies can be an explicit national priority whereas mathematics is not. Yet the development of the former thematic field is dependent on the latter thematic field. The second type of challenge according to the authors concerns the limits of the scope of priorities. Here, the relationship between thematic and functional priorities is of main concern. Successful priority-setting, they claim, may rely on complementary developments elsewhere in the research system e.g. building the capacity of research environments intended to implement the priorities. Hence, priority-setting must be sensitive to both thematic and functional aspects of an RDI field and how they possibly or actually relate to each other in the RDI system.

In Gassler's and his co-authors' (2004) comparison of priority-setting across six countries (Canada, Ireland, South Korea, Netherlands, New Zealand, and the United Kingdom), they apply a conceptual framework that goes beyond simply differentiating between the type of priority (mission-oriented, functional, and thematic). The type of priority constitutes but one dimension of the analysis. The second dimension of analysis, according to the authors, distinguishes between levels of national priority-setting for RDI. Here, levels refer to the hierarchical positions of priority-setting actors within the national innovation system. Priority-setters include, for instance, international bodies, national governments and ministries, research councils and sectoral funding agencies, research institutes, universities, etc. Gassler et al. also use a third dimension for their analysis, viz. the nature of the priority-setting. This, they suggest, is either top-down (or expert-based) or bottom-up (or participatory). Bottom-up priority-setting is a decentralized approach to prioritizing and is traditionally associated with the delegation of decision-making authority over RDI to the research community. The top-down, or the centralized approach to priority-setting for RDI, on the other hand, is typically associated with governments and the ministries formulating the objectives for RDI (OECD 1991). Today, we typically see a mix of the two approaches, viz. the bottom-up (or science-oriented) and the top-down (or politically and economically oriented). OECD (2003) refers to the mix as the "dual-system archetype" i.e. a type of hybrid approach. Priority-setting according to the dual-system archetype mixes the influences of stakeholders in different parts of the national R&D budget process. (OECD 2003). The three dimensions of analysis correspond to the questions: what type of national priorities are set? Where are national priorities formulated? And how is priority-setting organized? Hellström et al. (2017) note that the framework (type, level, and nature of priority-setting) captures the main variables of priority-setting on the country level, but it downplays priority-setting as an emergent activity. In reality, they suggest, prioritization includes the setting of more than one type of priority and involves a translation of priorities between several levels (e.g. from the government to the funding agency). Hellström et al. (2017) go on to suggest

that priority-setting should be understood in its institutional context. From a case study on priority-setting in the Swedish Energy Agency (SEA), they conclude that thematic priorities may develop through interactions with the institutional structures and work processes. Structures and processes provide opportunities but also constraints for prioritizing. A key tension, they observe, is the tension between building organizational capacity for implementing priorities (e.g. creating thematic RDI units in the agency, and consequently also path-dependencies) and seeking novel areas of investment. As a consequence of the tensions, priorities may conform to/be fitted into the present capacities of the agency rather than stimulating the growth of new ones.

Bosin (1992) proposes three models for understanding changes in priorities at the level of the agency and relates the changes to events that motivate or trigger prioritization. According to the first model, called comprehensive sweeps, (re)prioritization may be triggered by new administrations/executives or serious criticism of the agency. The second model relates to crisis or opportunity events such as fiscal crises in the agency and new legislation but also opportunities associated with new policies that align with the agency. The third model, institutional revisits, refers to reoccurring agency routines related to prioritizing such as annual budget planning. The type of triggering event determines how much time there is for prioritizing and what type of decisions the priorities support. For example, priority-setting triggered by a new agency administration may lend more time for agencies to prioritize (and thus more time to gather information and involve stakeholders) than an agency that responds to an unfolding, internal crisis.

Stewart (1995) argues that priority-setting is too often based on a benefit-cost model of research. According to the model, prioritizing certain RDI themes over others involves quantifying the variables likely to induce the highest rate of return from the available resources put into RDI. The model is based on making an ex-ante calculation of impacts, with the notion that economic outputs can be used as success indicators. For this model of priority-setting to work, Stewart argues, decision-makers must be able to fully map public preferences and access knowledge of which type of research most probably will meet those preferences. However, she argues, the anticipated benefits of research are not always economic or not necessarily quantifiable. Nor are they predictable. Stewart instead advances the idea that priority-setting for public sector research is best approached as a problem of system design. She argues that institutional processes and structures of a system set ‘de facto’ priorities by their modes of operation. She proposes three crucial questions that need to be addressed to understand priority-setting, namely: who makes the choices, what incentives confront them, and at what level/degree of centralization the choosing is done. According to Stewart, these questions generate three systemic models for priority-setting (see table 2).

Table 2. A typology of systemic priority-setting. Source: Stewart 1995

	User-based	Institutional	Political
Who chooses	Firms, citizens, etc.	Researchers	Organized interest
Incentives to choosers	User needs	Rewards for research	Group benefits and costs
Level of decision-making	Decentralized	Decentralized	Centralized or decentralized (pluralist)

The first, the user-based model, refers to a system designed to favor the preferences of end-users of research outcomes such as firms, professionals, and citizens. This market-oriented model supposedly brings user demand and scientific supply in balance. However, it may also pose a risk to long-term basic and strategic research and important capacity-building with no immediate payoff (e.g. training of researchers) by prioritizing the type of research that can bring instant utility to the market.

According to the institutional model, organizational arrangements for research cause certain priorities to be set. The model departs from the notion that the institutional setting in which for example researchers operate embodies incentive and disincentive structures. For example, co-funding requirements from funders can push priorities away from a collaboration between research performers and SMEs towards collaborations with large industries, or from departments in smaller universities to larger ones. To understand how key problems are given priority in a certain organization, the research community, or discipline, one may for instance want to identify what carries the most incentive; publication in academic journals? End-user satisfaction? Patent rights? etc. Stewart (1995) advocates institutional analysis as it may reveal "latent priority setting mechanisms which have no clear rationale" (p. 121) i.e. those structures within the institutional setting that automatically generate priorities and the levels at which key decisions are made. Accordingly, changing priorities may demand changes in incentive structures that resonate with the values and interests of researchers.

The political model departs from the notion that the authority to dispense funds brings with it an influence over how resources are allocated, e.g. to whom they are given and to what end. In pluralistic environments, consultations and bargaining (e.g. between research agencies and universities) can overcome misalignment between preferences between policy-makers, researchers, practitioners/interest groups, etc. The more interests that are organized and represented in the bargaining/consultations, the more likely the priorities will reflect national concerns and demands.

The systemic perspective proposed by Stewart helps to view priority-setting as a process of several but interconnected layers of preferences (users, institutions, and

politics), incentive and disincentive structures, and rationales for prioritizing. The systemic perspective to understanding priority-setting, Stewart argues, is hence best suited for a political system that is more pluralistic than centrally directed. One of Stewart's central points is that key decisions in science policy may be made at much lower levels in organizations than was intended, and be subjected to incentives and constraints not apparent at the higher level. In addition, researchers may struggle to combine several preferences (political, end-user, as well as disciplinary). This resonates with an empirical study by Miller and Neff (2013) that focuses on how ecologists and sustainability researchers define research priorities and questions. The authors conclude that de facto science policy priorities (e.g. research topics/agendas) result from how researchers balance aims of achieving science policy objectives (e.g. solving a social/policy problem) with disciplinary aims and norms (e.g. advancing scientific knowledge) as well as with career goals (e.g. winning grants and/or getting tenure/being promoted). They argue further that science policy-making is a social process that extends into researchers' development of research agendas. However, the authors also argue the dynamics involved in translating policy into scientific outcomes (which they refer to as co-producing science policies) are underexplored and could benefit science policy researchers as well as policy-makers in evaluating the efficacy of the policies.

In summary, this part of the literature review focused on priority-setting. It described the emergence of rationales/justifications for prioritizing e.g. that RDI results create public value and the assumption that RDI is amenable to planning/steering (e.g. Shils 1968; Sarewitz and Pielke Jr. 2007). It also highlighted some classic issues such as the normative debate about how science ought to be governed to create public goods/utility (e.g. Bernal 1939; Bush 1945; Weinberg 1963; Polanyi 1962/2000) and problems associated with the linear model of innovation and thus also difficulties associated with planning and executing policy to guide RDI (e.g. Godin 2017; Chalmers et al. 2014; Hellström and Jacob 2012; Elzinga 1986). The review also gave accounts of contemporary priority-setting for RDI in terms of its functions and types (e.g. Barré 2008; OECD 1991, 2009; Gassler et al. 2004), as well as trends and international comparisons (e.g. Gassler et al. 2007; Godinho and Caraça 2009). Finally, the review has highlighted research that advances a systemic perspective on RDI priority-setting (e.g. Stewart 1995; Georghiou and Cassinga Harper 2011).

In summary of this section, we may also note the growing policy focus on functional priorities in addition to thematic and mission-oriented ones (e.g. OECD 1991; Gassler et al. 2004), and that successful priority-setting must be sensitive to how functional/institutional priorities and thematic priorities relate to each other in the RDI system (e.g. Georghiou and Cassinga Harper 2011). Being an instrument for planning, priority-setting may include assumptions about the relationship between capacities/organizational arrangements and policy objectives by suggesting how capacity-building and institutional forms for knowledge production facilitate

between investments and desired outcomes (e.g. solutions to technological or societal challenges). But as proponents of the systemic perspective on priority-setting note, how priorities play out in reality may depend less on how policy-makers formulate priorities and more on key decisions made at lower levels of decision-making for RDI. Policy-makers may have little knowledge about the incentives and constraints that influence decision-making at these levels (e.g. Stewart 1995). From this perspective, understanding how the relationship between capacity-building/organizational arrangements and policy objectives for RDI is forged motivates a research focus on the implementation of RDI priorities. An implementation focus directs our attention to how RDI administrators and performers structure implementation by, for example, formulating objectives, developing and adjusting instruments for implementation, making or directing investments, and maintaining assumptions about the relationships between such factors. It also stresses the implementation outcomes hinge on the interests and ideas, creativity and problem-solving capabilities, and everyday organizational choices of the actors implementing the priorities. To create a frame for understanding such choices, the next section focuses on the literature concerned with policy implementation.

2.2. Policy implementation

The second part of the literature review focuses on policy implementation and the various ways in which scholars within the larger research field suggest how policy implementation may best be studied. The review focuses on the dominant approaches.

Implementation can broadly be defined as "what develops between the establishment of an apparent intention on the part of the government to do something […] and the ultimate impact in the world of action" (O'Toole 2000, p. 266). Or simply, that what follows once a 'bill has become a law' (Bardach 1977). A more detailed definition is provided by Sabatier and Mazmanian (1980, p. 540) who suggest that:

> Implementation is the carrying out of a basic policy decision, usually made in a statute (although possible through important executive orders or court decisions). Ideally, that decision identifies the problem(s) to be addressed, stipulates the objective(s) to be pursued, and in a variety of ways, "structures" the implementation process.

Implementation research addresses the consequences of public policy enacted as laws or statutes and how legislation is executed on the level of policy delivery. Policy implementation as a subject for research gained popularity among scholars in the 1970s. Some suggest that this was much owed to the fact that several social

programs initiated in the United States during the 1960s had been deemed ineffective by the 1970s. By opening up 'the black box' of policy implementation, that is unpacking the processes between policy formation (formulation and design) and policy outcomes, scholars tried to understand the failures, or limited success, of programs such as the War on Poverty (Hill and Hupe 2002).

The terms 'policy implementers' refers to individuals as well as organizations that carry out policy decisions. In implementation research, the former group is typically referred to as frontline staff (e.g. Lipsky 1980) and includes for example police officers, teachers, healthcare staff, etc. Organizations that execute policy are usually referred to as 'implementation agencies' and/or 'intermediaries'. They include various government agencies but can also be understood as private actors such as firms and non-profit organizations that have government mandates to implement policy (e.g. Shea 2011).

2.2.1. The top-down approach to studying policy implementation

Central to this approach is the notion of a policy cycle, also referred to as a stage model. The policy cycle model depicts the stages of policy formation and execution, typically agenda-setting, policy formulation of alternatives for action, decision-making (i.e. the formal decision to take on the policy), implementation, and evaluation. The stages are ordered chronologically (Jann and Wegrich 2007). Researchers who take a top-down perspective typically depart from this model when analyzing the causal relationship between policy statutes and implementation outcomes. A policy decision to initiate a program is the starting point for such analysis. The analysis typically results in conclusions as to whether the policy was a success or failure, that is, if the original policy objectives were reached or not and if the implementing agency complied with instructions from the top.

The American scholars Jeffery L. Pressman and Aron B. Wildavsky popularized the top-down approach in the 1970s. They suggested that implementation of policies begins once a set of initial conditions are created, e.g. when there is a policy decision to fund a program. The type of program Pressman and Wildavsky (1973) refer to "consists of government action initiated in order to secure objectives whose attainment is problematic" (p. xiv). They go on to suggest that "programs make the theories [i.e. the causal assumptions of the policy] operational by forging the first link in the causal chain connecting actions to objectives" (p. xv). According to this line of reasoning, policy implementation is about forging links in a causal chain. This reasoning highlights a central feature of the top-down approach viz. that the relationship between policy formation (formulation and design) and policy implementation is viewed as one-directional. For example, policy objectives are specified by policy-makers at the top and implemented by agencies and individuals (i.e. the bottom). The perspective on policy implementation implies that implementation activities are amenable to governmental control and corrective

actions should the implementing agents deviate from the policy statutes/objectives/instructions. The direction argument/assumption and the suggestion that implementation can be controlled, amount to an assumption that policy implementation can be planned or programmed from the top and that outcomes can be predicted. Not surprisingly then, this perspective conceives of policy-making as a rational process that involves matching solutions to policy problems (where the problem arises before the solution). Once the solution has been identified, an apolitical and bureaucratic process of implementing the solutions follows (Hupe and Hill 2016).

Researchers from the top-down tradition have traditionally tried to identify those factors that explain variation in implementation outcomes, sometimes resulting in long lists of variables for effective implementation (see for instance Sabatier and Mazmanian 1979; Mazmanian and Sabatier 1981). According to Pressman and Wildavsky (1973), achieving policy objectives depends on the number of veto/decision points in the implementation chain, where fewer are predicted to increase prospects of success. Fewer veto/decision points are assumed to reduce the number of instances where the policy may be re-interpreted and cause a distortion of the anticipated chain of causality (Pressman and Wildasvky 1973). In a seminal article by Sabatier and Mazmanian (1979), the authors outline a moderate list of higher-order of conditions for effective implementation (pp. 484-485). According to the authors, implementation is effective when:

- the program to be implemented is based on a sound theory connecting the intervention to implementation activities, change in target group behavior, and achievement of outcomes;
- the policy decision is unambiguous and structures the implementation process;
- agency management is committed to the policy goals and has the managerial and political skills to reach the goals;
- there is active support for the program by political leadership, and;
- the objectives are not undermined over time by for example new policies or changes in the socio-economic conditions that undermine key assumptions of the underlying causal theory (e.g. the relationship between air quality and emission levels) or political support.

In Wildavsky's later work, he compared policies to hypotheses. He suggested that policies "are not eternal truths" but more akin to hypotheses and thus "subject to modification and replacement by better ones until these, in turn, are discarded" (1979 p. x). Similar to Wildawsky (1979), but in the context of science policy, Thomas and Mohrman (2011, p. 261) argue that:

> Investment decisions and science policies are themselves hypotheses. They are based on incomplete knowledge of what avenues of science exploration are likely to yield useful knowledge, what areas of science will be adequately funded without policy intervention, and what dynamics will result from a policy and how they will impact science production and the linking of science to the larger innovation and mission system outcomes.

They go on to suggest that science policy implementation "is the ultimate test of these hypotheses, and the source of learning to inform future policy decisions" (p. 265). From this perspective, those responsible for implementation put policy to test. And like a hypothesis, a policy can be accepted or rejected. Additionally, lessons learned can be fed back into the policy process that generates new, improved policies. This perspective on policy implementation shifts the focus away from the implementation process as the main culprit should policy objectives not be achieved, to focus instead on the quality of the policy itself. Yet, it maintains a top-down perspective on implementation by assuming that policy can structure the implementation process/the testing of hypotheses and that success (hypothesis accepted) or failure (hypothesis rejected) should be measured against the original policy formulation. The next section describes some approaches to implementation that challenges that assumption.

2.2.2. The bottom-up approach to studying policy implementation

The top-down approach to studying policy implementation has sustained criticism from scholars who have argued that the approach downplays the influence of administration in policy-making. These critics instead assume that policy-making continues once an executive order has been made. Barrett and Fudge (1981) for example posit that there is a policy-action relationship. It involves interactions and negotiations between policy-makers and implementers over time. This blurs the distinction between policy formation and policy implementation emphasized in the top-down approach. In fact, some suggest that it is not meaningful to try to make a conceptual distinction between agenda-building, policy formation, and implementation at all (e.g. Woodhouse and Lindblom 1993; Sabatier 1986). The only relevant distinction is that policy design and policy formulation may constitute the early stages of a policy-making process while policy implementation refers to the later stage (Hill and Hupe 2014).

The bottom-up approach to studying implementation pays more attention to context-specific variables that affect the translation of policy into outcomes, such as the nature of the policy problem, agency structures and processes, organizational culture, and norms and values of the frontline staff. Elmore (1980) was one of the early supporters of the bottom-up approach. He argued that when forming policies, policy-makers should start their analysis at the intersection between administrative action and private/client choices, that is, where on the ground the social problem is

actually addressed. According to Elmore, the analysis should then proceed by following the trail of proximate rules, processes, structures, policy instruments, etc. leading up to a conclusion about what may be feasible policy objectives. He called this backward mapping, which can be contrasted to the top-down approach. The latter suggests that policy-makers should start with a policy decision and assess how that decision is best achieved and then make appropriate adjustments (e.g. creating rules and mandates) for the implementer.

While Elmore (1980) takes the perspective of the policy-maker in his backward mapping approach, bottom-up scholars generally do not aim at formulating policy advice. They are in fact less interested in determining why implementation succeeds or fails. Instead, they look for causes that affect action on the ground, that is, at the level of policy delivery. Central to the bottom-up approach is the notion that policy texts do not suffice as a focus for research aiming to understand how policy problems are resolved (or not) because they do not function as technical instructions for implementers in the first place (Hupe and Hill 2016). Public policy may be the outcome of struggles, or conflicts, over alternative political realities rather than rational responses to social problems leaving implementers with no clear direction of where to focus (Rochefort and Cobb 1993). Policy-makers may resort to the use of vague or ambiguous policy formulations to temporarily settle political disputes and reach compromises (Matland 1995). Vague/ambiguous formulations may intentionally be inserted into policy to create space for interpretations. Interpretative space may for example be necessary to get a policy bill through parliament (Nakamura and Smallwood 1980; Matland 1995). Winter (2012) suggests that policies that are the outcome of political disputes may be marked by invalid causal theory between areas of investments, policy instruments, and desired socio-economic outcomes. In sum, a 'good' policy may thus simply be the one that decision-makers can agree on (e.g. Lindblom 1959).

Some suggest that a policy may best be understood to constitute a mix of "factual statements, interpretations, opinion, and evaluation" (Majone 1989, p. 63). When vagueness, ambiguity, and/or unresolved political tensions are woven into the fabric of policy, they may later emerge as challenges during implementation (as would not be the case if instructions were clear). For example, once a policy bill is enacted into law, the implementing organizations and individuals that are commissioned to implement it (i.e. to achieve desired policy outcomes) typically need to confront such challenges. Proponents of the bottom-up approach, therefore, argue that because of ambiguity and conflicts imprinted onto a policy, the actual effect of a policy depends less on government intentions and more on how implementers and target groups attach meaning and interpret the policy, and makes sense of instructions coming from above (Steinberger 1980; Coleman et al. 2010).

For the reason elaborated above, bottom-uppers typically suggest that implementers do not necessarily stick to policy objectives formulated at the level of government. Rather, implementers (organizations and individuals) deal with policy problems in

ways consistent with their objectives, capacities, and constraints. These factors, considered determinants of policy in the bottom-up approach, are largely outside of direct government influence. For example, Hjern and Porter (1981) speak of an 'implementation structure' to refer to linkages between implementing agencies (public as well as private) at the level of policy delivery. According to the authors, top-down orchestration of implementation structures tends to be limited. Instead, these arrangements between implementers are highly self-selected. A structure is characterized by goal variety, absence of authority relations between actors from different organizations, and substantial amounts of local discretion. Hjern and Porter therefore argue that the cluster of implementing organizations should be the unit of implementation analysis. Other prominent scholars in the bottom-up tradition stress the role of frontline staff and how they use their local knowledge of the problems faced by their clients. In solving the problems, frontline staff may take action that is inconsistent with the instructions from above. For example, Lipsky (1980) coined the term 'street-level bureaucrats' (SLBs) to refer to the frontline staff of agencies that implement policy. SLBs develop strategies, procedures, and instruments to cope with uncertainties and work pressures such as large caseloads and 'limited resources to deal with unlimited needs'. SLBs may tweak instructions coming from above to make policy implementable. They can do so because of the relative autonomy and freedom they enjoy in the capacities of being experts/close to the client. One central point made by Lipsky is that choices and actions by SLBs amount to de facto policies.

2.2.3. The synthesis approach to studying policy implementation

The top-down as well as the bottom-up approach stress agency in policy implementation. The top-down approach does so by suggesting that policy implementers engage in the activity of forging links in an implementation chain and/or testing policy hypotheses. The bottom-up approach on the other hand stresses agency by emphasizing the capacities of implementers to self-organize, interpret policy, and use creativity and discretion to make vague or ambiguous policies operational. Thus, both approaches to understanding the pathway(s) (and deviations from the pathways) from policy enunciated at the level of government to the actual impact of the policy imply that one needs to identify relevant agents with a mandate to implement policy. Once identified, it becomes relevant to understand how the agents' choices influence the implementation process and how choice relates to policy outcomes. Some scholars have attempted to marry such insights. This has given rise to synthesis approaches to studying policy implementation. The synthesis approaches converge on the notion that lower-level decision-makers (e.g. bureaucrats) influence policy outcomes but that the action space of those implementers is limited by central steering. For example, Elmore (1985) complemented his concept of backward mapping with the notion of forward mapping. He argued that policy stability, as well as change, were contingent on

policy-makers' ability to match policy instruments and resources (forward mapping) with the incentive structures and capacities of implementers (backward mapping). Majone (1980) suggests that administrative arrangements (e.g. regulations, procedures, organizational structures, institutions, etc.) may form protective belts around a 'policy core' (e.g. privatization of healthcare). This may make it difficult for implementers as well as policy-makers to abandon a policy at the first sign of difficulties. Yet, the achievement of policy objectives may still hinge on implementers' ability and willingness to support the policy core. This involves taking actions such as selecting and solving sub-problems and achieving sub-objectives to protect the core and avoid actions that weaken it. Majone (1980) expresses a top-down view on policy implementation as his position implies that implementers are preoccupied with making original policy formulations work (the policy core). However, we can also note that he takes a bottom-up approach in the sense that he places great emphasis on the creativity and capacities of agents working at the lower level of policy-making.

Proponents of the synthesis approaches typically recognize that implementation takes place in political, complex systems. Such systems are for example characterized by multiple and diverse actors who may have different interests, capabilities, and stakes invested in the policy objectives. According to Hill and Hupe (2002), the German scholar Fritz Scharpf was one of the early proponents of a network-oriented approach to understanding public policies. At the end of the 1970s, Scharpf (1978) argued that policy formulation and policy implementation are shaped through interactions between a variety of actors, each with certain interests, objectives, and strategies. Against this background, Scharpf suggests that implementation analysis must focus on issues of coordination and collaboration between interdependent actors, and factors the facilitating and impeding factors (Hill and Hupe 2002). This network-oriented approach to implementation analysis resonates with later work by scholars in the synthesis tradition. O'Toole (2012) suggests that successful implementation is dependent on cooperation and collaboration between independent actors. In the context of inter-organizational structures of implementation, managers and administrators cannot take for granted that their choice will be supported. Instead, they need to actively build that support. Communication, bargaining, and the ability of managers/administrators to assess and navigate the inter-organizational settings are thus central features of this type of horizontal implementation arrangement. Inter-organizational arrangements for implementation that depend on a chain of actions – where the output of one organization's action is the input to another – may incentivize collaboration while at the same time place higher demands for efficient coordination and reciprocity among implementers (O'Toole 2012).

Goggin et al. (1990) argue that neither the top-down nor the bottom-up approach to implementation research take into account that implementation occurs on several levels that interact in one way or the other. Understanding how the interaction plays

out is important for a deeper understanding of the relationship between policy and implementation outcomes. The authors suggest that implementing actors negotiate the content of decisions with central authorities. The former, they argue can be considered political actors too, and implementation can be viewed as communication between central and local levels of government. Goggin et al. (1990) argue that communication signals (or 'messages' using the authors' language) may be interpreted differently by actors at the top and the bottom level, respectively. They suggest that this can be explained by variations in the contextual conditions between the two levels. Ripley and Franklin (1982) similarly argue that to model an implementation process, contextual factors such as the number and nature of stakeholders involved and their form of interaction must be taken into account. They also suggest that stakeholder interaction varies with the type of policy to be implemented. From this perspective, policy type should be a variable in any analysis aimed at understanding implementation processes and outcomes.

Freeman (2007) suggests that policy practitioners, such as bureaucrats, combine different types of knowledge during implementation. He refers to this as 'epistemological bricolage' denoting that implementers piece together bits of information and experience that fits their local context (p. 476):

> assembling and literally making sense of different bits of information and experience, often creating something new from what they have acquired secondhand. It shows how much policy making is knowledge work, and how learning might be thought of as a process of epistemological bricolage.

Kiser (1984) uses the notion of co-production to refer to when end-users such as citizens together with government agencies produce policy outcomes. From this perspective, implementation is extended to involve the choice and preference of the target group of the policy. A policy only succeeds insofar as the target group is inclined to cooperate with the implementing actors. Kiser (1984) uses the example of investigatory services by the police. He argues that the police's task to reduce crimes in a neighborhood is dependent on the collaboration of citizens living there. When collaboration occurs, police and citizens can be said to coproduce the outcome of improved neighborhood security.

Through the 'integrated implementation model', Winter (1990, 2012) tries to capture some of the main variables deemed important in the top-down approach (e.g. policy objectives, causal theory, and policy instruments) and the bottom-up one (e.g. implementation behavior of organizations and individuals), and how they may link up to one another (fig. 4.). In the model, he also incorporates the influence of the socio-economic context and various feedback loops between policy formation (formulation and design), the implementation process, and outputs and outcomes.

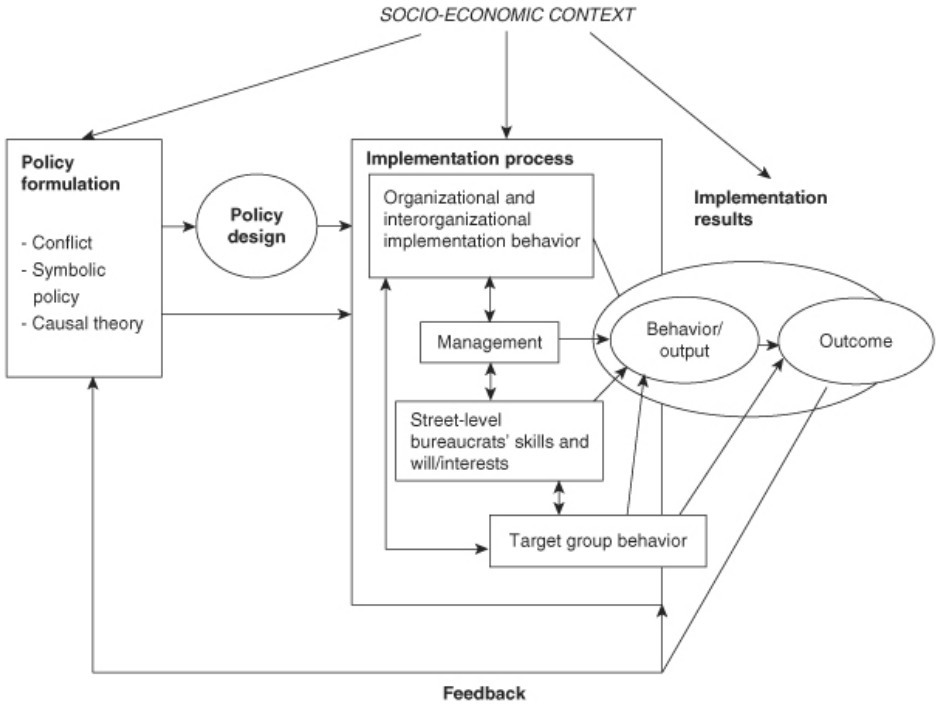

Figure 4. Integrated Model of Implementation. Source: Winter 1990, 2012.

The view on implementation as a highly complex activity characterized by vertical and horizontal linkages between policy-makers, implementers and outcomes, sensitive to policy type, and susceptible to contextual factors such as socio-economic condition, type of implementing organization, and SLB discretion, have prompted some to call for theories of the middle range (e.g. Goggin et al. 1990; Shea 2011). Middle-range theory differs from grand theories or meta-theories in the sense that they are more limited in scope and less abstract. They typically address specific phenomena, reflect practice, and are context-specific (e.g. Merton 1968).

In summary, this part of the literature review focused on approaches to studying policy implementation. From a traditional top-down perspective, implementation is treated as an administrative/technical process of achieving policy objectives, one that is amenable to structuring and control by policy-makers from the top (e.g. Sabatier and Mazmanian 1979; Mazmanian and Sabatier 1980). Bottom-up implementation theory on the other hand predicts that key terms of the original policy formulations will be operationalized by the implementer (aka frontline staff), and that interpretation, local sense-making, discretion, and creativity play important roles in that activity (e.g. Steinberger 1980; Coleman et al. 2010; Lipsky 1980; Freeman 2007). These processes may result in adjustments of the original policy.

The synthesis approach to studying policy implementation suggests that aspects of the top-down and the bottom-up approach can fruitfully be combined to elucidate how implementation involves iterations and communication between different levels of policy-making. Proponents of this approach also argue that theories of implementation should be sensitive to contextual factors, since these may differ between implementation situations (Goggin et al. 1990; Shea 2011). For example, policy type should be a variable in any analysis aimed at understanding implementation processes and outcomes (e.g. Ripley and Franklin 1982).

The next section of the literature review specifies the argument of why an implementation perspective on priority-setting may constitute a fruitful approach to gaining new insights into some of the central factors that mediate between political enunciations of RDI priorities and the point of delivery of RDI results. The section does so with a special focus on functional/institutional priorities. It focuses on some aspects of implementation research that are particularly relevant for analyzing the implementation of this type of priority viz. the role of theory in policy, interpretation, and choice.

2.3. RDI priority-setting and implementation

Section 2.3. is the last section of the literature review. In this section, the thesis will provide an implementation perspective on priority-setting.

One aspect of the top-down perspective emphasizes the role of theory in policy and policy-making. For example, Pressman and Wildavsky (1973) argue that policy implies theory in the sense that policies formulate and link together desired end results (objectives), initial investment/condition to achieve the objectives, and assumptions about what mediate between conditions/investment and outcomes/objectives. Evaluation research frequently refers to such cause-effect schemes as 'normative (program) theory', 'logic model', 'policy theory, 'espoused theory', or 'outcome line' (Chen 1990; Funnel 1997; Majone 1980; Argyris 1980; Mohr 1995). The terms denote what designers intend with a (policy) program. These terms can be distinguished from 'causative theory' or 'theory-in-use' which describe the observed relationship between an intervention and an outcome (e.g. Chen 1990; Argyris and Schön 1974). Similar to Pressman and Wildavsky (1973), Sabatier and Mazmanian (1979) use the term causal theory to refer to normative program theory/ espoused theory. They argue, a 'sound' causal theory i.e. one that accurately relates changes in target group behavior to the attainment of policy objectives is a necessary condition for successful implementation. They suggest that most policy decisions are based on a causal theory and that causal theory has a technical component. This component may be a scientific theory, hypothesis, or

narrative[6] (e.g. that human activities cause pollutant emissions and that there is a relationship between air quality and emission levels). The authors predict that if the technical component is flawed or incorrect, the causal theory underlying the policy as a whole will fail to generate desired results. Applied to priorities for RDI, this aspect of the top-down perspective on implementation directs our attention to the causal assumptions that underlie the priorities, or the priorities' normative program theory/espoused theory (hereinafter priority program theory). These are assumptions about how science policy objectives are best achieved. In the context of functional/institutional priorities, priority program theories typically relate effective interactions between key actors in the innovation system to outcomes such as novel RDI results with the potential of providing solutions to complex social and technical problems. By drawing on Sabatier and Mazmanian's (1979) notion of 'sound' causal theory we will in the next section see how constructing sound causal theories for RDI priorities may be challenging for policy-makers. We will also see how this challenge motivates a bottom-up/synthesis perspective on the implementation of RDI priorities as fertile ground for understanding how priority-setting for RDI is enacted.

2.3.1. The bottom-up/synthesis approach and implementation of functional/institutional RDI priorities

The bottom-up approach directs our attention to how vague or ambiguous policy formulations may be an effect of political conflict and compromises, and how the vagueness/ambiguity may constitute implementation challenges as well as opportunities (cf. Nakamura and Smallwood 1980; Matland 1995). There is no reason to believe that science policy differs from other policy domains in this regard. However, vagueness or ambiguity in RDI priorities may also be a result of the epistemic difficulties associated with planning for RDI results. While predicting/anticipating policy impact is a challenge to policy formation across all policy domains, the uncertain nature of knowledge production may make that challenge even greater for RDI priority-setting (cf. Pickering 1995; Hacking 1983; Knorr-Cetina 1981; Ziman 1984; Yaqub 2018). The fact that emergent scientific theory often plays a role in RDI priority program theory may add to already existing challenges associated with vagueness and ambiguity.

In the context of functional/institutional priorities, the role played by emergent theory can be illustrated with the use of notions of collaboration/co-production of

[6] Sabatier and Mazmanian (1979) label this the "statute's "technical" theory" (p. 485) or "the "technical" component" underlying causal theory (p. 486). The other component is a compliance component. It specifies "the means by which target group compliance can be obtained" (p. 486). According to the authors, both components must be valid, or else the policy objectives will not be achieved.

knowledge. These include innovation system theory (Lundvall 1992), the Mode 2 thesis (Gibbons et al. 1994), post-academic science (Ziman 1996), and the Triple Helix Model of collaboration (Etzkowitz and Leydesdorff 2000). Broadly speaking, these frameworks for transdisciplinary collaboration build on assumptions about how collaborations across sectoral boundaries and between diverse actors and types of expertise co-produce knowledge, and how the collaboration/co-production benefits research and innovation processes (e.g. Etzkowitz and Leydesdorff 2000). However, our present knowledge of the processes of 'co-production' is still limited (Polk 2015). For example, we know little about how arrangements for industry-university collaboration/co-production yield fruitful interactions between researchers (scientific knowledge) and users (practical knowledge), and the outcomes of that interaction (Hellström 2015).

As will be demonstrated below (see table 3), transdisciplinarity figures saliently in priority-setting/priority program theories. However, so does interdisciplinary collaboration – another framework/theory of how scientific knowledge is co-produced (see table 3). Transdisciplinary collaboration includes actors such as scientific knowledge producers (academic researchers) as well as users (e.g. firms), and public decision-makers and administrators (e.g. government agencies) and takes place in the context of application (e.g. Gibbons et al. 1994). Interdisciplinary collaboration occurs between scientific knowledge producers/academic researchers. Interdisciplinarity, as a way to organize scientific knowledge production, can be a means to address complex problems/close knowledge gaps between disciplines (e.g. biology) and specialisms (e.g. molecular biology) (e.g. Karlqvist 1999). Since at least the 1970s, interdisciplinarity as a mode of collaboration between various specialisms has become a 'buzzword' among science policy-makers (e.g. Hoffmann et al. 2013). Yet, interdisciplinarity still lacks an agreed-upon definition (Klein 1990; Holbrook 2013). Some welcome that. Graff (2016, p. 778), in a review of the history, historiography, and sociology of knowledge of interdisciplinarity suggests that by acknowledging the heterogeneity of interdisciplinarity, we might stand a better chance to develop and understand it:

> The diversity of definitions, organization, scope, and scale across interdisciplinarity needs to be recognized. So do variations in the nature of collaboration. Despite the rhetoric of much interdisciplinarity, there is no one form of interdisciplinarity, and this recognition mandates distinct approaches to developing and understanding interdisciplinarity in different fields.

Both types of collaboration, transdisciplinarity and interdisciplinarity, are associated with uncertainties related to how the types of collaboration are best organized and governed, the internal dynamics of interactions between diverse expertise, and how organization and dynamics relate to outcomes. It is therefore clear that for policy-makers to choose the 'right' type of organizational arrangements/capacities for achieving policy objectives may constitute a science policy problem in its own right. However, policy-makers choose nonetheless and

their choices become evident in priority program theories. Table 3 below displays three representative examples collected from Swedish government's Research and Innovation bills that provide the case background to each of the three case studies of the thesis. In each example, the priorities embody normative (program) theory i.e. assumptions about how policy objectives are attained by a certain type of organizational arrangement for RDI. Paragraph(s) from the bills express causal assumptions that have been converted into cause-effect-schemes by the author, where text in italics represents an initial investment decided by the government, "→" represents a causal implication, and text in bold represents a hypothesized end result (i.e. the desired policy outcome).

Table 3. Examples of priority program theory, collected from the Swedish Research Bill 2004/05:80 (background to case study 1), the Energy Bill 2012/13:21 (background to case study 2), the Food Bill 2016/17:104 (background to case study 3)

Long-term state investments in centers of excellence hosted by institutes of higher education and not constituted as 'loose networks' → creative and attractive research environment where top researchers conduct research and critical mass develop → improves the national ability to concentrate resources in strategic research and innovation areas → a. develops areas of scientific strengths → research reaches the international frontier → **Sweden becomes a leading research nation** b. attracts the attention of knowledge-intensive industries → improves collaboration between researchers and industry where Sweden has comparative advantages → **Increases Sweden's competitiveness in the global marketplace** Source: Research Bill 2004/05:80, pp. 88-89 (translated from Swedish)
Swedish R&I investments → meeting places for industry and institutes of higher education, public actors and civil society organization → stimulate collaboration and contacts between actors in the innovation system → stimulate R&I that addresses the challenge of **safe, clean, and efficient energy** Source: Energy Bill 2012/13:21, p. 23 (translated from Swedish)
[By government support to strategic agenda-building for research and innovation in the food sector], the sector formulates its need for collaboration between established and newer actors → increase in needs-driven research and commercialization of research results → strengthened knowledge and innovation system → more interdisciplinary investments where economy and market are integrated with natural science research → increased production of food items → **increased employment, economic growth, and sustainable production and consumption** Source: Food Bill 2016/17:104, p. 79 (translated from Swedish)

Table 3 elucidates normative priority program theory as it pertains to connecting investments/priority areas to capacities/organizational arrangements for the achievement of desired policy objectives. It illustrates how the RDI priorities allude to frameworks/theoretical concepts of various types of collaborations for co-producing knowledge, be they transdisciplinary or interdisciplinary. The import of such theories into science policy more generally has been the focus of earlier

empirical research and subjected to problematizing. By an investigation into how innovation system theory (IS) and the triple helix model (TH) are used on the level of the funding agency, Jacob (2006) shows that policy-makers deploy IS and TH narratives in policies and programs "to foster cooperation among researchers, industry and the rest of the public sector" (p. 456). Her analysis also demonstrates the difficulties associated with transferring these theories into practice. For example, while concepts such as IS and TH are descriptive or analytical, funding agencies rely on program staff to translate and sometimes merge the concepts for operational/action-oriented purposes. According to Jacob, the outcome of such translation processes typically reveals discrepancies between theory and practice. Circumstances like these further highlight the need to take a bottom-up approach to analyze the implementation of functional/institutional priorities. Because while frames/choice of collaboration may be imposed from the top, the details of how arrangements/capacity-building for RDI is best organized and achieved are typically handed down to the implementers themselves (e.g. Hellström et al. 2017). To make functional/institutional RDI priorities implementable, implementers may by necessity resort to locally predicated interpretations/sense-making of key concepts about collaborations for the co-production of knowledge (cf. Steinberg 1980; Coleman et al. 2010) and epistemological bricolage (e.g. Freeman 2007). They may also need to exercise discretion to act on the interpretations and the new knowledge (cf. Lipsky 1980).

3. Research design

As previously stated, the thesis aims to improve our understanding of enacted priority-setting as a function of the choices, actions, and motives of RDI implementers. To do this, one needs to decide *where* in the science policy system relevant/impactful choices and actions can be studied. One also needs to determine *how* to collect information on how these activities are formed and constituted. This chapter describes the research design of the thesis, and in doing so, it addresses these two methodological questions.

The thesis adopts an empirical case study design. The case study method is particularly suited for understanding contemporary real-life phenomena in-depth and the relation to the context in which such phenomena are embedded (Yin 2009, p. 18). Broadly speaking, the phenomenon of concern in the thesis is the implementation of RDI priorities and how conditions and content for RDI emerge from how implementers/administrators organize and execute the implementation. The central units of analysis are the choices, activities, and motivations of the implementers. In addition, the thesis adopts a naturalistic approach (Lincoln and Guba 1985) where the researcher aims to "observ[e], describe[e], and interpret[t] the experiences and actions of specific people and groups in societal and cultural contexts […] to create rich, evocative descriptions of social phenomena" (Armstrong 2010, p. 880). This approach is particularly well-suited for research where knowledge about the people, their activities, and the conditions that are investigated is insufficient (Armstrong 2010). In the context of the thesis, the central empirical concern is with those implementers that have a public mandate to implement RDI priorities.

3.1. Case selection and material

The thesis builds on three cases, each selected on how it improves our understanding of the choices, activities, and motives of implementers of RDI priorities. The ambition has been to let the cases cover as broad a spectrum of key levels of implementation of RDI priorities as possible, from government/sector (case study 3) to agency level (case study 2) to research performer (case study 1), while at the same time spreading the cases across several 'implementation sites', i.e. sectoral concerns (energy and food) and basic research (excellence initiatives). In this way,

a ‘maximum variation sampling’ is achieved, which allows a broad spectrum of observations to be made (Miles and Huberman 1994).

Broadly speaking, “[p]olicy implementation is what develops between the establishment of an apparent intention on the part of the government to do something, or to stop doing something, and the ultimate impact in the world of action.” (O’Toole 2000 p. 266). Accordingly, the study of implementation excludes studying agenda-setting and policy formation, the latter taken to mean the processes of formulating and designing policies. The thesis departs from this notion and regards RDI priority implementation to begin once a policy goal is formulated (cf. Bardach 1977) and identifies key levels of the implementation of RDI priorities. As suggested above, each case of the thesis represents a key level. The thesis argues that key levels include those of the research performer, the funding agency unit, and the sector/funding agency.

The case variation aims to form complementary parts of a wider phenomenon, namely enacted priority-setting. This selection rationale is in line with the case approach of choosing representative or typical cases in the sense discussed by Yin (2009, p. 48). The selection of level and the representativeness of each case for that level are motivated below.

3.1.1. Case study 1: From funding program to research results – Building capacity and governing interdisciplinarity in a Center of Excellence environment (articles 1 and 2)

The first case study of this thesis represents the implementation level of the research performer. The selection of the researcher performer as a key level for the implementation of RDI priorities is quite simple. Due to their training, researchers are in the best position to produce novel knowledge, make methodological advances, develop new technologies, etc. Some argue that in the capacity of being an ‘obligatory point of passage’ for any science policy, researchers determine the outcome of policy objectives (e.g. Callon 1986; Latour and Woolgar 1986; Gläser and Laudel 2016). In this thesis, the research performer is represented by researchers operating at the Centers of Excellence (CoE). What is sometimes referred to as the ‘excellence turn’ in science policy refers to a concentration of funds to support research that has the potential to have transformative effects on its field (e.g. Gläser and Laudel 2016). One approach to excellence funding is to steer funds toward building CoEs. This thesis argues that such funding schemes constitute an institutional priority or a choice of organizational conditions taken by the funder on behalf of the research community (Hellström and Jacob 2012). Against this backdrop, it is a relevant case for this thesis, which focus on how functional/institutional priorities are implemented.

Countries have developed and implemented CoE funding as a part of their science policy mix since at least 2005 (Salmi 2009). The features of the funding (e.g. high volume, long-term) and of the CoE (e.g. interdisciplinarity, ground-breaking research, international visibility and attraction, and organizational robustness) show high levels of conformity across countries (Hellström 2011; Orr et al. 2011; Aksnes et al. 2012). Such features were also present in the studied CoEs. For example, the CoEs that received the Linnaeus Grant were subjected to a high volume, long-term funding aimed at achieving typical CoE funding objectives such as creating strong and competitive research environments, facilitating interdisciplinarity, stimulating scientific renewal, and influencing universities' strategic priorities.

3.1.2. Case study 2: From strategic sector priorities to funding programs and projects – The role of program officer discretion in the Swedish Energy Agency (article 3)

The second case study of this thesis represents the implementation level of the funding agency unit. The selection of the funding agency unit as a key level for the implementation of RDI priorities was based on the following. First, the view on research councils and sector funding agencies as intermediaries between policy priorities and science is well-established (e.g. Guston 1996; Braun 1998; Rip 1994; Van der Meulen 1998). Second and more recently, scholars have recognized that programmatic staff in funding agencies are key actors in strategic/agency priority implementation (e.g. Hellström et al. 2017). The latter constitutes a new and interesting empirical domain within the study of funding agencies, and as such warrants further attention.

The Swedish Energy Agency (SEA) was chosen as the case organization. Like many other RDI funding agencies, SEA has a clear government mandate to implement general government RDI priorities into strategic sector priorities for RDI, and subsequently convert the latter into funding programs and projects. And, like many other agencies, SEA has developed clear routines and organizational structures for formulating and implementing strategic RDI priorities. The latter typically falls on the agency's unit that works with R&I within the agency's key strategic themes (e.g. energy systems studies, fuel systems, transport, etc.). The units employ RDI program officers and rely on their expertise to efficiently define, identify, and procure knowledge and research to make the priorities implementable.

3.1.3. Case study 3: From government priorities to a strategic sector agenda for R&I – Conditions that facilitated choice and activities in building an R&I agenda for the Swedish food sector (article 4)

The agenda-building of an R&I strategy for the Swedish food sector was selected to represent the implementation level of the sector/funding agency. This level, as a key level for the implementation of RDI priorities, was selected based on recent science policy developments. For example, OECD (2016) suggests that science policies in several member states converge on the notion societal challenges, economic growth, and competitiveness are best addressed when R&I needs are identified and implemented from the bottom up. In this context, governments try to stimulate stakeholders from industry to develop a strong interest in implementing priorities and by doing so, also enhance interaction between key actors in the innovation system (OECD 2015b). This type of functional priority-setting, which has resulted in a proliferation of strategic agendas for R&I within and across sectors, is a result of the science policy trend. Against that background, this thesis argues that strategic agenda-building on the level of the sector/funding agency has emerged as a key level for priority implementation, in this case the implementation of functional/institutional government priorities for RDI. Agenda-building is typically coordinated by the firms and comprises priorities that are negotiated and implemented by various stakeholders. Agenda-building typically takes place within a time-bounded government initiative and is often funded by public agencies.

The selected case had these types of characteristics. For example, the agenda-building was triggered by a government bill, the national Food Bill of 2017, which had as a priority to improve food sector R&I collaboration. The underlying assumption is that by stimulating collaboration via agenda-building, the sector would improve its productivity and innovation capacity (and thus increase the food export) as well as achieve a more sustainable production and consumption of food (Food Bill 2017). A government agency was appointed to host the agenda-building and a budget for doing so was provided. The agenda-building was led by the firms but included also other actors such as research performers and related industries (e.g. IT).

Below is an illustration (fig. 5) of the case selection and the implementation levels and what they are constituted of in terms of implementation scope and key implementers.

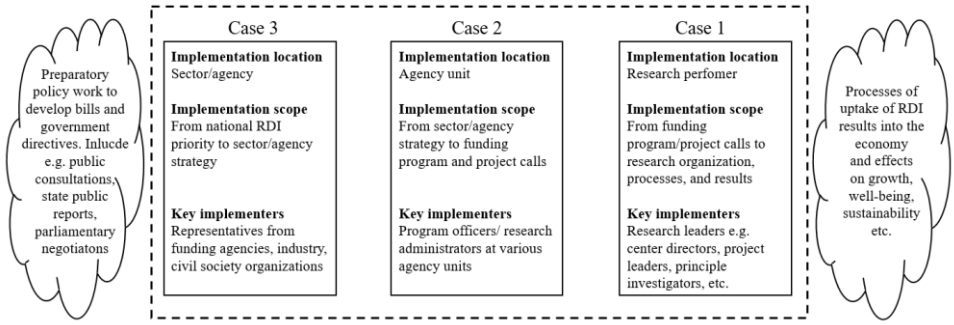

Figure 5. Overview of case selection. The scope of the explored RDI priority implementation in the thesis is illustrated by the dotted line. Boxes inside the dotted line describe the three studied levels of implementation of RDI priorities and key implementers.

3.1.4. Material

Table 4 summarizes the type of data sources of the thesis. Primary data refer to data generated by the researcher. Secondary data refers to data collected and structured by other actors. Data of primary relevance refers to data that relate directly to the research questions (although they do not always figure in detail in the results/analysis of the case studies). Data of secondary relevance refers to data that generate descriptions of the case context.

Table 4. Primary and secondary data sources categorized according to their relevance to the research questions.

	Primary data	**Secondary data**
Primary relevance	Accounts from RDI implementers at the level of: research performers (**case study 1**) funding agency unit administrators (**case study 2**) sector/agency management (**case study 3**)	the government bills containing RDI priorities (**all case studies)** Funding agency program and process plans, calls for proposals, external and internal evaluations (**case studies 1 and 2**) Project proposal, plans, and evaluation from the research groups (**case study 1**)
Secondary relevance	Accounts from Agency unit managers (**case study 2**) Agency coordinator and process consultant (**case study 3**)	International research directives e.g. OECD reports, EU strategies for related to the thematic and/or functional priorities (**all case studies)**

3.2. Data collection

The thesis deploys a qualitative research interview approach. The general aim of qualitative research interviews is to "understand the world from the subject's point of view, to unfold the meaning of their experiences, to uncover their lived world prior to scientific explanations" (Kvale and Brinkmann 2009, p. 1). The life world, as a topic for the qualitative research interview, should here be understood as "the world as it is encountered in everyday life" (Kvale and Brinkmann 2009, p. 29). The following are central components/assumptions of the definition of qualitative research interviews. First, interviewees (subjects) can provide descriptions of past events and give valid accounts of their actions and attitudes towards these. Secondly, these accounts can be subjected to systematic analysis where the interviewer interprets the meaning of what is said. Finally, the outcome of such analysis/ interpretation may be new explanations of social phenomena. Next follows a motivation for why the qualitative research interview approach is particularly suited for this thesis.

Realizing priorities set by someone other than the implementer involves making choices and performing activities/taking actions, and for such reasons, the thesis considers the implementers themselves the best sources of knowledge/information about how priority implementation unfolds. In contrast to, for example, surveys, semi-structured interviews may stimulate the interviewees to answer more on their terms. For example, semi-structured interviews typically give interviewees more space to answer the interview questions and latitude to steer the direction of the conversation as long as it keeps within the general research topics. The interviewer on the other hand has the flexibility to probe certain answers by follow-up questions (pre-formulated or arising from the discussion) or by asking for exemplifications (May 2011). Implementers are in a good position to describe the details of the process of how priority-setting is enacted on their level of implementation. They can also reflect upon 'what if scenarios', that is contra-factual events that may provide insights into the importance of various aspects of the processes and their bearing on results (e.g. what if you did not have access to complementary expertise during implementation?). Implementers can explain how and why certain choices were made during the implementation process, and link them to actual effects/results (as opposed to planned ones). Implementers can also describe how various factors/circumstances influenced (or not) the choice, activities and conditions for priority implementation. In doing so, the implementers themselves provide causal attributions relating to priority implementation.

The thesis uses semi-structured interviews to collect information about the interviewees' actions and experiences as they pertain to RDI priority implementation. In total, three interview studies were performed (case study 1 builds on the same interview study, but different analyses). For all studies, an interview guide was developed to support the interview. The guide structured the

interview according to a set of core topics and corresponding questions as well as some follow-up questions, posed if deemed necessary. Descriptive core questions concerned how implementation had unfolded. For example, interviewees were asked to give accounts of the sequences of implementation activities. More reflexive/analytical questions related to impacts of various kinds. For example, the conditions the interviewee deemed decisive for implementation or the relationship between activities/choice and effects. Interviewees were typically asked to provide examples when answering both types of questions, that is the descriptive and the analytical, respectively. All interviews were recorded and transcribed verbatim. Below is the motivation behind the selected interviewees.

In the first study, CoE directors were selected as interviewees. They were selected based on their central role in developing and managing the CoEs. In the capacity of leaders and highly distinguished researchers, they are in a good position to provide an overview of center activities, conditions, and results. Additionally, center directors are the main point of contact for the funder throughout all stages of center development, including mid-term and final evaluations of the centers. For that reason, directors are highly likely to be able to give accounts of how the relationship with the funder and the funder's objectives and modes of steering the CoE program influenced (or not) the CoE-building.

The second case study focused on how RDI program officers at the Swedish Energy Agency (SEA) implemented strategic priorities for energy relevant RDI. The program officers are rarely involved in formulating the strategic priorities but hold the responsibility of making the priorities implementable. We can assume this requires thematic expertise (e.g. technical knowledge of solar photovoltaic energy conversion systems) and knowledge about the need and capacities of research performers, as well as personal capabilities to navigate agency structures and routines to circumvent bureaucratic obstacles to efficient implementation. Interviewees were selected based on their administrative and executive roles in programs, on program boards, and in review and selection processes for RDI projects. Because of their roles, RDI program officers are in a good position to provide accounts of how SEA's strategic priorities are implemented. Interviewees covered program officers from a wide spectra thematic R&I areas. Personal referral was also used to identify relevant officers performing the tasks (Biernacki and Waldorf 1981).

The third case study focused on how representatives from the firms responded to government priorities aimed at improving R&I collaboration across the Swedish food sector's domestic value chain. Improved collaboration was one way in which the Swedish government assumed the sector would become more competitive and sustainable. Interviewees were selected based on their role in leading and coordinating agenda-building. They included members of a temporary steering group who oversaw the agenda-building process. Interviewees also include managers responsible for leading the three thematic themes/R&I areas of the

agenda. Finally, managers and analysts that coordinated various sub-themes under the three R&I areas were also interviewed. Taken together, steering group members, R&I area leaders, and sub-theme coordinators covered the main level of governance of the agenda-building.

Table 5 outlines implementation levels, the scope of implementation, and the type of implementer per each case study of the thesis.

Table 5. Description of the case studies in terms of the implementation level, the scope of implementation, and the implementer.

Case	Implementation level	Scope of implementation	Implementer
1	Research performer	From funding program/project calls to research organization, processes, and results	Research directors at ten Swedish Linnaeus Centers of Excellence
2	Funding agency unit	From sector/agency strategy to funding program and project calls	RDI program officers at the Swedish Energy Agency
3	Sector/agency	From national RDI priority to sector/agency strategy	Swedish food sector firms, in collaboration with the Swedish Agency for Growth and Economic Development and research performers

3.3. Data analysis

The data collected for studies 1-3 were analyzed using a general inductive approach. The approach is typically deployed to describe the actual effects of a program, as opposed to planned ones. While the research objectives provide the general focus of the inductive analysis, findings emerge from the analysis and not from a priori expectations (Thomas 2006).

According to Thomas (2006, p. 238), the general purposes of the approach are:

1. to condense extensive and varied raw text data into a brief, summary format;
2. to establish clear links between the research objectives and the summary findings derived from the raw data and to ensure that these links are both transparent (able to be demonstrated to others) and defensible (justifiable given the objectives of the research); and
3. to develop a model or theory about the underlying structure of experiences or processes that are evident in the text data.

As indicated in the purposes above, the process of conducting the analysis involves reducing the complexity of raw data by structuring and summarizing it. This was done by reading transcripts several times, interpreting the data in terms relevant, but not restricted, to the study objectives, and labelling text segments that the researcher

found meaningful using keywords and phrases to capture their content. These labels/codes were then used to assign the text segment to a more general category (a segment can be coded into several categories). Text coded into a category in this way typically signifies "meanings, associations, and perspectives associated with the category" (Thomas 2006, p. 240). During the process of coding, the researcher added a description to the category conveying the central meaning of the category. As several categories emerged, the researcher connected them by establishing relations of various kinds. In doing so, a system of categories could be created and worked into a model or framework abstracted from and symbolizing the textual data. In the present thesis, these models/frameworks were represented as conceptual typologies as well as temporal sequences and causal networks. Such a framework marks the end of the inductive analysis.

Data collected in the fourth and final qualitative interview study was analyzed using template analysis (King 1998). In contrast to the general inductive approach applied in the first interview studies, template analysis starts with general categories/codes identified a priori. The researcher derives these categories from an already existing, and usually at least partly, theoretically derived problem. Template analysis does not preclude the modification or removal of the categories, nor does it prevent the researcher from developing new categories. Text segments in the raw data that are relevant to the research question and correspond to an a priori category/theme, are coded as such. In the context of the fourth qualitative interview study, these categories concerned priority-setting/agenda-building activities, conditions perceived to facilitate the priority-setting, and outcomes of the priority-setting.

One of the challenges for inductive analysis is to ensure accuracy and consistency in the coding process. There are several ways in which to do this. The following approaches are based on strategies that both Thomas (2006) and King (1998) refer to as core approaches to ensuring accuracy and consistency. These include independent parallel coding where two or more coders engage with the same raw text and develop categories independently from each other. The coders then compare the results and decide how to proceed. When the degree of overlap is high, categories may be merged into combined sets. When overlap is low, coders may discuss how to adjust the analysis. This approach was deployed in studies one and two. In the third qualitative interview study, the raw text was first coded by the main author who also developed the initial set of categories. The second author then reviewed the categories and the raw data and came up with suggestions for revision. The two authors/coders discussed the revisions and settled on a final set of categories. A similar strategy for consistency checks was deployed in the fourth interview study. However, here the author recruited an external reviewer who gave feedback on the categories rather than revising them. The feedback resulted in some minor clarifications of the categories and their relation.

3.4. Reflections on the research design

The issue of internal validity was addressed under the section Data collection. The main threat to the internal validity of an explanatory study is when the study provides a false account of the factors that cause a certain effect. The researcher may incorrectly assume that factor *x* caused effect *y*, when in fact it was a third factor, *z* that caused y (Yin 2009). Above, it was made clear that semi-structured interviews were deployed to collect accounts of how the implementation of RDI priorities unfolded. These accounts contain causal connections/attributions identified by the respondent. Treating respondents' accounts as 'facts', in this case e.g. tentatively assumed correct descriptions of how RDI priority implementation unfolded, is an analytical posture in qualitative research. What the respondents say is what we take them to honestly mean and depict. It is based on the epistemological principle of charity, that is, if there are no reasons to doubt, then accept (Henderson 1987).

To reduce the risk of possible bias or falsehoods in the accounts, coherence and detail were emphasized and statements were factually scrutinized during the interviews and in the subsequent analysis. For example, during the interviews follow-up questions such as requests for exemplification and explication of background assumptions were used to get the respondents to elaborate statements/assertions.

External validity refers to if the conclusion of an explanatory study can be generalized beyond the present case(s) (Yin 2009). The issue of external validity was addressed under the section Case selection and material. In naturalistic inquiries, like the present one, the degree of analytical generalizability or transferability of a working hypothesis/finding/conclusion from context A to context B is a direct function of significant similarities between the contexts (e.g. Yin 2009; Kvale and Brinkmann 2009). Lincoln and Guba (1985) refer to this as fittingness i.e. "the degree of congruence between sending and receiving contexts" (p. 124). They go on to suggest that it falls upon the receiver of findings, and not the submitter, to assess if the findings are transferable from one context to another relevant context (Lincoln and Guba 1985, pp. 297-298). The thesis has taken several measures to facilitate the reader's assessment of the transferability of the findings to a new situation. It has, for example, provided background descriptions for each case. This measure was taken to contextualize the findings. The thesis also kept analytical summaries close to the content of the respondents' accounts. In doing so, it avoided over-interpretation and re-descriptions where the respondents' voices may be lost (e.g. King 1998, p. 133).

4.Summary of papers

4.1. Paper 1: Center of excellence funding: Connecting organizational capacities and epistemic effects

The study addresses the question of how a longer-term concentration of research funding may translate into novel results/discoveries. The study aims to identify mechanisms that mediate this relationship. It did so through a case study of a Swedish Center of Excellence (CoE) scheme. CoE schemes have increasingly become a science policy priority in many countries (Salmi 2009). The general program theory underlying CoE schemes predicts a scale return to research on the concentration of funds insofar as certain organizational conditions are created (e.g. co-location of researchers, a formal leadership/management structure, reporting and evaluation schemes, etc.). The study refers to the latter as institutional priority-setting, that is, the choice of organizational conditions taken by the funder on behalf of the researchers (Hellström and Jacob 2012). The study empirically investigates the relationship between resource concentrations, organizational capacities, and returns/epistemic effects (e.g. new scientific advancements). The qualitative case study comprises 10 of 40 CoEs that received a 10-year grant (the Linneaus Grant) in 2006 and 2008 respectively. The Swedish Research Council (VR) coordinated the grant. Semi-structured interviews were conducted with center directors. The interviews focused on the grant's effects on organizational capacity-building, governance activities, research processes, and results. The interviews were transcribed verbatim and analyzed using a template analysis (King 1998) where two broad categories were used viz. 'organizational capacities' and 'epistemic effects'. The result of the study is the identification of several capacity-building effects that can be attributed to the instrument itself (e.g. the instrument feature of stable financial guarantees) but also to how the CoEs directors choose to manage the CoE funds/instrument. Capacity effects can be attributed to the recruitment and development of international staff and junior researchers, resource investments and amplification of Matthew effects, and stimulation of cross-collaboration and knowledge-sharing. The interviewees tended to connect these capacities to discovery effects. The latter was identified as *epistemic integration and reach* (e.g. new collaborations between specialisms to address old and/or new problems in novel ways), and *epistemic venturing*, understood as risk-taking in terms of types of collaboration as well as addressing more risky research questions/problems. The

study explicates the mechanisms that mediate between resource concentration and epistemic/discovery effects viz. organizational arrangements facilitating slack (autonomy), availability of cooperative partners (critical mass), and concomitant cooperation between specialisms.

4.2. Paper 2: Governing interdisciplinary cooperation in Centers of Excellence

The study focuses on how directors of Centers of Excellence (CoE) used agency conditions, or institutional priorities set by the funder on behalf of the research community to stimulate, develop, and govern interdisciplinarity within the CoEs. The empirical study aims to identify linkages between internal governance activities for interdisciplinarity (ID) and the capacities that facilitate ID and research outcomes. The CoE funding scheme of concern to this study belongs to the family of science policy funding instruments that provide long-term, high-volume resources to basic or strategic research (and to a lesser extent, development). These schemes typically require top researchers to adopt formal leadership roles and to use the roles to build up environments conducive to ID. The ID requirement has emerged as a significant aspect of what can be understood as an institutional priority for science. Over ten years, a total of 40 CoEs were funded by the Linneaus Grant. The grant was coordinated by the Swedish Research Council (VR). This study uses a qualitative Small-N study that includes 10 of the 40 CoE. Semi-structured interviews were conducted with CoE directors. In some cases, the directors were accompanied by co-directors. Questions focused on the grant's effect on the organizational development of the CoE, center activities, and research processes. The interviews were transcribed verbatim and data was analyzed using a general inductive approach (Thomas 2006). The study identified several governing activities/choices by CoE directors that stimulated new capacities for ID in the CoE setting. The study also identified research outcomes/effects attributable to the new ID capacities. Activities/choices refer to training/nurturing a base of cross-cutting specialisms (e.g. setting up ID supervision teams for doctoral students), creating proximity and promoting slack (e.g. promoting permeable center boundaries and institutionalizing informal meeting places), and encouraging open-ended lines of inquiry (e.g. flexible allocation of funds and balancing focus and spontaneity). New capacities for ID include shared interests/complementary expertise, collaborative mindsets, and lower thresholds to start collaborations. Effects related to the new capacities comprise new research niches, verification/result transfers, and new lines of inquiry. From the results, the authors conclude that the directors' mindset of how ID is best governed, is central to creating pathways from institutional requirements for ID to outcomes. For example, directors seemed to think that ID should be stimulated rather than enforced. However, the study also concludes that directors

were able to build an interdisciplinary environment by using conditions provided by the CoE scheme. These facilitating conditions include on the one hand high-volume, long-term funding that the CoE directors could use fairly flexibly to stimulate lines of research that demanded an interdisciplinary approach. In addition, the CoE scheme expected the directors to take up formal leadership over the CoE. The directors could use this condition to exercise discretion over the internal CoE governance such as making and implementing choices of how ID was best stimulated.

4.3. Paper 3: Street-level priority-setting: The role of discretion in implementation of research, development, and innovation priorities

The study explores the phenomenon of 'street-level priority-setting', by focusing on how program officers at the Swedish Energy Agency (SEA) implement strategic priorities for RDI and in the course of doing so, make discretionary decisions. The study addresses the larger issue of how we can understand the factors involved in the process of translating national priorities into funding agency RDI programs, which may later structure objectives and organizational conditions for RDI performers. The study investigates empirically how program officers (POs) at SEA use discretion to make policy priorities for RDI operational. POs typically face several challenges during the implementation of RDI priorities. Some of these refer to the quality of the priority itself (e.g. it may be formulated in vague or ambiguous terms), others to institutional obstacles (e.g. agency path-dependencies, unrealistic or multiple expectations/demands on POs, and limited resources). The study uses the concept of 'street-level bureaucracy' (SLB) (Lipsky 1980) to understand how such discretion is exercised by the POs. In a specialized agency such as SEA, POs define, identify, and procure relevant knowledge and research with a varying degree of insight from the top. POs are also close to the clients, in this case public and private RDI performers who apply for grants. Under circumstances like these, SLB theory suggests that POs will exercise high levels of discretion with regard to priority implementation. The study used an inductive design, where the unit of observation was the POs and the unit of analysis was the discretionary activities they perform. A total of 17 semi-structured interviews were conducted, focusing on questions related to priority-setting activities, implementation of priorities, and facilitators and obstacles for priority implementation. Interviews were transcribed verbatim and analyzed using a general inductive approach (Thomas 2006). The results revealed four general dimensions of PO discretion in priority implementation. POs use discretion to (i) regulate the inflow of new knowledge and ideas, (ii) interpret the relationship between strategy and program design, (iii) tweak

and apply selection criteria, and (iv) determine the agency portfolio's balance between basic research and application/innovation. One of the central conclusions of the study is that POs exercise significant discretion in developing the routines for prioritizing in the agency and that this has an effect on the type and content of priorities. Additionally, they use discretion to formulate content for RDI as well as the way RDI is organized, e.g. creating new social conditions for interaction between research performers, developers, and innovators. Taken together, this amounts to several de facto priorities that emerge from the discretionary choices and activities of the POs.

4.4. Paper 4: Facilitating collaborative priority-setting for research and innovation: a case from the food sector

This is a qualitative case study into how firms, in collaboration with researchers and a government agency, developed goals and a strategic R&I agenda for the Swedish food sector. Such goals may for instance refer to increased national competitiveness, sustainability, and/or new interactions between key stakeholders in the innovation system. The study addressed how process conditions and stakeholder choices for specifying national R&I priorities in the food sector affected the way such priorities were formulated. This study identified activities and choices involved in developing strategic agendas for R&I, and the conditions that facilitate the development. Government stimulation of strategic R&I agenda-building is a science policy trend that can be observed across several European countries. While there are variations, the general policy design attempts to bring the industrial needs of R&I-intensive sectors to the fore, while at the same time stimulating the engagement of other relevant stakeholders, such as public and private research performers. The studied priority process/agenda-building took place between 2017 and 2018. It was hosted by the Swedish Agency for Growth but led/coordinated by firms from the Swedish food sector's value chain (e.g. primary production, food processing industry, and retail industry). 18 semi-structured interviews were conducted with participants holding leadership roles in the priority-setting/agenda-building. In addition to these respondents, the agency coordinator, as well as a process consultant, were interviewed. Interviews focused on process activities, moments perceived as decisive, and the results of the process. The interviews were recorded and transcribed verbatim and transcripts were analyzed using template analysis (King 1998). The researcher also observed priority-setting activities from December 2017 to May 2018 by participating in a total of 17 meetings. The main results of the study are the identification and elaboration of the main process activities and choices involved in the prioritization viz. adjusting scope (e.g. regulating participation and

priority content) and mapping out content components of the priorities and their relation (e.g. hypothesizing links between areas of investment and desired effects). The main results also comprise the identification and elaboration of the local conditions perceived to facilitate activities/choice, viz. government resources and time availability, mixed bottom-up/top-down steering, and complementary expertise. Additionally, the study shows where in the agenda-building the various conditions had facilitating effects. The study suggests that insights into these 'intermediate/micro-level relationships' of priority-setting/agenda-building can assist policy-makers as well as managers who aim to create sector consensus on R&I priorities.

5. Discussion

The thesis has focused on how choices made by implementers of RDI priorities affect the way the priorities are 'de facto' established and executed at various levels of the science policy system, or in other words, how RDI priority-setting is enacted into new conditions for the production of RDI. This discussion will focus on the results of the case studies in terms of the relationship between implementers' key choices, actions, and new conditions for RDI production.

The thesis identified three key levels on which the enactment of priority-setting takes place. It did so by focusing on three major trends in science policy. The trends of concern were: strategic agenda-building for research and innovation (e.g. OECD 2015b, 2016), the rise of competitive RDI funding and the growing influence of public funding agencies as mediators between science and policy (e.g. Braun 1993; Guston 2001), and funding of excellence research, aka the 'excellence turn' (e.g. Gläser and Laudel 2016). The corresponding levels included that of *the sector*, where stakeholders from industry, academia, and government typically engage in collaborations to convert policy objectives to strategic sector agendas for R&I (**case study 3**); the levels of the *agency unit* where RDI program officers typically translate sector priorities into funding programs for RDI (**case study 2**), and; the level of the *center of excellence management*, where center directors/leaders use funding conditions to build organizational capacities for knowledge production (**case study 1**). The maximum variation sampling approach (Miles and Huberman 1994) applied in this thesis has allowed a broad spectrum of observations to be made across the key levels of RDI priority implementation (i.e. the level of the sector, agency unit, and research performer/CoE management) as well as across a diversity of implementation sites (i.e. energy relevant RDI, food-oriented RDI, and excellence initiative/research). Each case was selected based on its theoretical relevance. To keep the larger policy context constant, the thesis used Swedish cases.

Each of the three case studies unveiled in significant and empirically grounded ways, choices, actions/activities, and motivations involved in enacting priority-setting for RDI. These choices and activities are performed by agents who directly, or indirectly via their organizational belonging, hold government mandates to implement priorities (cf. Lipsky's 1980 notion of 'frontline staff'). The case studies have unpacked several aspects of the priority-setting-implementation nexus that is, the interface between RDI priorities and the production of new RDI conditions. These conditions refer to ways of organizing RDI production through various

collaborative schemes/arrangements (**all case studies**), to new RDI themes for future RDI production (**case studies 2 and 3**), and to actual, novel results that advance research and technological development, and use (**case study 1**).

The remaining sections of this chapter will discuss the results of the three case studies in their totality. As the discussion will show, by focusing on similarities across the diverse samples it is possible to extrapolate from the three case studies some basic patterns of RDI priority implementation. In doing so, the thesis elucidates some aspects of behavioral similarities between actors who traditionally are perceived to belong to different policy cultures (cf. Elzinga and Jamison 1995). The notion of policy culture denotes that actors operate within a set of traditions, norms, values, and interests/perspectives on science and that these may differ between that academic (science), bureaucratic (government), economic (i.e. industry), and civil society (e.g. social movements and non-governmental organizations) actors. The thesis demonstrates that while the implementing agents can be considered as belonging to different policy cultures, they are also subjected to similar pressures, implicitly or explicitly, to make political priorities for RDI operational.

The underlying pattern as it pertains to choices, activities, and outcomes/new conditions for RDI production emerges when the empirical material from the three case studies of this thesis is combined. The empirical pattern can be explicated in the following way. New conditions for RDI production (e.g. strategic sector agendas for R&I, RDI funding programs, and research organization/scientific advancements) are shaped by implementation activities that are highly interactive and involve different types of expertise. These interactions typically have a social aspect (e.g., they involve persuasion/advocacy, relationship-building, and creating consensus, etc.) and a cognitive aspect (e.g. they involve creativity in making assessments and problem-solving, knowledge-transfers, and learning, etc.).

How these interactions shape the new conditions depend largely on discretionary choice of how to organize the interactions. The choices are discretionary in the sense that rather than being based on instructions 'from above', the implementers who make them typically base the choices on what they perceive to benefit effective implementation, and in some cases what goals and sub-goals they prefer realized. This type of choice is typically made bottom-up (in relation to policymakers), by a relatively small share of implementers within, and on behalf of, a larger implementation organization. One aspect of 'discretionary choice' of how to organize interactions between different types of expertise can be considered cognitive. That is the case when the implementer's choice is made with the main intention to stimulate creativity such as mutual problem-solving between different experts. Another aspect of choice appeals to the social, that is, when the choice of how to structure interaction is motivated by what the implementer perceives to stimulate socialization among implementers of different expertise. The empirical patterns explicated above are illustrated schematically in table 6.

Table 6. Empirical relationship between discretionary choice and new conditions for RDI production.

Discretionary choice of how to organize interactions (stimulates) →	**Interactions between expertise** from which new relationships and knowledge/insights emerge (shapes) →	**New conditions for RDI production** e.g. new themes, collaborations, and novel knowledge and methods

The discussion is divided into two sections. The next section (5.1) focuses on the relationship between discretionary choice, interactions between expertise, and new conditions for RDI production per each case study. The final section (5.2) discusses the approach to analyzing the implementation of RDI priorities – one that brings to the fore choice, actions/activities, and motivation of implementers – in relation to the strands of science policy literature concerned with the relationship between policy and RDI production.

5.1. The relationship between discretionary choice, interactions, and new conditions for RDI production

This section discusses the relationship between discretionary choice, interactions, and new conditions for RDI production in each case. The discussion will elaborate on how new conditions for RDI production can be understood, the interactions from which the conditions emerged, and the choices involved in organizing the interactions. The discussion will show how interaction and choice can be understood to have social as well as cognitive aspects. The main point of doing so is to elucidate how the implementation of RDI priorities is an aggregation of social motivations and actions as well as cognitive ones, and that to fully grasp the creation of new conditions in terms of de facto priority-setting or 'priority implementation', both these aspects must be taken into account.

5.1.1. Using funding conditions to build capacity for research

The first case study focused on how research directors at centers of excellence (CoE) used funding agency conditions to enable scientific organization-building and performance. It is vital to keep in mind that the choice, interactions, and outcomes discussed below took place in the context of high volume and stable/long-term funding. They also took place in an environment where the funder required the applicant to develop formal leadership functions. As demonstrated by the case study, the directors used these conditions to exercise discretion over how CoE research production was organized within the centers. For example, the stability

provided by the long-term grant in combination with the directors' mandate to make organizational choices of how to build capacity and manage staff appeared as key conditions for how the directors stimulated excellence/interdisciplinary research within the CoEs. Case study 1 also links interdisciplinarity to epistemic effects such as new knowledge and novel methods/instrumentation. The key insights for this study will be discussed under the heading of 'Interactions and new conditions', and 'Choice and interactions', respectively.

Interactions and new conditions

New conditions for research production, as outcomes of the implementation of the CoE scheme, may be understood in terms of how they were shaped by interactions between researchers. This part of the discussion centers on the cognitive and social aspects of the interactions that stimulated new connections between specialisms/integration of expertise (hereinafter *epistemic integration*). The thesis considers epistemic integration a new key condition for knowledge production within the CoEs. This is supported by the findings in case study 1 that demonstrate in various ways how epistemic integration constituted a bridging condition, one that yielded more epistemic effects downstream, or additional new conditions for research production if you will. Such further epistemic effects/new conditions included the creation of new niches between different fields, speeding up new initiatives/lowering thresholds for starting novel projects (incl. increased risk-taking), and ultimately the development of new knowledge and novel methods/instrumentation that start affecting new inquiries/explanatory models. The thesis argues that epistemic integration emerged from interactions between CoE researchers and that the interactions can be categorized as cognitive and social. As will be seen below, it is not a matter of 'either or' but rather of an interplay between the social and the cognitive that appears to shape epistemic integration.

One main aspect of epistemic integration, as a new condition for knowledge production, is the emergence of *new perspectives on the researchers' own disciplines/specialisms or epistemic orientation* (e.g. basic/applied) (cf. Klein 2010 on interdisciplinarity as an amalgamation of disciplinary perspectives or 'critical interdisciplinarity'). This aspect of epistemic integration emerged from *repeated interactions* between researchers, where researchers gradually appeared to have changed their attitude to the research of their colleagues and developed shared interests and mutual respect. Such interactions had a strong social aspect in the sense that they involved developing mutual language/ways to communicate across cognitively distant specialisms and epistemic orientations. A more profound social aspect of the interactions was that they involved practicing patience and subsequently building respect among researchers. For example, repeated interactions stimulated resilience to what sometimes appeared as 'silly' questions or even seemingly adverse attitudes (e.g. having their research questions viewed by their colleagues as trivial or irrelevant) and eventually developed into mutual respect

between researchers. The cognitive aspect of the interaction refers to assessments and learning. During the interactions, where researchers discussed intellectual problems, they started to identify parallels between cognitively distant disciplines (e.g. between clinical oncology and biology or between biology and physics) or specialisms (e.g. distant specialisms within the discipline of biology). In fact, as a part of the learning process, researchers took an important step towards developing new perspectives on their own discipline, viz. to look at problems from new perspectives/perspectives of the interacting discipline/specialism discipline.

While repeated interactions provided immediate benefits to individuals and individual projects, interactions also stimulated broader *academic community-building and research vitalization*. This more cultural/macro aspect of epistemic integration appeared as essential to building and maintaining a progressive intellectual CoE environment. The sustainability of community-building/vitalization/ hinged on continuous interactions between CoE members. For example, community-building/vitalization could be sustained and developed by informal but reoccurring encounters between specialism within the CoEs. During such interactions, researchers shared with a wider audience of colleagues (not necessarily directly engaged in the individual project organization) intellectual problems hindering them from making advancements. This type of interaction can be considered cognitive in the sense that it involved knowledge-sharing and exchanging epistemic advice on how researchers/groups could move inquiries forward. The social aspect of these broader types of interaction can be understood from how they involved building openness, tolerance, and transparency that appeared particularly beneficial to junior research staff (PhD students and post docs). For example, the character of the interactions demonstrated that asking for support was encouraged in the CoEs and contributed to the notion of CoE members as belonging to a community where one could vent one's problems (and receive support) as opposed to only sharing results/successes.

It should be noted that not all epistemic effects identified in case study 1 hinged on epistemic integration. For example, rather than closing disciplinary boundaries researchers would also use the expertise of others in a complementary fashion to take on a wider range of problems (cf. the notion of 'instrumental interdisciplinarity' by e.g. Salter and Hern 1996). This type of division of epistemic labor reportedly made 'science more efficient'. Yet the type of interactions from which it emerged, displayed cognitive aspects. This was the case when interactions stimulated the researchers to learn about the state-of-art of other fields. Also, social aspects of the interactions can be identified, such as involving unconditional networking with other researchers/complementary expertise not necessarily represented in the research group.

The next subsection discusses *how* the directors stimulated interactions from which epistemic integration emerged.

Choice and interactions

Organizational circumstances that facilitate epistemic integration/interdisciplinary research include continuity in funding (e.g. Pfirman and Martin 2017), high levels of autonomy among research units (e.g. Sá 2008), and institutional support from the host university (e.g. Lattuca 2002). These findings resonate with several of the results of case study 1. However, the case study also identifies ways in which the CoE directors themselves facilitate capacity-building in general, and epistemic integration/interdisciplinary in particular. In fact, these two governance activities appear to be synonymous in the context of the studied CoE setting. The directors could use conditions created by the CoE schemes to build management capacities (e.g. by exercising formal leadership of the CoEs) and use the capacities to structure the interactions from which epistemic integration emerged. From this perspective, epistemic integration was not simply something that emerged bottom-up (cf. Pfirman and Martin 2017). It was instead stimulated top-down by the directors. This subsection focuses on what the case study identified as key discretionary choices made by the research directors. These choices enabled interactions between specialisms and epistemic orientations (i.e. basic and applied sciences). Again, it is important to keep in mind that the stable and high-volume funding provided by the grant afforded the directors to make several important discretionary choices. Case study 1 suggests that fruitful interactions appear to strongly relate to managing a network of specialisms. We will now view this broader activity of the directors as consisting of three general types of discretionary choice (also identified in case study 1) that stimulated interactions from which epistemic integration emerged. As we will see in the discussion below, social and cognitive aspects are present also in choice-making.

The first type of discretionary choice refers to *ensuring and nurturing a base of cross-cutting specialisms* in the CoE's network. A dominant pattern within the CoEs was the recruitment of junior researchers (doctoral students and post docs). A cognitive aspect of the choice relates to the motivation/assumption by the directors that junior staff stimulates cross-collaboration in the CoE. Directors tended to consider junior staff to be of an 'open mindset', good at seeing epistemic connections between research groups, and thus more receptive to venture into new types of collaborations where they would act as glue/bridges between disciplines. For the CoEs to take full advantage of this, CoE directors would set up joint supervision where supervisors came from different disciplines. This was assumed to socialize junior staff into interdisciplinarity and can be understood as a social aspect of the choice of ensuring and nurturing a base of cross-cutting specialisms in the sense that it involved the transfer of norms and rules involved in working interdisciplinary.

On the organizational level, ensuring and nurturing a base of cross-cutting specialisms in the CoE's network refers to on the one hand how directors decided to balance between the autonomy/identity of the CoE and its links to the founding

departments/disciplines, and on the other how they decided to manage the level of distance between disciplines/specialisms. A social aspect of choice here concerned maintaining good social relations with the founding departments by, for example having them represented in the CoE's steering group. This was important because the CoE relied on disciplines to produce researchers that would go into the CoE's highly interdisciplinary environment.

While all CoEs appeared to have hosted a range of different specialisms and epistemic orientations, directors across the sampled CoEs differed in how they chose to manage the level of distance between disciplines/specialisms. Some chose to start broadly by, for example, including distant specialisms within a broad discipline such as biology. Other centers opted to recruit from disciplines with perceived 'weak identities' (and thus assumed to be more susceptible to cross-collaboration/interactions) or to host specialisms that already shared a common knowledge-base and principles. In any case, this can be understood as a cognitive aspect of the choice of ensuring and nurturing a base of cross-cutting specialisms in the sense that it was motivated based on how intellectual conditions for interactions were best created. By investing in specialisms with a short cognitive, directors stimulated the exploitation of common knowledge bases. By investing in specialisms with long distances, directors stimulated the exploration of several knowledge-bases/domains.

The second type of discretionary choice relates to how interactions were stimulated is in case study 1 referred to as *creating proximity between CoE researchers and promoting slack*. Creating proximity was closely related to lowered thresholds for turning interactions into collaboration (which yielded verification and transfer of results i.e. faster transfer and integration of results and instruments between specialisms). Promoting slack was associated with stimulating interaction from which shared interests/complementary expertise emerged (which eventually generated e.g. the discovery of new problem areas).

Creating proximity and promoting slack involved the directors' choice of institutionalizing platforms for interaction such as project-oriented seminars, coffee meetings, colloquia, etc. These platforms were typically informal in character and researchers could interact with other researchers on unconditional terms e.g. without expectations to engage in collaborations. The social aspect of the choice refers to how directors appeared to assume that social encounters constituted important explorative steps towards further interactions (fruitful or not). A related social aspect was present in the directors' choice of stimulating the co-location of researchers within the CoEs. Co-location under 'the one roof' was typically intended to lower the threshold for engagement between researchers. However, directors sometimes chose to be pragmatic about the extent to which co-location was socially feasible. For example, to keep researchers from different disciplines within the CoE in the longer term, some directors chose to keep permeable center boundaries so that the researcher could come and go as they pleased. There are also cognitive aspects of

the choice to create proximity and promote slack. They refer to how directors set the epistemic direction for the CoEs such as deciding general lines of research inquiries to be pursued as well as clear expectations on the co-located CoE members. Cognitive aspects also include the promotion of openness in terms of data-sharing including disseminating preliminary results to researchers from other disciplines/fields who did not take part in the original inquiry. These aspects of creating proximity and promoting slack clearly enabled interactions between specialism and/or epistemic orientations.

The third type of discretionary choice related to how interactions were stimulated refers to *encouraging open-ended lines of inquiry*. In general terms, this choice is associated with providing space for researchers to agree on epistemic problems. The cognitive aspects of the choice refer to how directors maintained long-term research perspectives in the CoEs and promoted a focus on issues that required complementary disciplines (theoretical as well as practical) while not departing from spontaneity or the possibility for researchers to close off less fruitful paths and change direction to, for example, risky topics. It also relates to how directors supported flexible inclusion of external expertise e.g. the readiness to include/invite other fields when center researchers faced problems they could not solve within the CoEs. The social aspect of the discretionary choice can be illustrated by how directors sometimes allowed flexible fund allocation (e.g. transfer funds between projects based on needs) including setting up financial systems that awarded collaborative projects as opposed to projects that showed interesting/novel epistemic results.

The social and cognitive aspects of discretionary choice and interactions are summarized in table 7 below.

Table 7. Social and cognitive aspects of discretionary choice and interactions involved in implementing a CoE scheme.

	Social aspect	Cognitive aspect
Discretionary choice	*Ensuring and nurturing a base of cross-cutting specialisms* Appointing supervisors from different disciplines to socialize junior staff into interdisciplinarity Having founding departments represented in the CoE steering groups to maintain good relations *Creating proximity between CoE researchers and promoting slack* Co-locating researchers and promoting informal meeting places to stimulate further interactions/socialization between CoE researchers Maintaining permeable boundaries to retain competence/attract talent *Encouraging open-ended lines of inquiry* Flexible transfer of funds between projects Setting up financial systems that awarded collaborative projects	*Ensuring and nurturing a base of cross-cutting specialisms* Recruiting junior staff to stimulate cross-collaboration in the CoE Investing in specialisms/disciplines with long distances between them to stimulate exploration of different knowledge bases Investing in specialisms/disciplines with short distances between them to stimulate the exploitation of common knowledge bases *Creating proximity between CoE researchers and promoting slack* Setting the epistemic direction and expectations/deciding general lines of research inquiries Sharing data and preliminary results with external researchers to stimulate new interactions *Encouraging open-ended lines of inquiry* Maintaining long-term research perspectives Promoting a focus on issues that required complementary disciplines/expertise
Interactions	Developing mutual language/ways to communicate across cognitively distant specialisms and epistemic orientation (social/cognitive) Practicing patience and subsequently building respect among researchers Developing openness, tolerance, and transparency Unconditional networking with other researchers/complementary expertise not necessarily represented in the research group	Identifying parallels between cognitively distant disciplines/specialisms Developing new perspectives on the own discipline/looking at problems from new perspectives/perspectives Exchanging epistemic advice on how researchers/groups can move inquiries forward Learning about state-of-art of other fields

5.1.2. Exercising discretion to implement agency priorities into funding programs for energy relevant RDI

The second case study of the thesis focused on how research, development, and innovation (RDI) program officers at the Swedish Energy Agency (SEA) – a sectoral RDI funding agency – implemented agency strategy into funding programs for RDI and RDI projects. By drawing on the concept of street-level bureaucracy

developed by Lipsky (1980), the study identified different types of discretion deployed by RDI officers at SEA to develop and manage RDI funding programs and projects. Programs are the instruments by which funding agencies such as SEA organize, attempt to stimulate, and steer RDI towards the attainment of politically relevant objectives (e.g. infrastructure for sustainable energy supply) as well as epistemic ones (e.g. advancement of theories and methods, including new technologies).

With the rise of public funding agencies as intermediaries between policy and science, studies into how these organizations regulate policy-science relations have flourished. Studies have provided insights into how the relationship between policy-makers and researchers is mediated, or brokered if you will (e.g. Guston 1996, 1999, 2001; Braun 1993, 1998; Braun and Guston 2003; Rip 1994; Van der Meulen 1998). Central here is the notion of rational choice amongst the actors involved in funding and implementing science policy priorities. For example, studies typically apply principle-agent theory to understand how the relationship between government, funding agencies, and researchers is cast (e.g. Braun 1993; Shove 2003). Findings tend to converge on the notion that funding agencies influence cognitive developments of science by regulating conditions for science directly or indirectly via economic capital (the redistribution of funds) and selection criteria for research proposals (via formulations in funding calls and/or instructions to review panels, e.g. 'impact') (Braun 1998). The present case study complements such findings by unpacking key parts of the agency processes of developing funding programs for RDI. The discussion below illustrates how RDI officers exercise discretion to organize interactions between the officers and RDI performers. It also shows how the content of funding programs sometimes emerges as a cumulative effect of the interactions that follow from the officers' discretionary choice. Funding programs for RDI can in this context be understood as de facto priorities or new conditions for RDI production.

The study identifies several types of discretions that RDI officers at SEA exercise to develop the programs. The conditions in which these discretions take place are characterized by a low degree of top-down steering from central agency management, such as a lack of clear instructions on how RDI officers should deploy/implement agency strategy. For example, the RDI officers reported how agency strategy rarely dictated/informed the officers how they should work with implementing the agency's strategic areas (e.g. transport and renewable energy). In addition, the officers typically possessed a high level of technical expertise in the RDI areas that they administered as well as expertise about agency routines, e.g. how operations are run within the agency. The quote below comes from one of the officers7. It illustrates how officers relate their work to the strategic level of prioritizing. As implied by the cited RDI officer, officers contrast their expertise to

[7] This data is extracted from the interview protocols. However, it was not presented in article 3.

that of external stakeholders. The latter are typically selected and invited by SEA to formulate strategic RDI priorities for the agency/sector (referred to as 'externals' in the quote below):

> Our work is about program management and getting things done. […] We work with operations and do not have many connections to the strategic discussion. […] Those who [participate there] are externals and are very clever but an important skill here is to know how things work concretely, and perhaps [the externals] do not possess that skill to the same extent. (Program officer)

High levels of professional/operational expertise among administrators in combination with a lack of top-down instructions are conditions generally held as conducive for administrators', or 'street-level bureaucrats', ability to exercise discretion over policy implementation (cf. Hudson 1989; Lipsky 1980; Maynard-Moody and Musheno 2000).

New conditions for energy relevant RDI production

In a broad sense, the programs developed by the RDI officers provided new conditions for RDI production. Programs may be intended to influence RDI performers in terms of epistemic orientation (e.g. steer performers from addressing fundamental questions to more applied ones, and vice versa) and in that sense, create new cognitive conditions for the RDI performers. For example, RDI officers sometimes exercised discretion to balance the agency's portfolio of projects in terms of the distribution of investments between basic sciences, applied sciences, and commercialization of research results (innovation). This involved the activity of continuously assessing and shifting the portfolio balance by, for example, redirecting projects from having a basic orientation towards a more applied/commercial one, and vice versa. By increasing the funding level to more research-oriented categories officers created conditions for the production of new basic knowledge. By making these types of funding more long-term, they also enabled RDI projects to fund PhD students throughout their studies (typically four years). The latter can be considered a new cognitive condition for knowledge production in the sense that it stimulated renewal/critical mass-creation. The officers also influenced new cognitive conditions for RDI performers by choosing specific themes for RDI, such as future-oriented technologies. The case study refers to the above as tweaking *the content* of agency priorities, that is when officers decide themes and epistemic orientations (i.e. basic, applied, and commercialization) of programs to attain broader agency objectives/priorities.

Additionally, officers applied discretion to tweak agency priorities on *form*, that is how RDI performers should organize to stimulate the production of energy relevant RDI. For example, RDI officers would sometimes formulate programs in ways that the programs ushered applicants into new collaborative arrangements (e.g. by connecting researchers known to the agency with specific firms, also well-recognized within the agency). In the two ways elaborated above – deciding (i)

themes and epistemic orientation and/or (ii) the mode of collaboration between RDI performers – RDI officers used funding programs to develop new cognitive conditions (e.g. novel issues for RDI performers to address) and social conditions (e.g. new RDI partners) for the researchers, developers, and innovators of energy relevant RDI. What will be discussed next is how the development of RDI programs was influenced by interactions between RDI officers and RDI performers, and how the former typically organized the interactions by discretionary choice.

Choice and conditions

The thesis argues that program development was facilitated by interactions between RDI officers and RDI performers in some significant ways. It suggests that funding calls constituted one important way in which interactions were facilitated. Funding calls are typically used by funding agencies as instruments to focus applicants towards thematic priorities (i.e. agency relevant RDI themes) and/or functional/institutional priorities (e.g. modes of collaboration and organizational structures for RDI production) (cf. case study 1). The present case study however illustrates how RDI officers at SEA also used project calls to organize interactions with RDI performers, and that funding program content emerged from such interactions.

Funding calls appear to have facilitated interactions by functioning as communicative devices for exchanging messages between the RDI officers and RDI performers. This resonates with what Goggin et al. (1990) refer to as 'messaging' as a way for implementers at different levels of an implementation system to interact via the exchange of texts/messages. RDI officers chose to keep calls broad (discretionary area of 'scope' in article 3). This discretionary choice was on the one hand motivated from a cognitive perspective. By keeping the calls broad, the officers tried to stimulate RDI performers/applicants to express their areas of interest more freely. The intended cumulative effect of this would be a map of interesting and potentially novel RDI issues. This type of interaction with the RDI performers (mediated by the proposals) triggered cognitive activities among the RDI officers. These activities included assessments and learning about the market of ideas in general, and about specific lines of novel RDI inquiry in particular. Officers could use this newly acquired knowledge when developing funding programs (or adjusting existing ones) (cf. the notion of epistemological bricolage in Freeman 2007). This perspective on the interaction between funding agencies and research performers complements perspectives that typically look at how agencies and agency processes influence research content. For example, Knorr-Cetina (1981) refers to transepistemic arenas as a condition under which researchers interact with funding agencies. As a consequence of such interaction, Fujimura (1987) suggests that researchers adjust their research agendas to the extent that they formulate 'do-able' problems (to be funded). The present case study demonstrates how the reverse also applies, that is, through interaction research performers may influence the

content of funding programs (cf. 'reversed epistemic drift', paraphrased from Elzinga 1986). On the other hand, the discretionary choice of keeping calls broad had a social aspect. RDI officers kept calls broad to discover and build relations with new, interesting RDI partners, and in doing so expand and renew the agency's base of RDI performers.

To facilitate interactions via the calls, the RDI officers made additional discretionary choices. They used general agency criteria flexibly or selectively to stimulate interactions between the officers and a broader range of RDI fields (discretionary area of 'criteria' in article four). The discretionary choice of how to tweak criteria to stimulate interactions with RDI performers had a cognitive aspect. First, to reach out to social researchers, the officers refrained from operationalizing key agency criteria such as 'energy relevance'. By keeping criteria vague, officers created space for interpretations, assuming that it would facilitate engagement with interesting fields and disciplines that were typically not funded by SEA. Secondly, the officers sometimes operationalized standard criteria (again, energy relevance) into sub-criteria assumed to appeal to RDI performers focusing on specific issues (e.g. climate negotiations). The discretionary choice was made with the intention to stimulate interactions with specific types of RDI fields. In some cases, RDI officers removed criteria altogether. This they did when they perceived criteria as obstacles to efficient communication with users. For example, removing co-funding as a requirement stimulated interactions with small and medium-sized enterprises (SMEs) – a category of users that were typically put at a disadvantage when cost-sharing was a selection criterion for joining RDI programs. The thesis suggests that this is a social aspect of the discretionary choice of stimulating interaction by tweaking criteria. It is social in the sense that by engaging in interaction with users/SMEs, agency officers would be in a better position to understand private sector needs and develop programs accordingly.

By choosing to keep calls broad and tweak general agency criteria, RDI officers stimulated interactions with RDI performers that were highly explorative in character. From the interactions, knowledge emerged that the officers could use to spot market gaps (e.g. new thematic niches for Swedish energy relevant RDI) as well as to identify opportunities to strengthen the energy innovation system (e.g. by connecting previously distant RDI performers). These insights laid the foundation for new funding programs.

It is important to note that programs/new conditions for RDI production typically emerged from *repeated interaction* between RDI performers and RDI officers. From repeated interaction, the officers developed a good understanding of where they could find excellent researchers and resourceful firms (a social aspect of interactions). For example, by departing from their knowledge of who represented excellence research officers would decide which types of technologies to focus RDI programs on. From repeated interactions with RDI performers, via funding calls, the officers also aggregated deep and current knowledge of the market of ideas (a

cognitive aspect of interaction). In sum, by immersing themselves in an ongoing dialogue with the RDI market (people and ideas) officers came to possess knowledge about world-leading researchers in the relevant fields, which firms had the potential to reach commercial success (and what their needs/challenges were), and how people of complementary expertise could be combined to create epistemic as well as commercial/social value. This knowledge appears to have enabled the officers to interact more directly with RDI performers, and in doing so exercise more immediate influence over conditions for RDI production. For example, officers would sometimes, within already developed programs, create new governance structures for specific RDI projects by actively participating in the implementation of the project. They would for instance occasionally insert themselves in the reference groups of SEA funded projects.

As demonstrated by case study 2, and at the center of discussion here, the knowledge from which funding programs were developed and/or adjusted, emerged in some interesting ways through repeated interactions between RDI officers and RDI performers. Such interactions were to some large extent organized via funding calls that officers designed using discretions (cf. Lipsky 1980 on how bureaucrats *modify client demand* by e.g. pacing and timing interaction and adjusting the content of interactions).

The social and cognitive aspects of discretionary choice and interactions are summarized in Table 8 below.

Table 8. Social and cognitive aspects of discretionary choice and interactions involved in implementing strategic priorities in SEA.

	Social aspect	**Cognitive aspect**
Discretionary choice	Keeping funding calls broad in scope to discover new, interesting RDI partners/expand and renew the agency's base of RDI performers Removing standard criteria to stimulate interactions with users/RDI needs	Keeping funding calls broad in scope to stimulate RDI performers/applicants to express their areas of interest more freely/create a map of interesting and potentially novel RDI issues. Keeping standard agency criteria vague and/or customized to stimulate interactions with specific RDI fields of RDI/disciplines
Interactions	Learning about world-leading researchers in relevant fields and which firms had the potential to reach commercial success (and what their needs were) Building relations with new RDI performers	Learning about the market of ideas in general, and about specific lines of novel RDI inquiry in particular in Assessing new ideas/lines of inquiry in relation to agency priorities Assessing how complementary expertise could be combined to create epistemic and/or social value.

5.1.3. Making political objectives implementable by strategic R&I agenda-building

The third case study investigated how firms from the Swedish food sector made government policy for research and innovation (R&I) implementable by building a strategic R&I agenda. The agenda-building can be understood as a process of transforming general political aims for R&I found in the National Food Bill of 2017 into sector objectives/ends for R&I, and a concretization of the means assumed to reach the objectives. The process generated R&I priorities that expressed means-ends formulations. These formulations can be understood as normative theories (cf. Chen 1990). Here are two illustrative examples of such formulations extracted from the agenda (Sweden Food Arena 2018). The first has a clear thematic orientation, whereas the second has a functional/institutional one:

- By 2025, plant breeding within national protein crops has decreased Swedish dependence on soya imports. To achieve this, the sector will inter alia, focus on excellence research on Swedish plant-based proteins.
- By 2025, there is a strong collaboration between the food sector, academia, and the healthcare sector. To achieve this, the sector will inter alia, establish interdisciplinary R&I programs with a focus on food and health. The programs will include basic science, clinical research, applied research, and commercialization of existing research.

The priorities of the agenda can be understood to constitute new conditions for future R&I performance. They do so in the sense that they embody a concerted attempt from the sector (sanctioned by the government) to impose its preferences (aka needs-driven R&I) on the science funding system and ultimately onto the research performers (cf. OECD 2015b, 2016). For example, about a year after the creation of the agenda, it was partly incorporated into the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas) national research and innovation strategy for a sustainable and competitive food production system (Formas 2019).

Choice, interactions, and new conditions

In the context of the third case study, new conditions for RDI production refer to the content/priorities of the strategic R&I agenda. The sector firms developed the content in collaboration with a public agency (the Swedish Agency for Economic and Regional Growth) and a selection of research performers and related industries. The agenda formulated objectives for research as well as for application/innovation. The agenda also suggested how the objectives best would be achieved by, e.g. formulating how the R&I should be organized in various types of arrangements for co-producing RDI/knowledge. These included interdisciplinarity and new industry-university collaborations (aka transdisciplinarity). Content emerged via interactions in two stages. At both stages, firm representatives with special mandates to manage

the agenda-building (steering group members, research area leaders, and theme coordinators) made discretionary choices of how to organize interactions between various types of expertise, broadly understood as internal (sector expertise) and external (expertise from research performers and related industry).

The first stage of creating new conditions for R&I production involved operationalizing three larger research areas (Health and Taste, Circular Food, and Digitalization and Automation). This stage, referred to as adjusting scope in case study 3, generated eleven R&I subthemes. The interactions from which the subthemes emerged displayed social as well as cognitive aspects. For example, the interactions yielded comprehensive inventories of sector challenges and capacities across the entire domestic value chain (e.g. primary production, industry, and retail). This can be understood as a cognitive aspect of interactions in the sense that the joint inventories involved analysis, assessments, and learning of the challenges and opportunities faced by actors from various parts of the domestic value chain. However, the interactions also involved relationship-building between firms from different parts of the value chain (e.g. between industry and primary production) as well as between firms at the same location of the chain (e.g. between competitors). This social aspect of interactions involved constructively addressing internal disagreements (e.g. between producers of animal and plant proteins respectively) and negotiating how to reach common ground on subthemes. Once the participants had produced a list of subthemes within each research area that they could agree on, participants identified overlaps between the proposed subthemes and collapsed, de-prioritized, or removed them completely. This aspect of interaction can be understood as cognitive in the sense that it involved detecting patterns between subthemes and assessing the themes on basis of how they related to R&I production. The end result was eleven R&I subthemes driven by sector needs and distributed across the three research areas.

To stimulate interactions during scope adjustment, the steering group members and the research area leaders (hereinafter ‘management’) made discretionary choices that can be understood from their social and cognitive aspects, respectively. Management chose to regulate participation to include only food sector firms as participants (as opposed to research performers and related industries). The social aspect of this discretionary choice related to the perceived need for the sector to mobilize internally before it could engage external actors in the agenda-building. The cognitive aspect of the choice related to the perceived risk of capture of subthemes by epistemic interests of researcher performers e.g. that the inclusion of academic researchers at the early stages of agenda-building would risk making the subthemes too technical. Hence, keeping participation to include only firms was intended to ensure social cohesion and needs-driven R&I subthemes. Additionally, the research area leaders made the discretionary choice to only provide vague formulations of R&I selection criteria for subthemes. This can be considered a cognitive aspect of discretionary choice in the sense that the intention was to

stimulate the participants to creatively explore and exchange a broad range of ideas about possible R&I content. Throughout scope adjustment, the interplay between these social and cognitive aspects of discretionary choices stimulated explorative interactions from which the subthemes emerged.

By the end of the scope adjustment the subthemes were void of much content. During the second stage of agenda-building, the firms thus further developed the subthemes. They did so through interactions where R&I objectives within each theme were formulated and actions assumed to reach the objectives were identified. Case study 3 refers to this stage of agenda-building as mapping out content and its relation. At this stage of agenda-building, the research area leaders chose to re-organize participants into smaller groups under each subtheme. On the one hand, the leaders allocated participants across the themes based on what they assumed would create engagement/commitment among the participants and thus continue to stimulate dynamic interactions. For example, some leaders based their discretionary choice on how they perceived the interests of other participants. They also appeared to factor in how well different participants would be able to collaborate. This can be understood as the social aspect of the choice of how to structure interactions.

However, the leaders also tried to balance the group in terms of value chain representation. This cognitive aspect of discretionary choice relates to the assumption by the leaders that expertise was spread out across the domestic value chain, and that the explorative interactions in the smaller groups/subthemes would benefit from complementary expertise internal to the sector. As case study 3 shows, the assumption was correct. For example, interaction between internal, complementary expertise stimulates the identification of mutual challenges and the exchange of perspectives on how the challenges could be addressed. Interactions between internal expertise also stimulated assessments of how subthemes aligned with policy objectives and in addition, worked to validate ideas such as what could be interesting initiatives within the subthemes. All these aspects of interaction can be understood as cognitive in the sense that they involved significant levels of analysis/assessments, knowledge transfer, and mutual learning.

Re-grouping participants by the strategies mentioned above appeared to have increased the level of shared interest within subthemes. At the same time, the discretionary choice of how the re-grouping intentionally increased the cognitive distance between participants in the sense that they were organized to include a diversity of internal sector expertise (cf. Nooteboom 2020). In order further stimulate explorative interactions, management chose to attach external experts from academia and related industries (e.g. the IT sector) to the subthemes[8]. This cognitive aspect of discretionary choice of how to structure interactions further

[8] In two out of the three research areas, management identified actors in collaboration with the host agency and an external process consultant. In the third research areas (Health and Taste), procurement of external expertise was made by theme coordinators and was highly voluntary.

increased the cognitive distance within the groups. However, the external experts were only mandated to act as advisors (as opposed to the other participants who acted on equal terms). Thus, the firms had the discretion to make final decisions about content, which can be conceived as a social aspect of choice. It served to protect firm interests. The interactions that followed from the choice to include external actors had clear cognitive aspects. For example, the interactions enabled the participants to acquire knowledge about the state-of-the-art within relevant disciplines/specialism. The interactions also had social aspects. For example, the interactions prompted the firms to reflect on their needs and enhanced the way the firms articulated these to get researcher performers to understand the theme.

The interactions between internal and/or external, complementary expertise gradually narrowed/reduced the choice alternatives related to how the firms could operationalize the subthemes into objectives (e.g. new tools for novel food production methods) and how they could link the attainment of the objectives to specific R&I results (e.g. new knowledge about how human senses interact and multi-sensory effects) and modes of R&I production (e.g. create interdisciplinary research project between sensory sciences and psychophysics). In doing so, the interactions moved the implementation forward to the point that there was a complete strategic food sector agenda for R&I.

The social and cognitive aspects of discretionary choice and interactions are summarized in Table 9 below.

Table 9. Social and cognitive aspects of discretionary choice and interactions involved in implementing national priorities for food-related R&I **Table 9**. Social and cognitive aspects of discretionary choice and interactions involved in implementing national priorities for food-related R&I

	Social aspect	**Cognitive aspect**
Discretionary choice	*Scope adjustment* Excluding research performers and related industries to facilitate social cohesion/avoid sector fragmentation *Mapping out content* Allocating participants based on interests and personal characteristics across subthemes to create/maintain engagement/commitment Limiting external actors' formal influence by only giving advisory status	*Scope adjustment* Excluding research performers to stimulate needs-driven R&I content Formulating vague/general criteria for how to operationalize broader research areas into subthemes to identify a broad range of R&I needs/content *Mapping out content* Balancing participation across the value chain in subthemes to stimulate interaction between complementary, and internal expertise. Attaching external experts from academia and related industries to the subthemes to further stimulate explorative interactions
Interactions	Relationship-building between firms from different parts of the value chain as well as between firms at the same location of the chain (e.g. between competitors) by constructively addressing internal disagreements and negotiating how to reach common ground on R&I subthemes/issues Critically reflecting on internal needs during mapping out content and enhancing persuasiveness of argumentation	Performing comprehensive inventories of sector challenges and capacities across the entire domestic value chain by analysis, assessments, and learning about the challenges and opportunities faced by actors from the various part of the domestic value chain Identifying overlaps between proposed subthemes and collapse, de-prioritize, or remove subthemes. This involved patter-recognition and assessment of how much themes related to R&I Transferring knowledge about solutions to shared challenges, validating ideas, and acquiring knowledge about the state-of-the-art within relevant disciplines/specialism Assessing how subtheme content aligned with policy objectives

5.2. Specifying the contribution

Two strands of scholarship have contributed significantly to how we understand priority-setting. Within the first strand, research focuses on priority-setting exercises such as foresight and forecasting. This concerns how government, public agencies,

and industry set priorities for research and development, and increasingly also for innovation (e.g. Irvine and Martin 1984; Martin and Irvine 1989). In this strand of scholarship, less attention is paid to how the priorities trickle down through an implementation system. The second strand adopts a more systemic perspective on priority-setting (i.e. goes beyond studying priority-setting as exercises, small or large). It typically identifies several variables from which we can understand how priority-setting is constituted, e.g. type of priorities, approaches to priority-setting (top-down/bottom-up/hybrid), and the level of priority-setting (e.g. Gassler et al. 2004). The systemic perspective also directs our attention to the several rationales for priority-setting and how they may operate in parallel (Bosin 1992), including how priority-setting should take into account interdependencies in the knowledge producing system (e.g. Georghiou and Cassinga Harper 2011; Chalmers et. al 2014). Within this strand, there are also researchers such as Stewart (1995) who suggests that key decisions for RDI are made at much lower levels of organization than is intended. This perspective on priority-setting implies that how RDI priorities play out in reality may only partially be explained by how policy-makers formulate priorities. The way the system is structured is also an explanatory factor since certain structures open up for certain priorities to be set while restricting the possibilities for others.

This thesis complements both strands of scholarship. It does so by investigating the relationship between choice and (inter)actions of lower-level decisions-makers, who enact priority-setting at key levels in the implementation system for RDI priorities. The studies show empirically how choice and interaction in their aggregated form can be understood to shape new conditions for RDI production. In this way, the thesis contributes to a central discussion within the science policy literature viz. how policy, or external circumstances, influences conditions internal to scientific knowledge production (e.g. choice of research problems and how to pursue them), and ultimately: cognitive development of science (e.g. Gläser and Laudel 2016). Broadly speaking, cognitive development of science is associated with improvements in the explanatory and predictive power of theories (Hempel 1965) and methodological advancements or technological progress (Stokes 1997; Rosenberg 1982).

The bottom-up/synthesis approach taken by this thesis emphasizes that certain frames are imposed from above regarding how much RDI priorities can be adjusted to local conditions (cf. Sabatier and Mazmanian 1979). These priorities/frames imposed from the top can be understood to embody agreed upon choices (e.g. type of policy problem to address and type of investment to address the problem) as well as an agreement on how investments will yield desired outcomes (cf. Thomas and Mohrman 2011). With the increased focus on functional/institutional priorities in science policy (e.g. OCED 1991; Gassler et al. 2007; Hellström and Jacob 2012), choices about how implementers should organize and collaborate are central. In other words, 'priority program theories' (cf. Chen 1995) tend to formulate types of

desirable interaction between key actors in the innovation system assumed to mediate between policy problems, investments, and solutions. The literature review suggested why priority program theories are challenging to formulate and elaborated on how such challenges may be transferred downward in the implementation system (see section 2.3).

The bottom-up perspective also emphasizes that while operating within policy frames set from the top, implementers enjoy considerable levels of discretion to make choices concerning implementation. The thesis has elucidated how discretion constitutes a central aspect of the implementation of RDI priorities. As shown above, discretion manifests itself as space to self-organize (cf. the notion of self-selection in local implementation structures by Hjern and Porter 1981). Across all three case studies, implementers' discretionary choice governed the specificities of how to organize interactions between different expertise/collaborative arrangements assumed conducive to efficient implementation. Discretion also extended into the local sense-making and interpretation of priorities from 'above', attaching meaning to the priorities, and acting on those interpretations/meanings to make priorities operational (cf. Coleman et al. 2010; Steinberg 1980; Lipsky 1980). The results suggest that key discretionary choices in RDI priority implementation are those that stimulate interaction between different expertise/domains of knowledge from which new conditions of RDI productions emerge.

In **case study 1**, key discretionary choices included ensuring and nurturing a base of cross-cutting specialisms, creating proximity between CoE researchers and promoting slack, and encouraging open-ended lines of inquiry.

In **case study 2**, key choices concerned adjusting the scope of funding calls and tweaking agency criteria. In the case study (with corresponding article three), the two choices constitute but two out of four types of discretionary choices (the others being programming and epistemic trade-offs). The reason for their special attention in the discussion is that they relate directly to how RDI program officers stimulated interactions. However, the knowledge that the officers accumulated from such interactions affected programming (e.g. when officers selected among which future-oriented technologies to invest in) as well as epistemic trade-offs (e.g. how officers decided to steer research performers and users/firms into collaboration).

In **case study 3**, key choices that stimulated interactions were labelled regulating the participation of actors during scope adjustment, applying vague selection criteria for R&I sub-themes, re-organizing expertise in subthemes, and extending participation to include external actors.

Interaction is central to the bottom-up/synthesis approach: be it on the individual level, e.g. between implementers and policy-makers (e.g. Barrett and Fudge 1981; Goggin et al. 1990) or civil servants and end-users such as target groups (e.g. Kiser 1984; Lipsky 1980), or on the systemic level, e.g. between implementing organizations (e.g. Hjern and Porter 1981). Interaction between diverse actors and

interests, motivations, and objectives is typically considered a significant factor mediating between a policy stimulus (input such as demands and support) and policy outputs and outcomes (e.g. Long and Franklin 2004). Each case study of this thesis identified several new conditions for RDI production that, via the implementers' accounts, can be directly linked to interactions occurring during implementation. This resonates with how the bottom-up/synthesis approach predicts the dynamics of implementation to play out. For example, Kiser (1984) suggests that implementation involves interactions between implementers at different levels (e.g. police/citizens) that result in the co-production of implementation outcomes. Freeman (2007) argues that policy practitioners (e.g. bureaucrats) assess and combine different types of knowledge during implementation.

The result of these processes is typically something 'new'. The thesis shows that piecing together knowledge from different types of expertise/sources of knowledge, constitutes a central part of the interactions that characterize the implementation of RDI priorities, and that 'epistemological bricolage' contributes to determining the type of conditions for RDI productions, or de facto priorities, that are created. It also shows what is implied in Kiser's (1984) notions of the co-production of policy outcomes viz. relationship-building between implementers at different levels (e.g. program officers at the Energy Agency and researchers) constitutes yet another central aspect of implementation interactions, and ultimately the creation of new conditions for RDI production/de fact priorities. Kiser (1984) suggests that a policy only succeeds if the target group is inclined to cooperate with the implementing actors.

Table 10 below is an analytical summary of case tables 7-9 and as such, it captures the substance of cognitive and social aspects of choice and interactions, respectively. The table also illustrates the empirical relationship between the choices and interactions that yielded new conditions for RDI production. The relationship between choice and interactions can be conceived of as one-directional, i.e. choice precedes interaction. As elaborated above, in the accounts of the respondents the cognitive and social appear to be two sides of the same coin when it comes to discretionary choice.

In terms of interactions, the cognitive and social interplay. However, because of the relatively high diversity of expertise/cognitive distance in each of the cases, social bonding sometimes appears as a precursor to the successful integration of expertise/domain specific knowledge. While this seems to hold across all case studies, the social aspect of the interactions was most salient in the first and third case studies. In these case studies, the implementers responded directly to a functional/institutional priority, the aim of which was to stimulate new collaborations/organization for the implementer (**case study 1**: CoE environment and **case study 3**: new collaborations between the actors in the domestic value chain for food). However also in **case study 2**, the social aspect of implementation activities contributed to producing new conditions for RDI production. For example,

and as discussed above, identifying new niches for energy relevant RDI appeared to relate to repeated interactions between RDI officers and RDI performers. There was however, no instruction from 'above' concerning how the program officers should interact with the RDI performers. In any case, these interactions included the social aspect of officers getting to know performers presently funded by SEA as well as RDI performers of high potential, new to the agency. With such knowledge, RDI officers could adapt their language and more efficiently communicate with the RDI performers. Officers would also develop insight into which type of expertise that, when ushered into collaboration, would have the potential of generating interesting RDI projects/results.

Table 10. Summary of critical factors, and their relation, involved in shaping new conditions for RDI productions/de facto priorities during the implementation of RDI priorities. The critical factors can be understood as discretionary choice and interactions and their social and cognitive aspects. The arrows indicate the relationship between the social and the cognitive, and choice and interactions, respectively.

	Social aspect ⟺	**Cognitive aspect**
Discretionary choice ⇓	Interactions organized to: Facilitate the discovery of people, interests, norms, and values Create commitment/ engagement Establish social cohesion between implementers/ expertise Develop shared objectives/ consensus among implementers	Interactions organized to: Generate new ideas Identify intellectual capacities and complementary knowledge Solve mutual problems Transfer knowledge Facilitate learning
Interactions	Networking Advocacy/persuasion Negotiating/bargaining Developing mutual language Developing openness tolerance, and transparency Trust-building Finding common ground	Interpretations and assessments Comprehensive inventories of ideas and existing RDI Validation of ideas/intermediate results Identification of parallels between diverse expertise/domains specific knowledge Adopt new perspectives in one's own knowledge domain Find solutions to mutual intellectual problems

By adopting a bottom-up perspective on the implementation of RDI priorities, the thesis has demonstrated how priority-setting can be conceived to extend into implementation. It unpacked some aspects of what can be considered a black box of implementing RDI priorities (cf. Easton 1965), or a 'missing link' in priority-setting research if you will (cf. Hargrove 1975) and it elucidated how the discretionary

choice and the interactions that they stimulated have a social as well as a cognitive side. The next section elaborates how that result fruitfully can be framed as a 'socio-cognitive approach' (e.g. Rip 1981, 1997) to the implementation of RDI priorities.

5.2.1. A socio-cognitive approach to the implementation of RDI priorities

The thesis illustrated the centrality and interrelatedness of cognitive and social discretionary choice in terms of how it structured the implementation and ultimately shaped some new conditions for RDI production at each of the studied levels of implementation. This 'socio-cognitive approach to the implementation of RDI priorities'[9], here taken to mean the analysis of how the social and cognitive interests and actions interrelate in enacting priority-setting for RDI, is elaborated below.

By using discretion to organize interactions in one way rather than another, implementers of RDI made some outcomes more likely than others: whether to intentionally include or exclude certain actors, or to set the rules for how involved actors interacted. The discussion of each case study in section 5.1 provided empirical accounts of the relationship between discretionary choice, interactions, and new conditions for RDI production.

The discussion brought to the fore the social and cognitive aspects of discretionary choice and interactions and their internal relationship per each case, and in doing so also demonstrated how they appear to be dominant features of the implementation of RDI priorities. The thesis refers to 'aspects' simply because the same type of choice/interaction can be understood as being cognitive and social. For example, interactions for capacity-building may involve the social aspect of bonding between implementers (e.g. building mutual respect) as well a cognitive aspect, such as problem-solving and knowledge-transfers.

The thesis concludes that *interactions* that demonstrate both these aspects appear to be critical to the creation of new conditions for RDI production. It is evident from the case studies that *discretionary choice* that stimulated the type of interactions

[9] The social and the cognitive aspects of science and policy, and the way they interrelate is a fundamental issue in science policy research. Rip (1981, 1997) for example introduces 'a socio-cognitive approach to science policy' by arguing the need to base science policy on knowledge about how the social structures of science (e.g. interest, norms, and values) interrelate with science's cognitive development (e.g. methodological advances and discovery in scientific fields or disciplines). In addition to this, Rip suggests that science policy needs to be reflective of how social and cognitive interests, norms, and values of politics and administration relate to scientific interests, norms, and values. This thesis has adopted a terminology similar to that of Rip's viz. 'the socio-cognitive approach to the implementation of RDI priorities', here taken to mean the study of how social and cognitive interests and actions interrelate, and together contribute to enacting priority-setting for RDI.

critical to creating new RDI conditions, also include social and cognitive aspects. The thesis therefore concludes that significant choices of how to organize these interactions are those that are motivated on social as well as cognitive grounds. In **case study 1**, the research directors' choice of ensuring and nurturing a base of cross-cutting specialism included recruiting junior staff to build capacity for interdisciplinarity. The cognitive aspect of the choice related to how the directors assumed that junior staff would create epistemic connections between research groups/disciplines. A social aspect of the choice related to how the directors set up interdisciplinary supervisor teams to socialize junior staff into a culture of interdisciplinarity. In **case study 2**, the discretionary choice of keeping calls broad at the Swedish Energy Agency can serve as another example. The cognitive aspect of the choice refers to how program officers assumed that broad calls would encourage RDI performers to express their interests more freely. This choice would enable the officers to interact with a market of new ideas. The social aspect of keeping calls broad related to how officers sought to discover and engage with new actors, other than 'the usual suspects'. In **case study 3**, the discretionary choice of regulating scope/participation in the building of a strategic R&I agenda for the Swedish food sector involved the exclusion of researchers in the early phases of converting national priorities into an agenda. The research area leaders did so to stimulate interactions focused on shaping needs-driven RDI, which can be considered as the cognitive aspect of the choice. The social aspect of the same choice refers to how the research area leaders seemed to assume that by excluding research performers in the initial phase of agenda-building, the sector would create space for new social relations within the sector.

The socio-cognitive approach taken by this thesis is one enables us to analyze in more detail the way discretionary choice concerning how to organize implementation affect how new conditions for RDI production are shaped, and work such understanding into more realistic program theories for RDI priority implementation (cf. Bardach's 1977 notion of 'backward mapping'). It also represents a perspective more closely aligned with the trend towards functional/institutional priorities (cf. OECD 1991; Hellström and Jacob 2012) which, to a much larger extent than thematic priorities, depend on appropriate assumptions about the relationships between the social and the cognitive. To adopt an implementation language: the socio-cognitive approach to the implementation of RDI priorities is one way of opening up the black box of priority-setting (cf. Easton 1965). In doing so, we can develop systematic knowledge regarding what emerges, or is induced, as RDI implementers deal with a policy problem, be it to create new fundamental knowledge, increase economic competitiveness, or to address grand societal challenges (cf. O'Toole 2000).

In sum, this thesis suggests that in the shift from promoting specific areas of science and technology (aka 'thematic priorities') to addressing more systems-oriented challenges and modes of organizing RDI production (aka functional or institutional

priorities but also ‘new’ mission-oriented priorities), there is an increased need for understanding implementation of RDI priorities and the nature of the implementing system as an interplay between cognitive and social choices. Studying priority-setting as enacted by various implementers seems particularly relevant where the implementation of RDI priorities takes place in a decentralized implementation system. In a decentralized implementation system, central control over resources and how they are allocated can be predicted to be low and implementer discretion to make executive decisions can be expected to be high (cf. Tosun and Treib 2018).

6. Conclusion

The final chapter concludes the thesis and ends with a discussion on how the results of the thesis may be of relevance to policy-makers.

Of central concern to this thesis was the discretionary choices involved in implementing RDI priorities. These are choices not necessarily apparent from the onset of priority-setting. Instead, they may emerge as implementers perform their tasks, which is the reason such choices and their consequences need to be studied in the context of implementation. The thesis has shown how priority-setting for RDI is enacted along the lines of cognitive/social discretionary choices, which in turn are closely related, and shape new conditions for RDI production, or de facto priorities. This 'socio-cognitive approach to (understanding) the implementation of RDI priorities' also feeds into the classical dichotomy/debate about the steering/governance of science (see section 2.1.3. for the classic issues in science policy viz. the internalist and externalist position on priority-setting). In particular, it opens up the box of external factors likely to affect conditions for RDI production. It gives an empirical account of how new conditions for RDI production are dependent on several sub-processes/sub-ordinate decisions that shape RDI conditions on content as well as form after a policy decision is made. The processes/decisions amount to the continuation of steering of RDI production and include social aspects and cognitive ones that are linked.

The results of the thesis show that implementation of RDI priorities is knowledge-work just as it is social, whether we are talking about the implementation of a CoE scheme aimed at generating strategic research or if we consider the building of a strategic R&I agenda for the food sector.

6.1. Reflections on the place of discretion in RDI priority-setting

The final section will elaborate on some general issues regarding the place and role of discretion in the implementation of RDI priorities. The main point of this discussion concerns how discretion may be at odds with democratic principles. A second aspect concerns what challenges discretion may pose to the production of RDI. The ambition is to formulate and discuss several issues, drawing from both

political theory and the general implications of the thesis that might be of interest to policy-makers interested in understanding the consequences of discretion for RDI production.

6.1.1. A need to govern discretion?

When priority-setting is viewed as an aggregation of choice and action that emerge during implementation, the boundaries between priority-setting and implementation become blurred. Placing discretion at the centre of the priority-setting-implementation nexus opens up a normative discussion that is rarely conducted in the literature on priority-setting, viz. how discretion at different levels of implementation may be at odds with democratic ideals, and what that may mean for the production of RDI. The discussion will take two democratic ideals – overhead democracy and discursive democracy – as the point of departure.

Overhead democracy refers to the ideal that elected officials, by the power vested in them by the voters, are in the rightful position to make policy decisions on behalf of the public. A deviation from those decisions during policy implementation is then to be considered undemocratic (Redford 1969). In contrast, proponents of discursive democracy argue that the type of representative policy-making implied in the overhead democracy does not suffice as a democratic governance model. Instead, democratic decision-making should be based on the quality of the arguments and not on the hierarchical position of the decision-maker (e.g. Dryzek 1990). In short, policy-making should be, at least partly, conducted from the bottom up and enabled by discursive design and rationality. According to Dryzek (1990), such design maintains permeable boundaries to participation where rules are developed by the group, as opposed to a principle from the top. Involvement of stakeholders, interactive processes, and co-production are salient tenets of a discursive democracy (O'Toole 2000).

Applied to the context of the implementation of RDI priorities, it is clear that the exercise of discretion poses policy challenges to both these ideal types of democratic governance, and ultimately the production of scientific knowledge. These policy challenges will be discussed below with the following questions in mind: does discretion undercut the legitimacy of RDI investments? And associated with this: is there a need to govern discretion?

Discretion and overhead democracy

In terms of challenges to the ideal of overhead democracy, decision-makers operating at the street-level of RDI priority-setting may distort the RDI priorities decided by democratically elected lawmakers. The thesis has brought to the fore several reasons why policy implementers may deviate, via policy adjustments, from parliamentary or government decisions (e.g. Lipsky 1980). There are several

reasons why 'street-level priority-setting' of the kind discussed in this thesis adjusts top-down RDI priorities. For one, discretionary adjustments may be necessary, if not expected by members of parliament, to make broad formulations of RDI priorities operational. At the same time, discretionary adjustments of RDI priorities may also result from implementers' incapacity to manage different kinds of pressure. Implementers may be subject to internal power struggles within, or between, implementing organizations, and consequently adjust RDI priorities to mitigate conflict (cf. the notion of 'good policy' by Lindblom 1959, or notion of 'catch-all agenda setting' by Coenen et al. 2017). **Case study 2** of this thesis describes a situation where firms producing products based on animal and plant proteins respectively were at odds with one another. The main issue concerned how to translate the government's priorities of improving environmental sustainability into an R&I agenda. To keep the process together, the implementers had to creatively find ways to motivate an R&I focus on animal protein from a sustainability perspective.

Additionally, implementers of RDI priorities may also be subjected to pressures associated with satisfying client demand e.g. to accommodate strong interests from large industries, influential academic institutions, or other national or international coalitions. SLB theory predicts that as a way of coping, street-level bureaucrats pay more attention to demanding clients (e.g. Lipsky 1980). Discretionary adjustments may also follow from limitations in the implementer's knowledge about how to translate scientific theories into practice (for a recent account of this issue, see Ulmanen et al. 2022). While implementers of RDI priorities may be experts in their fields, this does not automatically qualify them as interpreters of theoretical concepts such as innovation systems, mission-oriented innovation, triple helix collaboration, missions, interdisciplinarity, or excellence, to mention a few (e.g. Jacob 2006). Yet, institutional and functional RDI priorities often draw upon, or at least rely on, such concepts. Consultation of relevant research literature may be one way of reducing the risks of misinterpretation. However, in cases where the research is conceptual rather than empirical, or where empirical findings do not travel easily across contexts, consultation may do little to reduce such risk. Additionally, successful consultation of the literature presupposes time availability and certain levels of interest and absorptive capacity of the implementer.

Finally, implementers of RDI priorities may simply adjust the priorities because of constraints placed on implementation. For example, agency-level implementers typically work with short deadlines and parallel, unrelated tasks. Thus, they may not have sufficient time or budgets to involve the right type of people, analyze, reflect, and search for the most optimal ways of implementing priorities.

In sum, implementers may exercise discretion to mitigate situations like those mentioned above. In doing so, they may offset good, and democratically decided priorities for RDI. In Sweden, the process preceding parliamentary decisions on the types of bills that concern RDI typically involves broader hearings among relevant

stakeholders. Stakeholders include, but are not limited to, universities, funding agencies, and the business sector. Hence, a distortion of the priorities may be even more precarious from a democratic point of view given the additional democratic layer of stakeholder consultations before members of parliament enact the priorities into law.

Discretion and discursive democracy

Discussed so far, are some ways how discretion may distort (via adjustments or even reformulations) RDI priorities identified through broader, deliberate consultations with relevant stakeholders, and enacted into law by a democratically elected parliament. The circumstances above illustrate some ways in which discretion exercised during the implementation of RDI priorities may be at odds with overhead democracy. Next, we will turn to how tension plays out between discretion and discursive democracy. The results of the thesis suggest that discretion in the implementation of RDI priorities can be at odds with the principles of discursive democracy, such as inclusion, deliberation, and non-hierarchical decision-making. We will also explore how this may affect the production of RDI.

One of the central principles of discursive democracy is that decision-making processes are inclusive, deliberate, and non-hierarchical (e.g. Dryzek 1990). As shown in this thesis, RDI decision-making at the level of implementation of national RDI priorities (**case study 3**) or strategic RDI priorities (**case studies 1 and 2**) tended to exclude any substantial participation from the research community[10]. This is one way in which discretion in the implementation of RDI priorities may be at odds with the ideals of discursive democracy. For example, in **case study 2** the program officers at Swedish Energy Agency exercised discretion to control when and how research perspectives were included in the development of funding programs (i.e. new conditions for RDI production, or, de fact priorities). In **case study 3**, the firm representatives in the food sector's value chain exercised discretion to regulate when and how researchers were invited to participate in the priority-setting. How circumstances like these may affect the production of RDI will briefly be discussed below.

In the case studies discussed, implementers of RDI priorities exercised discretion to make decisions on how to organize RDI on the behalf of the research communities. As an example, program officers at the Swedish Energy Agency would match-make, or steer researchers into firm collaborations based on what the officers considered best for the researchers and the firms. Similarly, without comprehensive or deep consultations with relevant research communities, the representatives from the food

[10] The term research community is here used in a rather broad sense. A research community in the context of this discussion can be taken to mean those researchers who are directly or indirectly affected by new conditions for RDI production.

sector firms formulated needs for increased interdisciplinary connections between scientific fields that they perceived to be disconnected.

Exercising discretion to organize RDI in ways assumed to benefit the creation of private or public value (aka utility or relevance) is just one way how street-level priority-setting may disrupt disciplines' or scientific fields' 'optimal' trajectories (e.g. more significant discoveries and/or improved, complementary knowledge about observed phenomena, etc.). This may also be the case when implementers of RDI priorities make decisions about (i) research themes and (ii) investment trade-offs between research, development, and innovation, respectively. Again, when discretion is exercised to exclude research communities from the implementation activities that ultimately shape the conditions for RDI, scientific trajectories or entire fields that are immature/or still in the phase of development may be disrupted. Especially if they are exposed to utility pressures, or when funding streams are shifted away from them to more applied fields (cf. the finalization thesis by Böhme et al. 1976 and epistemic drift by Elzinga 1986, raised in section 2.1.4.). In the case of discretion exercised by program officers at the Swedish Energy Agency, the results show how officers periodically changed RDI themes and altered the funding mix between more basic and applied sciences. Some of the more basic fields within energy research may depend on stable funding over longer periods. If funding for basic science is removed, researchers may have to abandon important tracks to work on more applied issues.

In the case of the food sector, the firms held a mandate to organize the strategic agenda-setting. This enabled the organizers to exclude researchers in the critical phases where the general themes were set. The motivation behind this was that actors from the value chain needed to build (or actually mend) relationships. To include researchers in the early phases of agenda-building, where R&I themes were formulated, was assumed to derail the process of relationship-building. Due to the firms' exercise of discretion in this regard, researchers were not able to weigh in on research themes. The themes ended up being highly reflective of the needs of the firms. Since the priorities constituted an important building block in the food sector's relationship-building process, there seemed to be little room for researchers to make alterations at a later point (i.e. during the activity referred to in **paper 4** as mapping out theme content components and their relation). Instead, the researchers acted mainly as advisors within the thematic boundaries set up by the firms.

By focusing on how directors at Centers of Excellence (CoE) used conditions set up by the funder to promote basic science and strategic research, **case study 1** illustrates what it may take for researchers to make expedient adjustments to the conditions for R&D production that were shaped by actors external to the research community. The results of **paper 2** (governing interdisciplinarity) indicate that successful implementation of the institutional priority of interdisciplinarity (i.e. an organizational decision made by the funding agency on the behalf of the researchers) seemed to hinge on the CoE directors' judgement, and integrity to act on that

judgement, of what constituted an appropriate cognitive distance between collaborating disciplines. The results of **paper 1**, suggest that the way the CoE funding scheme was set up (high volume, long-term funding to already well-established researchers and groups), enabled the CoE directors to mitigate attempts of external steering.

6.1.2. Concluding remarks

As the thesis has illustrated, enacting priority-setting for RDI is a stepwise process where RDI priorities are implemented at several levels "above" that of the execution of RDI. At these levels, implementers of RDI priorities exercise discretion in ways that shape new conditions for RDI production. So how can the study of the implementation of RDI priorities help us to understand the potential long-term effects of discretionary choice on RDI productions? First, by studying how the implementation unfolds, we can better understand the implications of discretion on democratic modes of governing science policy. It appears that there are good reasons to be critical of street-level priority-setting regardless of whether we support a governance model appealing to the overhead democratic ideal or the discursive one. Secondly, the approach to implementation of RDI priorities taken here elucidates how discretion may be exercised to regulate the participation of the research community. In the case of the thesis, regulation typically meant restricting the research community's access to the interactions that ultimately shaped conditions for RDI production. Consequently, such conditions, be they organizational or thematic, may not be field sensitive. This may have disruptive impacts on scientific fields' optimal trajectories (e.g. more significant discoveries and/or improved, complementary knowledge about observed phenomena, etc.).

One of the additional insights, as it pertains to discretion's longer-term effects on scientific knowledge production is that implementers exercise discretion to organize implementation, and that one significant driver of discretionary choice is to create bonds between different stakeholders. The bonds are forged through social as well as cognitive interactions. The interactions in turn yield some agreed-upon conditions for RDI production, or de facto priorities. In this way, the resulting RDI conditions do not only imply new themes and ways of organizing RDI. They also involve the time and efforts that the implementers have invested in forging new relations. In fact, one may think of new conditions for RDI production/de facto priorities as embodiments of these new, social relations. Because of this, there may be few incentives to alter the conditions/de facto priorities in face of contestation from research communities.

So, is there a need to govern discretion? This may be a matter of perspective. This final part of the thesis has critically examined how the exercise of discretion in implementing RDI priorities may yield conditions that in turn may pose challenges to scientific knowledge production. This is how far the thesis can go in addressing

the question. However, the approach to studying implementation of RDI priorities exemplified here, may direct policy-makers attention to when, where, and how during implementation of RDI priorities, discretion emerges, and what its effects may be. This may prove useful as guidance to policy-makers with an interest in governing priority-setting as well as its constituent elements of discretion.

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OXFORD

Center of excellence funding: Connecting organizational capacities and epistemic effects

Tomas Hellström*, Leila Jabrane and Erik Brattström

School of Economics and Management, Lund University, 221 00 Lund, Sweden

*Corresponding author. Email: tomas.hellstrom@fek.lu.se

Abstract

This study investigates the relationship between resource concentration/stability and new results/breakthroughs in the context of a Swedish Center of Excellence (CoE) scheme. A common assumption in using the CoE instrument is that there is a scale return to research on concentration of funds. However, the details of how funding connects to such returns are typically assumed rather than empirically investigated. The present qualitative study sets out to identify the mediating mechanisms connecting organizational capacities made possible through the CoE grant (e.g. recruitment/human capital, data/infrastructure and various collaborative arrangements), and epistemic effects such as extension into new problem areas and higher degrees of risk taking in research generally. We conclude that a CoE program theory can be conceived in terms of resource stability yielding research flexibility, and that the common mechanisms connecting the two may be found in organizational arrangements facilitating slack (autonomy), availability of cooperative partners (critical mass) and concomitant cooperation between specialisms. It is our belief that by explicating such mechanisms CoE program theory can be greatly improved.

Key words: Centers of Excellence; funding instrument; capacity; epistemic effects

1. Introduction

At least since 2005, various countries have adopted Center of Excellence (CoE) funding as part of their S&T policy mix (Salmi 2009). The CoE scheme is an instrument intended to encourage high-quality collective research constellations via funding arrangements and organizational requirements that are more substantial and longer term than those of traditional project funding. CoE schemes have in common some notion of excellence, and particular expectations that are associated with that label in terms of evaluation and conduct. These typically involve high research quality and productivity, resource attraction and concentration, international visibility and attractiveness (including staff recruitment), and organizational robustness (good governance) (Hellström 2011; Orr, Jaeger and Wespel 2011; Aksnes et al. 2012).

Researchers who apply for CoE funding normally have to formulate an organizational plan in addition to a research plan. Running a CoE is different from running a smaller project. Research leaders are taking a more formalized role than usual. They are expected to build an organizational structure and corresponding processes that make the participating researchers function as one unit, or sometimes as a network of units (Atkinson-Grosjean 2006) in the pursuit of some common goals. Factors such as organizational structure, formalized leadership, integrative activities, governing boards, internal evaluation and external reporting regimes therefore become important features of CoE evaluations.

While the shift to CoE funding is a fairly recent one, there is now plenty of experience about how this type of institutional choice for funding has affected research organizing (Hellström 2011; Langfeldt et al. 2015; Borlaug 2016). Yet to date little is known about how researchers adapt their research content to excellence funding schemes (Gläser and Laudel 2016). We consider CoE funding to be a *choice of organizational conditions for research* made by the funders on behalf of the academic community. It is therefore an instance of 'institutional priority setting' or choice in the sense discussed by Hellström and Jacob (2012). This choice is expected to bring about certain benefits, e.g. critical mass, professional academic leadership, accountability, interdisciplinarity, and of course generate the results and discoveries that are assumed to require such efforts. It is also expected that these outcomes are amenable to steering via evaluation and other mechanisms, or what one may refer to as 'epistemic governance'.

The assumption of this study is that this institutional priority (as expressed in the CoE funding instrument) affect the way researchers

pursue knowledge production in their field. It might simply have organizational effects (which of course it was supposed to have) but, more importantly, there are reasons to believe that core aspects of knowledge production such as how to construct research problems, which types of projects to pursue, how to divide research labor in terms of these problems, etc. are also among the effects of the CoE instrument. In other words, the effects of instrument choice are both social/organizational and epistemic, as these two dimensions of science can be expected to be closely interrelated. The present study asks the following question: What are the main organizational and epistemic impacts of CoE funding with regard to activities made possible among researchers? Specifically, this question pertains to the larger issue of how organizational and epistemic effects are related to CoE funding, and specifically what mechanisms connect organizational capacities and epistemic effects, such as discovery processes. By organizational capacities in this context, we mean resources and capabilities embodied in, for example, infrastructure, organizational structures and processes, and personnel (competences/skills) (cf. Hellström 2011). Epistemic effects relate to new knowledge creation, i.e. new results, new research trajectories and breakthroughs in science. Since this is a qualitative study, epistemic effects are not assessed using metrics, but through accounts of such effects provided by the participants.

To pursue this question, the study takes its point of departure in the 2006 and 2008 Linnaeus CoE environments funded by the Swedish Research Council (VR). The calls stipulated that applications contain information on such things as financial management, organizational structure, leadership, connections to the host university, and a few others organizational aspects. What the present study offers is an account from the researchers themselves, specifically the CoE leaders, about how they view the effects of the Linnaeus scheme on their research, in terms of organizational structuring and pursuit of knowledge. It does so by offering a qualitative description and interpretation of the organizational capacity building effects of the scheme, their associated epistemic effects, and, perhaps most importantly, those mechanisms that mediate between organizational and epistemic effects. The study is based on interviews with center directors who participated closely in the process of building up the CoEs and followed closely their growth and maturation. In this position, they have had the opportunity to observe how new organizational capacities have evolved as a result of this type of funding, and their effects on research and discovery. Previous results (reviewed below) tend to agree on which organizational factors impact excellence in research. They do, however, remain silent or highly ambiguous on the factors mediating between the two. A study is therefore merited which addresses CoE funding schemes from the point of view of their qualitative organizational and epistemic effects and mediating mechanisms. Toward the end of this article we will propose an outline of a general program theory for CoE funding, namely, how resources distributed in this way yield conditions, intermediate outcomes, and finally certain epistemic effects (cf. Rogers 2008).

2. Research background—the organization of research excellence

A number of studies have explored the role of the research environment in facilitating research performance and quality (Pelz and Andrews 1966; Youtie, Libaers and Bozeman 2006). They identify a number of organizational factors that tend to support excellent, creative, or ground-breaking research, and which can typically be synthetized into two overarching themes: availability of resources, and organizational characteristics that encourage certain behaviors. Typical emphasis is on resources in terms of human and financial capital. Recruiting quality scientists is considered important but so is ensuring a diversity of knowledge and skills in the team (Schmidt, Graversen and Langberg 2003; Tijssen 2003). When it comes to funding, several studies highlight resource stability and flexibility as key factors enabling high-risk, high-impact research (Hemlin, Allwood and Martin 2004; Laudel 2006; Heinze 2008; Heinze et al. 2009). Gläser and Laudel (2016) designate the move by research councils to favor such funding conditions as an 'excellence turn' in science policy. They view this as an attempt to mitigate the effects of standard grant funding, where the funder's thematic priorities and selection processes typically obstruct innovation and pushes researchers toward mainstream, low-risk research, and applied topics. In an earlier study, Laudel and Gläser (2014) review the impact on research of one such excellence scheme, directed not toward groups but individuals, namely, the European Research Council grants for individual researchers. They identify a number of mediating factors (e.g. uninterrupted research time, long time horizons, and risk- and diversity-tolerant environments) that connect epistemic properties (e.g. task complexity and high technical and strategic uncertainties) to institutional conditions (e.g. high levels of funding, flexible budget structures, long-term funding). This study expands on such insights in the direction of CoEs, which adds an organizational dimension to the epistemic effects of funding mechanisms.

The import of resources is not always straightforward. In their pioneering study of US research laboratories, Pelz and Andrews (1966) emphasized that the perceived accessibility of resources was sometimes more relevant to results than their actual availability. Such findings point in the direction of subtler socio-psychological and organizational factors. Resource factors tend to be bolstered by a set of organizational conditions and processes and mediated by, for example, social climate and group composition. A common notion is that diversity stimulates creative research (Hollingsworth 2002). However, for scientific diversity to yield results, organizational arrangements that facilitate multidisciplinary interaction and collaboration are required. These include spatial arrangements in the form of shared facilities and offices, and social arrangements such as shared meals (Hollingsworth 2002; Hemlin, Allwood and Martin 2004; Heinze et al. 2009). Communication and collaboration are vital not only within the research organization but with external groups as well (Schmidt, Graversen and Langberg 2003). An important related dimension is organizational structure: flat structures with low levels of bureaucracy seem to be regarded as the most advantageous (Hemlin, Allwood and Martin 2004; Heinze et al. 2009). Youtie, Libaers, and Bozeman (2006) point out the importance of adopting a balanced approach: one should avoid 'over formalization', yet a certain degree of institutionalization is necessary to achieve ambitious research goals.

Research autonomy is another often emphasized factor. The freedom to define and pursue new lines of enquiry is valuable at the organizational and individual levels (Hollingsworth 2002). However, research autonomy is often contrasted with the need for coordination and program coherence (Tijssen 2003; Hemlin, Allwood and Martin 2004). Hence, leadership ability to integrate scientific diversity and provide strategic direction is considered critical (Schmidt, Graversen and Langberg 2003; Heinze et al 2009).

The secondary effects of concentration of funding have also been addressed in the literature, namely, various versions of the type of cumulative influence known as the 'the Matthew effect' (Merton 1968; 1988). This refers to how recognition (e.g. measured by publications and citations), material rewards (such as funding), and other capital (such as human resources) accumulate for scientists or research organizations in a self-reinforcing manner (see also Cole and Cole 1973; Latour and Woolgar 1986; Zuckerman 1987). Available studies of research environments awarded large grants are divided on the status of such claims, especially as it relates to how 'endogenous' scale-effects, in terms of grant and group size, relate to research performance. Some suggest that both performance and prospects of acquiring additional funds increase with grant size (OECD 2014; Bloch and Sørensen 2015; Bloch, Schneider and Sinkjær 2016). For example, an OECD report (OECD 2014) states that CoEs with larger budgets (> USD 1 million per year) are more prone to engage in co-operation with other research. The same report suggests that amount of funding correlates positively with the level of diversity in interdisciplinary collaboration, and that collaborations lead to new types of research and possibilities to pursue high-impact, high-risk, and long-term goals (OECD 2014). According to Bloch and Sørensen (2015), concentration of funds in larger research centers is an important factor in stimulating interaction and mutual learning.

A number of studies also suggest positive relations between collaboration and scientific productivity (Price and Beaver 1966; Zuckerman 1967; Diamond 1985; Pravdic and Oluic-Vukovic 1986; Katz and Martin 1997; Narin, Stevens and Whitlow 1991). Multiple case studies further show that research excellence initiatives attract top researchers creating critical mass essential to achieving scientific breakthroughs (Hicks and Katz 2011; OECD 2014). However, results on the impact of accumulation of resources diverge. Langfeldt et al. (2015) conclude that, while the status of CoE participants may increase after receiving a CoE grant, this does not necessarily translate into additional rewards from competitive schemes. Fortin and Currie (2013) suggest that above a certain cut-off point, scientific impact (measured by publications and citations) is generally a decelerating function of additional funding, at least for excellence schemes in single disciplinary fields.

As we have seen above, the results on the relations between resources, organizational properties, and research effects such as quantity (i.e. research productivity), quality and breakthrough (e.g. through publication impact and peer assessment) tend to point toward some common factors. These include resource availability, skill diversity, risk tolerance and informal, flat organizations. However, the mediating factors between resources and epistemic effects are not well known in their detail, and neither are the qualitative characteristics of the epistemic effects that follow. It is our expectation that further qualitative research into organizational and epistemic factors, as well as their mediating connections, can contribute toward a better understanding of the effects of CoE funding. This is what the present study sets out to offer.

3. Method

3.1 Case background

In 2005, the Swedish Research Council (VR), in collaboration with the Swedish Research Council for Environment, Agriculture, and Planning (Formas) initiated the Linnaeus grants, a competitive funding program for the establishment of 40 CoEs in Sweden. The aim of the grants was to create strong and competitive basic research environments, create synergies, facilitate scientific renewal, and influence universities' strategic priorities. The application requirements in the Linnaeus Grant Call outline the expectations of VR and the subsequent evaluation criteria. Applicants were expected to demonstrate potential for strategic and high-quality research, to establish commitment on the part of the HEI to which they belonged, to have a clear financial plan, to promote efficient coordination, national and international collaboration, to develop purposeful organizational and leadership structures, as well as communication and dissemination strategies. Each center was granted between 5 and 10 million Swedish krona (approximately 500,000 to 1 million euros) annually for a maximum of 10 years and the hosting university was required to provide additional support equaling at least 50% of the grant amount. In 2006, 20 Linnaeus centers were established in response to the first call for applications. The other 20 centers were approved in 2008 in a second round. The terms of reference stipulated that each center would be evaluated at three different occasions. The first and second evaluations were intermediary evaluations and were conducted by expert panels 1.5–2 years and 5 years, respectively, after the grants were awarded. The first evaluation assessed the organizational aspects of the centers. The second evaluation focused on scientific performance. A final evaluation is scheduled for the end of the 10-year period.

3.2 Data collection

The present study builds on a subset of the 40 CoEs encompassing 10 centers, which had at the time been operating under continuous funding from the Linnaeus grant for a time period of 8–10 years. The sample was selected to ensure variety in terms of the disciplines/subject areas and the year of the award. A majority of the centers studied are from the 2006 call, since these had the most time to develop and observe the effects of interest; however, a few centers from the 2008 call were also included to control for possible temporal variations. No such variations were observed in the interview data. In addition to interviews, the researchers had access to the program calls and the two rounds of evaluation reports (2-year and mid-term reports). Table 1 below provides a brief overview of the cases.

In selecting respondents, a central concern was that these should have a maximum oversight of the development of the center, preferably from the beginning. The only actors who filled that criterion were the founders/directors and, where applicable, their successors. Interviews were therefore conducted with center directors (total 10), in some cases jointly with their co-directors. Interviews were conducted in the Spring of 2016; each occasion lasted for about 1 h and focused on questions regarding center context, the grant's effects on organizational development, center activities, and research processes. Specific questions included:

- How has the Linnaeus CoE funding affected your research in terms of (a) organization (how research projects are run and related, teams etc.) and (b) the way that you pursue knowledge in your field?
- What aspects of the CoE experience have been the most important in this regard? How has the form of funding, evaluations, and other relationships (e.g. to the university) impacted on the research and ways of doing research?
- Can you identify negative or positive effects in this regard?

Interviews were conducted in an informal manner, where respondents were left to explore these topics themselves and make their own connections. The interviewers would ask follow-up

Table 1. Overview of selected cases

Center	Year	University	Subject area
Linnaeus Centre on Engineered Quantum Systems (LINNEQS)	2006	Chalmers	Physical Sciences and Engineering
Learning, Interaction and Mediated Communication in Contemporary Society (LinCS)	2006	University of Gothenburg	Humanities, Social Sciences, and Educational Sciences
Centre for Studies on the Therapeutic and Prognostic Potential of Mesenchymal Cells of the Tumor Stroma (STARGET)	2006	Karolinska Institutet	Medicine
Hemato-Linné	2006	Lund University	Medicine
Organising Molecular Matter (OMM)	2006	Lund University	Natural Sciences
Innovation, Entrepreneurship and Knowledge Creation: Dynamics in Globalizing Learning Economies (CIRCLE)	2006	Lund University	Humanities, Social Sciences, and Educational Sciences
Lund University Centre of Excellence for Integration of Social and Natural Dimensions of Sustainability (LUCID)	2008	Lund University	Humanities, Social Sciences, and Educational Sciences
Centre for Marine Evolutionary Biology (CeMEB)	2008	University of Gothenburg	Natural Sciences
Lund Centre for Control of Complex Engineering Systems (LCCC)	2008	Lund University	Physical Sciences and Engineering
Uppsala Centre of Evolution and Genomics (UCEG)	2008	Uppsala University	Natural Sciences

questions where necessary. Interviews were conducted at the center and were recorded and transcribed verbatim. They were later followed up with complementary questions where it was deemed necessary. In all cases, the respondents were informed that the interviewers/research project had no connection with the CoE funder. They were also aware that the CoE grant had come to a non-negotiable end, and that their answers had therefore no evaluative impacts in this regard. To minimize the possible effects of bias in the accounts, follow up questions were used, exemplification of statements was sought as much as possible, and coherent, detailed accounts were emphasized and factually cross-checked during the interviews and in the subsequent analysis.

3.3 Data analysis

The present study addresses the empirical question of the way in which CoE funding affected organizational capacity and epistemic effects in the research groups that received funding. The units of analysis are the recipients/groups and their activities in building organizational capacity and creating new knowledge. To elicit results within this domain, the empirical study employed a template analysis utilizing two broad categories: 'organizational capacity' and 'epistemic effects'. Within these two general themes, sub-categories were developed using what Thomas (2006) refers to as 'the general inductive approach'. The procedure followed a standard method of first going through the interview transcripts in detail, identifying accounts and elaborations which denoted activities explicitly or implicitly relating to the above themes. These statements may be referred to as 'meaning units' following Giorgi (1997), and they are taken to represent ascriptions regarding how the grant affected the environment and the results of research. Meaning units were captured by assigning codes in the form of short descriptive labels or simple keyword summaries to such statements. Codes were then clustered based on commonalities identified relating to the broader themes of the research question. Using these codes, the themes were broken down into lower level categories according to the same method of identifying similarities and co-extensive qualities in meaning units. The dimensions identified in this way are presented in the next section together with explanations and illustrating quotes. The authors have selected the most representative quotes with respect to content across disciplines, and those that were most illustrative of the specific effect reported. The selection of quotes presented in the below is therefore not indicative of disciplinary differences, but rather of how well they illustrate the effects that were observed throughout the material.

4. CoE funding, research capacity, and discovery

Within the two main themes six sub-themes emerged from the interview material. The main themes thematize the topic of this study—organizational and epistemic impacts of the CoE instrument. In terms of their content, the sub-themes make up the central contribution of the study, as they provide insight into the specific impacts in terms of the main themes: research capacity and epistemic effects (discovery). The sub-themes corroborate that capacity (and organizational vitalization) effects are associated with epistemic effects and that, in the perception of the research directors, these are associated with the CoE funding instrument. Table 2 gives an overview of the content of the two main themes of interest.

In the following, these themes will be explicated with the support of a number of selected quotes from the research directors.

4.1 Theme 1: Research capacity—building research organization

This theme covers the organizational aspects of CoE funding, typically the development of various capacities on the level of the center, group, and individual researcher. These range from human capital, to financial, data, and infrastructural effects, and vitalization in terms of collaboration and knowledge sharing.

4.1.1 *Recruitment and development*

One of the most apparent effects of CoE funding is the ability to expand the research environment in terms of new staff and also to enrich and develop junior staff in the direction of the research program through leadership opportunities, social interaction, and training. An illustrative quote bearing on the first type of effect:

> We were able to recruit new people—new group leaders, young group leaders. We recruited two of those [...] it has increased the

Table 2. Funding effects on capacity and discovery

Capacity	Content
Recruitment and development	Human capital, autonomy, social reach, learning synergies
Resource and Mathew effects	Stability, signal value, attractiveness, 'managerial Mathew effect', information capacity
Cross-collaboration and knowledge sharing	Academic vitalization, new combinations, culture and community building
Discovery	
Epistemic integration and reach	Integration of specialism, disciplinary renewal, basic-applied integration, methodological development
Epistemic venturing	Risk-taking in problem selection, new directions of inquiry, short to longer term research strategies, unexpected collaborations

> interaction and collaboration between the investigators. (**Hemato-Linné**)

A salient feature in this regard, and one that occurs several times in the interviews, is the type of opportunities that the CoE milieu can offer upcoming researchers in terms of autonomy and leadership, and the way in which this opportunity acts as a powerful attracting force for the centers.

> [The Linnaeus grant] has had more impact on the young scientist because we have attracted a lot of young group leaders to the environment [. . .] We had a number of people who came, and who trained here initially but then went abroad, mostly to the United States. They have then come back and written their grants and then established their groups. They have done it within our environment. There is no doubt that program made our environment attractive to young people. (**Hemato-Linné**)

Due to the long-term nature of the grant, one could also observe a quality effect in recruitment:

> [The grant] gave a longer planning horizon. It is easier to recruit people if you can say we have the money for 10 years. So we got higher-quality people. (**CIRCLE**)

In several instances, the center worked as a platform for expanding the reach of junior and new staff, by connecting them to other university environments. The overtly cross-cutting ambition of the centers tended to make this a natural move:

> At the level of the PhD students and the post docs [. . .] they now have this cross-department community where they know other students and post docs and they meet on monthly seminars and annual retreats. And I think this has broadened their perspectives and made them better prepared for future work. (**STARGET**)

Finally, the combinatory opportunities for education were apparent in several cases, i.e. the location of interdisciplinary centers between subjects made PhD schools easy to assemble on the basis of existing offerings.

> We needed a summer school. We do not do the same things but similar enough that the students and post docs would benefit from the same lecturers. (**LINNEQS**)

4.1.2 *Resource effects (and Mathew effects)*

In terms of monetary resources, there are some non-obvious circumstances that nonetheless ran through most of the reporting from the centers. One has to do with the often small relative size of the grant vis-à-vis the total budget, and its role as such:

> We still pull in money from many other places, so the grant is only maybe 10-15% of the total turnover. But it is the biggest chunk. Since it is long term, it is a backbone. [. . .] the rest of the 85% of the money that we bring in is really fragmented. So having something that is big and long-term is very important. (**LINNEQS**)

The stability offered by the grant is one important aspect. Another is the signal value that stability carries to other funders, and the fact that funding is often perceived as more effective if combined with existing resources:

> What is more important is that a couple of other external grants have been directed toward this. Now for example, all these other persons that came in to CeMEB that were not part of the original funding, they came with their own grants. They brought their own money in. (**CeMEB**)

Stability in funding also increases real research achievement which in turn leads to competitive attractiveness:

> The environment has been growing as a result of the grant. We have become more competitive in areas where we were not competitive before, so we certainly have a better opportunity to bring in funding from outside. (**LCCC**)

This category of capacity effects can take on unexpected forms. In one instance, one may want to speak of a 'managerial Mathew effect' where the center used their money to delegate the application work away from core research staff—a strategy that turned out to be very successful.

> It has made it possible for us to get more grants because, for the Hemato-Linné money we hired a grant manager. [. . .] So, yes, it has led to new projects but that is because we have been able to improve our capacity to get extra funding. (**Hemato-Linné**)

A significant resource effect was related to those capacities offered by new investments in data collection and infrastructure for generating new data. A typical example of a data/infrastructure resource is the genome database at CeMEB. The quote below illustrates the self-reinforcing effects of such resources, in the sense of a Mathew effect where results beget more results:

> When you provide these rather comprehensive resources like a genome of a species, this species become more attractive as a model for all kinds of other studies. Then of course, people are invited to come and collaborate with us. They can come and get this genome information and can benefit from what we have done there. (**CeMEB**)

4.1.3 *Cross-collaboration and knowledge sharing*

One central aspect of organizational capacity is found in the possibility for vitalization and academic community building. Such community seems to be supported by certain organizational activities and facilitates knowledge sharing. One such activity is the informal but recurrent work-in-progress seminar as opposed to the more traditional formal seminars typically found at the departments:

> The Linnaeus coffee meetings make us a community. They facilitate collaboration. Especially, it gives PhD students and post docs a chance to present in front of a broader audience. Not always just results but also the problems they experience in reaching the results. They can get feedback, not only from their supervisors but also from other colleagues (post docs, supervisors). [. . .] It is allowed to show your dirty laundry. Not just the finished products. It seems to work. (**LINNEQS**)

New research constellations forged within the centers were also a source of research vitalization:

> The grouping of these people somewhat raised the expectations, our expectations of ourselves. [. . .] it also created a set of contacts which were in some cases really very useful for the individual projects, but also providing a sort of intellectual environments which really impacted on the work. (**STARGET**)

Such collaborations were also successfully incentivized by some of the centers, e.g.:

> We basically gave people 250,000 to 350,000 [Swedish krona] a year depending on how much they were collaborating within the program [center] and also we tended to give a little more to the young people. (**Hemato-Linné**)

Again, younger members of staff were central to this process, and tended to act as bridges between projects led by more senior members.

> Post docs [act] as glue between the different research groups. Typically, they would be involved in collaborative projects. (**UCEG**)

4.2 Theme 2: Discovery—epistemic renewal effects

The building up of organizational research capacity is of course intended to have certain effects in terms of results, hypotheses, and novel instrumentation—i.e. new knowledge and methods. Such 'discovery effects' were found in most cases and pertain to three types. The first two involve the integration of existing areas of research and extending into new ones. They have been grouped together here since they can be clearly separated from a third kind, 'epistemic venturing', which involves pursuing risky projects that generate and test new hypotheses and attempts to develop new theory.

4.2.1 *Epistemic integration and reach*

Many of the centers represent a type of interdisciplinarity that is often associated with cutting-edge science. It is therefore not unexpected to see an integration of specialisms within the centers. It is interesting to note though that some of these new 'niches' came as unexpected outcomes from center activities:

> We have created new niches in between the different fields which we were not aware of before. It is more like we have found more connections between them. (**UCEG**)

In some cases, it is not so much the combination of fields as the possibility to renew one's way of practicing a traditional discipline, once one is transported into a new context:

> So, these two philosophy PhDs, they decided very early on to base themselves here. So, they have been practicing philosophy in a completely different environment than all their colleagues. And that has resulted in a significant different kind of philosophy thesis. [. . .] It is rather unusual that you can do your PhD in an eclectic mode so to speak. (**LUCID**)

The combination of expertise available in the center and its network made it possible for researchers to extend their inquiries further and take on a wider range of problems:

> One positive thing was that we could use each other's expertise, which is making science more efficient in a way. I would not be able to cover that broad range of expertise within my own group. I would not be able to keep up with what is happening in all those fields. Instead I can use the expertise of the others. Having these networks of different expertise that is useful in our own research was the main advantage, I would say. And then also to be able to use each other's extended networks. (**UCEG**)

One type of integration/extension, which has historically proved useful but risky, is when scientists combine their effort with instrumentalists, and in that way extend their inquiry further.

> But we have had a lot of collaboration with the group that is looking at materials and devices with electron microscopy. They have spent a lot of time analyzing the devices we have made. And this is starting now to be very valuable but it has taken a long time. So this long time perspective was also valuable for that. (**LINNEQS**)

A version of this integration/extension is the inclusion of new methods and the epistemic effects this carries. The more radical the new methodological innovation, the more likely one is to have to rely on outside actors. In one of the centers, a breakthrough came about as a result of the new setting offering an unexpected methods competence:

> We had one project on skin, and we collaborated with a method specialist. We tried out something new [assuming that] method development could answer an unanswered question, which it did. (**OMM**)

The available time dimension may be critical in forging such relationships, as could be observed in the following quote:

> The time that is available [. . .] is the key to this different, or new—at least for me—way of thinking about collaborations. For example, we started to invite physicists. They are modelers. They don't know anything about biology but they are really clever in doing models. And of course it took like 2-3 years before we started to understand what they were talking about, and for them to understand what we were talking about. (**CeMEB**)

Epistemic integration and extension also comes about through the type of resources created on center level, and which attract new contributions to the research program. This resembles a kind of 'epistemic Mathew effect' where outside scholars increase the pools of new knowledge due to previous discoveries available at the center.

> We are really, really happy that people do this [utilize the genome database] because the more you get into a model, the biology and all the aspects of a species, the more useful

it also becomes for the studies that we are interested in. (**CeMEB**)

4.2.2 *Epistemic venturing*

Short-term funding may provide a disincentive to take on tougher challenges for the fear of failing to show results at the end of the funding period. Correspondingly, long-term funding may enable some researchers to take on riskier projects:

> The long term perspective allowed people to be more ambitious and more daring and that resulted in good studies. (**STARGET**)

More specifically, such projects would carry high epistemic risk—characterized by high potential but highly uncertain outcomes:

> Because the funding was long term, we dared to move into trickier questions. That would be impossible if you only get a small personal grant and you have four years to produce something. So, in that sense, we could aim for more difficult questions. Those would typically be potentially high impact questions, but a little bit unreliable in terms of getting results on a yearly basis. (**UCEG**)

This is captured on the researcher level with a quote that illustrates how center money enabled a PI to change direction toward a risky, hot topic:

> So for instance, two of the PIs started to do topological insulators, and they were free to do that because this was a new and hot topic. [. . .] we knew we would have funding for quite a long time ahead. We did not have to try the simple things. (**LINNEQS**)

This type of funding, on occasion, also allowed researchers to test risky hypotheses about possible research trajectories and thereby close off less fruitful paths:

> For example, these guys who got financed to do graphene, they had money to do electrons on helium, which proved to be too difficult, so they decided to switch. [Electrons on helium] was one of these really difficult experiments that we did not succeed with. So then after two years, we closed that down and we gave this money to graphene instead. (**LINNEQS**)

It is easy to understand, intuitively, how slack in terms of financial resources and time can encourage risk-taking. It is more difficult to capture the social circumstances that make this a fact in research. One quote captures a type of negative social stratagem that may be encouraged by short-term grants:

> If you have a 3 year-grant [. . .] people already have ideas in their drawers and they just throw them out saying 'lets do this', and they do 'this' [. . .]. But if you have ten years, you can start to think about 'well, what can we do now?' (**CeMEB**)

We will end this section by more clearly connecting organizational capacity to the propensity for epistemic venturing, risk-taking and discovery, namely, where the case is such that disciplinary collaboration encourages risk-taking in research.

> [The cross-disciplinary nature of the collaborations] has increased the speed of the progress and the readiness to try new things. It reduced the threshold for starting novel projects, because of the, sort of, personal vicinity. (**STARGET**)

We will now turn to the discussion and conclusions, where we will attempt to reconstruct a number of mechanisms from the above that can account for how resources connect to epistemic effects via such organizational capacities.

4.3 Discussion and conclusions

The aims of CoE program schemes are varied but usually center on a few topics, namely, the generation of critical mass in a field and subsequent effects such as progress in research and innovation. Sometimes, there are intermediary outcomes such as promoting the ability of universities and research areas to prioritize by focusing effort. In the case of CoE schemes aimed at basic research, such as the one investigated in this study, the assumption is that concentration of resources can facilitate research capacity and subsequent epistemic effects, e.g. new scientific advances. The kernel of such a program theory is quite simple: funding leads to capacity, which leads to scientific development. As we saw in the research overview, previous studies converge on factors such as resource availability and stability as precursors of high-risk, high-impact research (e.g. Hemlin, Allwood and Martin 2004; Laudel 2006; Heinze 2008; Heinze et al. 2009). The first step of analysis, and one that has been conducted in this study, is to explicate the content of the components of this effect chain (Table 2). However, what is less clear is what kinds of mechanisms condition the causative relation between these.

The present study suggests that the relationship between capacity and research can be usefully rephrased as one where resource volume, concentration, stability and the flexible use of these resources stimulate progress in research. The key question is—What can be gleaned empirically about how resources yield capacity and how capacity stimulates research? A qualitative study of this kind cannot elucidate to what extent types of capacity correspond (typically) with specific epistemic effects. What it can do however is to exemplify, with a certain level of realism, mechanisms that mediate between capacity and epistemic effects. This is possible, as these mechanisms are accounted for explicitly in the qualitative descriptions provided by the respondents involved in these processes. Several such mediating narratives are present in the interviewee quotes, and they do suggest a common principle that can be used to make theoretical sense of the program theory sketched above. In essence, this principle can be summarized as:

> ***(A) Resource volume, concentration and stability →Time/resource slack and critical mass/available partners → collaboration → new connections of expertise to address new/old problems and a higher degree of risk taking in research.***

In what follows, we will look at each of the themes from the results in terms of this principle, and relate them to some previous research. We will start with the epistemic effects and work backward toward their precursors.

The epistemic effects were of three kinds: extension and integration of knowledge and epistemic risk taking or venturing. The first two can be summarized as the connection of specialisms and expertise to address old problems in new ways or address new problems altogether. The accounts related how the researcher or the group, by making new contacts with relevant expertise, were able to develop new methods/instrumentation or improve old ones, utilize expertise to solve a problem and combine expertise to elaborate a problem or find a new problem. Epistemic venturing was suggested to be stimulated by the slack offered by the stability and volume of resources, which in turn led to more daring questions being posed, longer term engagement with tricky problems, and testing of new research

Table 3. Progression from resources to epistemic effects in CoEs

Resources →	*Slack/critical mass →*	*Collaboration →*	*Epistemic effects*
Stable financial guarantees	New recruitments and scholarly development	Interaction and collaboration around data sources	Using complementary expertise on new and old problems
Matthew effects: Attracts researchers with grants who wish to co-locate	Frees up time for researchers through investment in management functions	New research constellations/groups	Testing and exploring new research programs
Improves academic credibility and thus more resources	Longer time-frames and reduction of 'reporting urgency'	Common social platform for reaching out to other academic groups and communities	Testing risky hypotheses/projects

trajectories. This type of slack is analogous to the autonomy factor identified by Hollingsworth (2002) as key to an inventive research environment.

Similar to the present study, previous research found that stable financial guarantees attract top-quality researchers (e.g. Hicks and Katz 2011; OECD 2014). Specifically, in the present case, we observed how researchers with grants who wish to co-locate at a resource-rich center improve academic credibility and capacity, which generates more resources. It also frees up time for researchers through investment in management functions. The sub-theme 'recruitment/development' suggested that long-term funds for recruiting new people stimulated interaction and collaboration, and in effect new constellations. Such qualities have been argued to be vital for research productivity and quality (Narin, Stevens and Whitlow 1991; Katz and Martin 1997). These factors illustrate mechanisms for translating resources into critical mass and available partners. Similarly, under this sub-theme, we find the uses made of the center as a common platform for reaching out to other academic groups and communities, e.g. via cross-cutting PhD schools. New information infrastructure improves quality of data and inquiry and also leads to more outside collaborations. The interviewees showed how collaboration was also stimulated internally through informal 'project-oriented' seminars, and new research connections generally across the university and the field, which in turn raised expectations on results and impacted research. Such observations give further support and content to arguments by e.g. Hemlin, Allwood and Martin (2004) and Heinze et al. (2009) to the effect that collaboration and communication need infrastructural and organizational support of various kinds. It also supports Schmidt, Graversen and Langberg (2003) in the observation that such infrastructure platforms can stimulate outside collaboration.

By drawing on the qualitative content discussed above, we are now able to explicate the general principle expressed in (A) in terms of some central mechanisms. Table 3 is an attempt to unpack these mechanisms, to illustrate how resource stability can yield epistemic flexibility by way of creating slack/critical mass and stimulating collaboration.

It is important to note that not all epistemic effects come about as a result of collaboration. Some of the examples of risk taking in research (epistemic venturing) seem to have been stimulated by resource slack alone rather than availability of co-located expertise. This points in the direction that some important epistemic effects from resource concentration can be had without the typical co-location conditions set out in most CoE schemes. However, the dominant pattern found in this study supports the notion that critical mass of co-located researchers and concomitant collaboration is an essential facilitator for development in research.

An additional observation can be made regarding the import of some design features of the CoE instrument. The Linnaeus CoE call stipulated a number of formal requirements on the centers in terms of leadership structure and communication among others. These requirements were followed up mainly through two interim evaluations in the first 5 years of the centers, relating to organizational structure and processes, formalized leadership, communication plans, and other formal reporting regimes. However, the results from this study do not make it evident that such governance attempts operated as mediating factors between resources and epistemic effects. As a matter of fact, according to the interviewees, such attempts at more detailed epistemic governance (demands for certain organizational structures, interim evaluations, and penalty/rewards mechanisms) have had little effect on the direction of the epistemic production of the CoEs. Instead, respondents reported that these funder 'steering signals' made little difference to the way they ran the center once the grant had been received. This absence of effects from specific features of the instrument may be related to the fact that the directors were already highly accomplished academics with enough leadership skills to make a CoE work. It could also be related to the proportion of funding made up by the CoE grant (typically 15–20% of the total center budget), which may not have been substantial enough to enable steering from the funder to take effect. No doubt this issue deserves more thorough investigation.

The design features, that we conclude have had an impact on epistemic production, instead appear to be those features of the instrument that embody the values of stability and flexibility. These two features seem, independent from steering from the funders, to have activated a number of capacity functions (e.g. relating to recruitment practices, and the accumulation of supporting technologies and funds) and epistemic functions (e.g. interdisciplinary collaboration and risk-taking).

One core assumption of this study remains to be fully corroborated, i.e. that institutional priority-setting markedly affect how researchers construct research problems, which types of projects they pursue, and how they divide research labor and other resources in terms of these problems. However, in the above, we have been able to distinguish central mediating mechanisms between organizational and epistemic capacities and to identify these as outcomes of the funding scheme. In effect, the proposed connection between funding stability and epistemic flexibility is in part supported and usefully

exemplified in a way that may further understanding of the operation of this type of funding instrument.

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Paper II

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Governing interdisciplinary cooperation in Centers of Excellence

Tomas Hellström, Erik Brattström and Leila Jabrane

Department of Business Administration, Lund University, Lund, Sweden

ABSTRACT

In the past years Centers of Excellence (CoE) has risen to prominence as a funding instrument in science. The idea is that by focusing resources, people and attention within a center environment, and over a substantial time span, excellence in science can be promoted. Similarly, interdisciplinarity is often seen as an enabling condition or even necessary for frontier research. This article builds on a qualitative interview study with Swedish Centers of Excellence (CoE) directors, and asks the question: - how is interdisciplinarity governed and developed within a CoE environment, and what is its effects in terms of research processes and organization. The study presents a detailed account of a number of aspects of interdisciplinary governance, conditions and outcomes, and describes how these relate via specific mechanisms. Together the results illuminate how CoE governance creates pathways to interdisciplinarity, that allow collaboration to go beyond mere interaction, and towards integration of specialisms.

Keywords
Centers of Excellence; interdisciplinarity; research environment; governance; funding; impact

Introduction

This article uses a qualitative Small-N study to investigate how processes supporting interdisciplinary research are stimulated, created and maintained at Centers of Excellence (CoEs), and what these processes result in. In recent years CoE programs have become popular instruments of research policy across the globe. The basic idea of this way of funding science and innovation is to build substantial capacity in one or several areas of inquiry, by investing sizeable funds over a longer time period compared to traditional projects. Also, there is usually a requirement that the investment leads to the creation of a stable social milieu for research, where knowledge creation is conducted in cooperation, 'under one roof', in a center setting. CoEs have various aims, mostly in promoting certain areas of science and technology, and to lesser extent development (Hellström 2011; Orr, Jeager, and Wespel 2011; Aksnes et al. 2012). They also typically have a number of 'meta-aims' that relate to capacity to enter into and to explore emerging fields of science, to create cooperation among scholars, to professionalize academic governance, and to promote organizational capacity for governing science at the frontier (Hellström 2018).

For these reasons interdisciplinary cooperation is often a requirement in program calls, and a standard indicator in evaluations of such centers. The assumption here is that it is through cooperation between disciplines and specialisms that new discoveries are likely to happen, and that capacity for such cooperation is likely to stimulate environments of learning, within and across departments and at universities generally. CoEs are usually located at universities, and represent a type of organizational innovation there, i.e. they represent investments in growth, priority setting within the

CONTACT Tomas Hellström Tomas.hellstrom@fek.lu.se

university, and a support for sustaining academic achievement. In this regard cooperation and interdisciplinarity are qualities that ensure spill-over and integration between the center and its surroundings. For the purpose of reinforcing these structural, processual elements, CoE evaluations often look for organizational structures that promote cooperation, and leadership that supports boundary-spanning activities (Hellström 2011).

Interdisciplinarity may be conceived of on several levels. For example, one may consider various disciplinarities coming together within a singular researcher's work; as a form of interpersonal interaction between representatives of different fields; and on larger organizational scale, as cooperation between departments and faculties (Pfirman and Martin 2017). In this article we mainly consider the last two forms, and specifically the second, since the unit of analysis is the CoE and the cooperative dynamics taking place there. We believe that an understanding on this level of integration is vital to appreciate how the university as a whole can benefit from interdisciplinarity, not only from CoEs and other units created to pursue academic goals, but also from applied interdisciplinary activities such as those involved in Grand Challenges oriented research. Combining domain expertise to solve scientific and applied problems typically involve creating routines that respect, yet challenge the disciplinary identities of participants, and that can facilitate problem extension and knowledge integration among a diversity of researchers (Hellström 2012).

Here a delimitation is in order. Since this study is focused on basic research oriented CoEs, it does not deal with transdisciplinary activities that crosses sectoral boundaries and aims to knowledge creation 'in the context of application' etc (Gibbons et al. 1994). That being said, in the pages that follow we will carefully outline what we mean by interdisciplinary collaboration. The article will proceed as follows: in the next section we will discuss some previous research on CoEs and interdisciplinarity, as a means of contextualizing and further delimiting our research focus. Secondly, a methods section, where we outline the approach; a non-comparative, Small-N study involving 10 Swedish CoE in the natural and social sciences, medicine and engineering. Thirdly, the results section will outline our main findings regarding the governance, supporting conditions, and outcomes of interdisciplinary work at these centers. The article ends with discussion and conclusions.

Excellence, organization and interdisciplinarity

Excellence

When discussing research excellence on the organizational level, one typically refers to environments that demonstrate high scientific quality and productivity, resource attraction and topic concentration, and that are highly visible and attractive to international talent (Orr, Jeager, and Wespel 2011; Aksnes et al. 2012; Hellström 2012; Borlaug 2016). Other evaluative dimensions include organizational matters such as leadership, organizational structure, outreach/visibility and collaboration (see Tijssen 2003). Many CoEs are expected to demonstrate some kind of interdisciplinary collaboration, at least in the broad sense of acting as platforms for interaction between specialisms and competencies. A strength in this regard supposedly lies in these organizations' ability to provide platforms for a type of interaction; a sort of bottom-up organization of research, which is not as easily accommodated within departments and faculties (Hellström 2011; Langfeldt et al. 2015; Borlaug 2016). Gläser and Laudel (2016) refer to this as the 'excellence turn' in science policy. The type of funding logic implied in CoE schemes and other excellence initiatives usually works through allocating more money over longer time periods than traditional grants. Laudel and Gläser's (2014) review of the impact of the European Research Council (ERC) grants for individual researchers identifies a number of effects from substantial, long-term flexible funding, e.g. uninterrupted research time, long time horizons, and risk- and diversity-tolerant environments.

This corresponds well to what some observers, e.g. Heinze et al. (2009) have found, namely that extra-mural collaborations play a great role in research excellence, and that successful groups, such as CoEs, draw on larger collaborative networks, provide links between disjointed peers and

stakeholders, and work under conditions that reflect interdisciplinarity. Other organizational aspects include mechanisms supporting collaboration through sharing of laboratory or office space, maintenance of collaborative networks, and access to complementary research skills (Heinze et al. 2009). Likewise, Martin, Allwood, and Hemlin (2004), in their work on Creative Knowledge Environments (CKEs), suggest that collaboration with other groups is a robust predictor of creativity. Common observations in this literature include that organizations that generate significant research contributions typically display visionary, nurturing and integrative leadership, scientific diversity, interdisciplinarity and integration of activities (see Hollingsworth and Hollingsworth 2000; Hemlin, Allwood, and Martin 2004; Heinze et al. 2009). With these preliminary observations, we can go on to discuss insights from the literature regarding what interdisciplinarity is, how it is typically stimulated, and related challenges.

Interdisciplinarity

The traditional sense of a discipline is that of a unified, autonomous corpus of knowledge (Silliman 1974), which supports an area of instruction or expertise, that is the 'disciplining' of students by the profession of academic instruction and research (Guntau and Laitoko 1991). When we refer to disciplines in the context of interdisciplinarity, we talk about these broader units of inquiry, the intellectual units which 'structure the framework in which day-to-day decisions, actions and interpretations are carried out by groups of scientists' (Whitley 2000, 8–9). We also recognize that within the framework of interdisciplinarity, a discipline can also be understood in a more limited sense, as a specialism, e.g. molecular cell biology, which is located within a broader discipline, such as biology. As a consequence, we assume that interdisciplinarity can also be collaboration between specialisms within a broader intellectual field, where these specialisms typically have their own journals, conferences, types of methods and instrumentation, and work on distinctive theoretical problems.

The literal meaning of 'interdiscipline' is 'between disciplines' (Stember 1991), which is a space of potential, yet uncovered knowledge between two or more fields of knowledge, here taken to be disciplines, intellectual fields or specialisms, where researchers can meet to study parts of reality not yet researched. Interdisciplinarity then is a means for closing knowledge gaps between disciplines, fields and specialisms, by formulating problems and organizing research through cooperation (Karlqvist 1999). There are many and overlapping descriptions of interdisciplinarity, and at the same time a conspicuous lack of one singular, agreed-upon definition (Klein 1990; Holbrook 2013). This may be a sign that interdisciplinarity is not one distinguishable form of research at all. Rather it may simply be a way to describe of how research, especially at the forefront of inquiry, is usually conducted, in cooperation between specialisms that draw on various disciplinary sources of knowledge (results, theories, methods, etc). In fact, some argue that defining interdisciplinarity is less important than making the 'correct appreciation of the true nature of the problem to be solved' (Hansson 1999, 342).

So, perhaps interdisciplinarity should not be described as a particular type of knowledge, but rather in terms of a form of cooperation between areas of knowledge or specialisms in science. One way of describing such cooperation is through the notions of interaction and integration (see e.g. Lattuca 2001). The notions of interaction and integration refer to the degree of collaboration (for a comprehensive account, see Klein 2010). The first is that of interaction/communication, where cooperation is characterized by the exchange of background or contextual material between disciplines (e.g. Simon and Goode 1989). In this sense, disciplines are auxiliary or supplementary (Heckshausen 1972). The second form of interdisciplinary relationships is that of amalgamation and mixing of disciplinary perspectives and intellectual resources. Here, integration occurs when research design refines fundamental questions (Klein 2010).

Interdisciplinarity serves different strategic aims, in science and in society, and has different consequences. For example, when a problem-solving aim is pursued, one may talk about an instrumental use of interdisciplinarity. This can be a strategy to serve the needs of either the disciplines (Kann 1979), or those of the nation state as in the case of applied or strategic research (Weingart 2000). Salter and Hearn (1996) suggest that, in instrumental interdisciplinarity, institutional boarders are

typically maintained and researchers simply increase the problem-solving capacity of their own discipline by appropriating ideas and methods from another discipline. As a contrast to instrumental interdisciplinarity, Klein (2010) points to a critical use of interdisciplinarity which aims at transforming incumbent structures of knowledge, education, and politics. Similarly, Aram (2004) points out how interdisciplinarity could challenge 'assumptions of institutional and social power embedded in disciplinary work' (382). Klein (2010) concludes that instrumental and critical interdisciplinarity varies in degrees of interaction/integration, where the former is considered to display a lower degree compared to the latter.

Facilitating conditions

The factors facilitating interdisciplinary research can be divided into two main categories: external and internal (Klein and Porter 1990). A number of studies point to institutional support for interdisciplinarity as an important contextual factor (external). Such support can range from simple intellectual openness within disciplinary departments (Lattuca 2002), to actual policies and practices such as joint appointments and special mechanisms for assessment and recruitment (Lattuca 2002; Porter et al. 2006), to the establishment of independent interdisciplinary research units (National Academies Committee 2005; Sá 2008). Among external factors, emphasis is also placed on funding conditions. The latter can have great influence over the desirability, focus, pattern, and time horizon of interdisciplinary endeavors (Boix Mansilla, Lamont, and Sato 2016; Pfirman and Martin 2017).

When it comes to internal factors, a common thread in the literature on the success of interdisciplinary teams is the importance of managing differences and creating common ground (Lattuca 2002; Öberg 2009; König et al. 2013). By definition, members of interdisciplinary teams have different backgrounds and skills, coming from different disciplines or specialisms. The extent of the desirable disciplinary distance among team members might be a matter of a trade-off (Porter et al. 2006). On the one hand, diversity may generate creative and novel outcomes; on the other hand, it may lead to disagreements and conflicts. Therefore, personal characteristics such as flexibility, willingness to learn, capacity to interact effectively with people from different backgrounds, and skilled leadership are seen as highly favorable (Klein and Porter 1990; Boix Mansilla, Lamont, and Sato 2016). Similarly, arrangements and processes facilitating interdisciplinary interaction and dialogue are also considered to be of utmost importance (National Academies Committee 2005; König et al. 2013). Beyond the organization of workshops, seminars, meetings, and training, interdisciplinary teams should develop opportunities for informal 'collegial contact' to develop trust and understanding and allow for 'serendipitous connections' (Pfirman and Martin 2017). Physical proximity is one way to ensure such informal interactions regularly (Klein and Porter 1990).

Method

Case background

The empirical focus of this study is the Linnaeus grants, a competitive CoE program for basic (and to some extent strategic) research, established by the Swedish Research Council for Environment, Agriculture and Planning (Formas) and the Swedish Research Council (VR). The grants aimed at creating strong research milieus, scientific renewal, and influence the universities' research priorities. The application requirements outline some expectations of the centers, e.g. to promote efficient coordination, national and international collaboration, to develop purposeful organizational and leadership structures, as well as communication and dissemination strategies. Altogether 40 centers were established in 2006 and 2008, with a duration of 10 years. Each center was granted between 5–10 million SEK (ca 500.000–1 million euros) per year, with 50% co-funding from the host university. The designation of the Linnaeus centers as representing 'excellence' in the sense discussed above, rests partly on the highly competitive nature of the application procedure and the international evaluation

processes applied to each application. This ensured that the centers selected for funding were constituted of top-performers in their respective fields. Furthermore, subsequent bibliometric evaluations have showed that these centers together had on average a 60% higher citation rate compared to the world average (VR 2015).

Data collection

The study builds on a 10 center subset of the 40 CoEs. These were selected to cover the disciplines/subject areas representatively. Table 1 provides an overview of the selected centers.

In selecting respondents, a central concern was that these should have a maximum oversight of the scientific development of the center, preferably from the beginning. Actors who filled that criterion were the founders/directors. Interviews were therefore conducted with center directors (total 10), in some cases jointly with their co-directors. Interviews were carried out in the of Spring 2016, and lasted for about 1 h in each case. The interviews were open-ended, but focused on center context, the grant's effects on organizational development, center activities, and research processes, e.g.:

- How is the Linnaeus CoE related to research in terms of (a) organization (how research projects are run and related, teams etc. and (b) in terms of the way that knowledge is pursued in the area?
- What aspects of the CoE experience have been the most important? How has the form of funding, evaluations and other relationships (e.g. to the university) impacted on research and ways of doing research?

Interviews were conducted in an informal manner, at the respective center, and were recorded and transcribed verbatim. They were later followed up with complementary questions where it was deemed necessary. In all cases, the respondents were informed that the interviewers/research project had no connection with the funder. They were also aware that the CoE grant had come to a non-negotiable end, and that their answers had therefore no evaluative impacts in this regard.

Data analysis

The analysis utilized what Thomas (2006) refers to as 'the general inductive approach', where interview protocols are carefully read in order to elicit general commonalities and categories in the material, taking the point of departure in a research question. The procedure followed a standard

Table 1. Overview of the centers.

Center	Year	University	Subject area
Linnaeus Center on Engineered Quantum Systems (LINNEQS)	2006	Chalmers	Physical Sciences and Engineering
Learning, Interaction and Mediated Communication in Contemporary Society (LinCS)	2006	University of Gothenburg	Humanities, Social Sciences and Educational Sciences
Center for Studies on the Therapeutic and Prognostic Potential of Mesenchymal Cells of the Tumor Stroma(STARGET)	2006	Karolinska Institutet	Medicine
Hemato-Linné	2006	Lund University	Medicine
Organising Molecular Matter (OMM)	2006	Lund University	Natural Sciences
Innovation, Entrepreneurship and Knowledge Creation: Dynamics in Globalizing Learning Economies (CIRCLE)	2006	Lund University	Humanities, social sciences and educational sciences
Lund University Center of Excellence for Integration of Social and Natural Dimensions of Sustainability (LUCID)	2008	Lund University	Humanities, social sciences and educational sciences
Center for Marine Evolutionary Biology (CeMEB) –	2008	University of Gothenburg	Natural Sciences
Lund Center for Control of Complex Engineering Systems (LCCC) –	2008	Lund University	Physical Sciences and Engineering
Uppsala Center of Evolution and Genomics (UCEG) –	2008	Uppsala University	Natural Sciences

method of first going through the interview transcripts in detail, identifying accounts which denoted activities explicitly or implicitly relating to the research question. These statements may be referred to as 'meaning units' following Giorgi (1997), and they are taken to represent ascriptions regarding, in this case, how the center conditions affected interdisciplinary collaboration. Meaning units were captured by assigning codes in the form of short descriptive labels to statements. Codes were clustered based on commonalities identified relating to the research question. Using these codes, the themes were broken down into lower level categories according to the same method of identifying similarities in meaning units. The dimensions captured in this way are presented in the next section together with explanations and illustrating quotes. The authors have selected the most representative quotes with respect to content across disciplines, and those that were most illustrative of the overall results.

Results

This section is divided into three main categories derived from the data: governance, conditions and outcomes. The logic behind this overarching division is obviously the simplicity of sequence, where typically governance actions are expected to facilitate conditions which in turn generate outcomes. Although these categories are certainly analytically separable and also correspond to the empirical pattern found in the data, they are not fully analytically and empirically distinct. For example, the conditions for interdisciplinary research reported by the respondents may be more or less in line with the governance measures taken to facilitate interdisciplinarity. Also to some extent conditions overlap with outcomes, since some outcomes of governance have to do with facilitating conditions. Nevertheless, governance, conditions and outcomes can be separated by their sequence, circumstances, and by the intentions that bring them about, as expressed by the respondents. They are also fruitful in ordering the subcategories into a structure, which is logical as well as corresponds to the content of responses found in the material.

Governance

This heading covers typical interventions performed in order to facilitate cross-field and cross-specialism cooperation. These consist of training/nurturing of juniors, developing organizational structure and processes, and finally supporting an informal epistemic environment.

Training/nurturing

This activity involves enabling early career and doctoral researchers in cooperative, cross-border activities through various means. One of these is joint supervision and funding of juniors, e.g.

> We have joint supervision of PhD students where the supervisors are from the different fields that participate in the center. **(OMM)**

And:

> One post-doc was funded by two different Linnaeus centers at two different faculties, the natural science and the medical faculty. **(OMM)**

There is also evidence of integration activities on the junior level, for example intellectual meeting places such as the cross-departmental seminar:

> [we] also now have this across department community where PhD students and post docs meet on monthly seminars and annual retreats. And I think this has broadened their perspectives and made them better prepared for future work. **(STARGET)**

An important instantiation of this pertains to nurturing connections between basic and applied (clinical) perspectives already early in the career, this amounting to an often overlooked but central form of cross-boundary interaction:

> The third thing is probably also that we have somehow succeeded in the ambition to create a training environment for younger scientists who are [now] better prepared to do what is called translational research. They have grown up in an environment where basic scientists and clinical scientists interact. **(STARGET)**

Organizational structure

The centers are often placed within faculties, and build on cooperation between departments there. The composition and structure of a center is thus heavily influenced by the structure of the faculty. In some cases, there is more of a cross-boundary department structure at the faculty, which helped facilitate interdisciplinarity at the center, e.g.

> If you go to a university abroad most often those competences would not be in a single department, instead there would be people spread out in computer science, in electrical engineering and mechanical engineering, and mathematics. But in [university], there is already an organisation, a department structure which is quite well aligned with the needs of the centre. **(LCCC)**

Attracting and keeping people from different disciplines in the centers may be a matter of having permeable organizational boundaries, but also being clear about direction.

> Several of the guys that we didn't invite from the start, because of lack of information, are now key persons. So, we have an organisation where you don't really say this is we and no one is allowed to come, but we have it permeable so people can come and go. […] If you are clear on what your expectations are on the people that join, and you are clear on what the benefits will be […] then there is no problem. **(CeMEB)**

One way of steering the center to more cross-boundary cooperation, given the influx of personnel from different fields, is by means of maintaining an interdisciplinary meeting processes, e.g.

> Because even if we are a lot of people we spent at least half of the time of the meetings in group discussions. We have presentations but they are fairly short, […] and we divide up in small groups and discuss the same topic. Sitting 20 people around the table is no point. Disciplines are mixed in the groups. **(CeMEB)**

Informal epistemic environment

Informality, or slack, in the environment makes it more conducive to cooperation, since it means less of a risk to engage in uncertain partnerships. The long-term perspective of excellence funding is one important facilitator here:

> […]Building these bridges between disciplines has been really fun and rewarding. That is something with a long-term perspective. You won't deliver anything during the first couple of years but later you can deliver something that is really new and very interesting. **(CeMEB)**

The long-term perspective makes it possible to maintain an open-ended line of inquiry, which allows new connections to be made beyond the discipline, e.g.

> […]this money was not really generated to fund a particular line of investigation. **(Hemato-Linné)**

Yet, the informality of the environment makes it necessary to maintain energy and collaboration once cooperation has been initiated:

> It is very easy to lose focus. I think you have to work to stay together, to collaborate and to maintain the energy. **(LinCS)**

Finally, an important aspect of governing collaboration in an informal research environment is to be able to select and maintain focus on issues that requires complementary disciplines, while not departing from spontaneity:

> The whole idea of the centre is this collaboration and synergy that you get when you meet and talk to people and come up with, well, when you find the issues that different competences can help solving. When you are compatible but also complementary. **(CeMEB)**

Conditions

The conditions category refers to the circumstances that are perceived to facilitate interdisciplinarity in the center environment, rather than to direct interventions. Conditions include time availability and core funding, and the presence of shared interests and complementary expertise.

Time availability

Having the time to cooperate and the discretion to allocate the funds freely seem to be important factors. Typical statements to this effect are:

> I can verify a very common statement about interdisciplinarity: it takes time. That is something I can really verify. So, the most positive is that we had 10 years of research without any [predefined] deliverables, so complete freedom over 10 years. **(LUCID)**

And that;

> It was important that it is such a long term grant. And also that it, sort of, not forced but stimulated people to work together in constellations that we did not do before. And in a way these two aspects are connected because if you have a ten-year period you dare to collaborate with people that are not that close to you in terms of the field they work in. So I think it stimulated some really new things. **(UCEG)**

Cooperation hinges on time in at least two respects. Firstly, it takes time to decide on a direction between specialisms, and how to forge that path to mutual satisfaction, e.g.

> Yes, it is always a challenge when you work together […]. The end result is always much better but it takes more time to agree upon exactly what should be done, etc. So it's like a time lag before you get started […]to understand each other when you come from slightly different disciplines within a discipline like biology. **(UCEG)**

In this case the respondent refers to cooperation within a broad field, biology, where one may speak of cooperation between sub-disciplinarities or specialisms which are not typically integrated. Secondly, mutual respect between epistemic orientations, such as basic and applied, is something that develops over time:

> There have of course been some cases where the more basic scientist would think that the clinical questions are somehow trivial, and the clinical scientist would think that some of the basic questions are irrelevant. But I think as time went along, mutual respect increased. That has been very nice to see. **(STARGET)**

Shared interests and complementary expertise

Center researchers typically agree on a shared set of intellectual problems and opportunities, to which they find reasons to direct their resources. Such agreement is perceived to facilitate cross-specialism cooperation. An illustrative quote:

> You have to have new people who are not the same as those already there but who share some kind of interest that can latch onto the interests that are really there. **(LinCS)**

Facing a practical challenge, which cannot be resolved from within disciplinary perspectives helps motivate the inclusion of another field in the process of inquiry. Practical challenges may require complementary disciplines to join forces, e.g.

> We have a spin-off project which is called BAMBI (conservation in the Baltic Sea). In that project we have social scientists on board and that is really interesting. […] The reason to invite them there was that there was an urgent need to deal with management in conservation. There was a need to understand more about how management dealt with genetic biodiversity. **(CeMEB)**

The engineering disciplines have a natural tendency to combine and synthesize disciplinary knowledge for the purpose of solving problems, as is illustrated in the following quote:

> A complex engineering system could be many things. It could be control of a factory, an airplane, but it could also be large-scale infrastructure network, like the power network of Scandinavia or the power network of Europe, or

> the traffic network of a city. […] So it is many different applications areas but there is a common knowledge base that we are building, and common principles, and sometimes you can transfer experiences from one area to another area in a very useful way. That is the motivation why we keep all these different kinds of applications under the same umbrella. **(LCCC)**

This illustrates how a shared knowledge base may be host to a diversity of applications if it is already applied in its orientation. However, outside of the applied disciplines a shared knowledge base may not come as naturally. One reason is the continued reliance on the disciplines to produce the researchers that go into interdisciplinary environments. This may require a balancing act. An interdisciplinary environment that succeeds in maintaining its ties to the disciplines must balance between a strong center identity and good relationships to the disciplines (in this case departments), e.g.

> So, we said we are going to have a centre where we sort of maintain strong and dual dialogue with the departments. [but] which has its own identity; its own interdisciplinary identity. It is strong in itself but it exists based upon solid and good relationships with the departments that created it. **(LUCID)**

The strength of disciplinary identities that make up an interdisciplinary environment is a crucial factor when it comes to integration of perspectives. In this sense not all disciplines have the same potential, e.g.

> Generally, I think it is easier to work with disciplines with not so strong identities. So geographers, they have no strong identity. You never hear somebody say I am a geographer therefore blabla, but we hear quite often I am a political scientist so therefore blabla. **(LUCID)**

As was seen under the governance heading above it may fall upon the younger researchers to make the connection between disciplines:

> The junior researchers are very important because they are the ones who are most open-minded and see the connections between different types of groups. […] post docs act as glue between the different research groups. Typically, they would be involved in collaborative projects. **(UCEG)**

Outcomes

Interdisciplinary outcomes were of a widespread character and covered the closing of disciplinary distances among center participants, the facilitation of discovery and verification processes in ongoing research, as well as transfer of results and models from one field to another.

Closing disciplinary distances

An important outcome of an interdisciplinary center is of course the enabling of fruitful interdisciplinary encounters. One such is illustrated in the quote below:

> One of our members is a professor in clinical oncology, basically treating breast cancer patients and identifying new treatments. At the other end is a person who is very much into development of novel methods to analyze biology. He has developed new methods to characterize cells at much higher resolutions. These two people would not have met without this network but they now met long before this work started to be public. **(STARGET)**

A requirement for this is of course that the participating researchers already are in a state of mind that supports them in identifying disciplinary similarities and complementarities. One outcome in this regard has to do with how the center environment affects a collaborative mindset, e.g.

> All of the researchers in the center are biologists. Biology is a broad field. So the center is very broad. That was a problem in the beginning […] because we came from different parts of biology. But once we started to understand each other we saw the parallels. It was kind of cool. **(UCEG)**

Rather than just transferring knowledge, the closing of disciplinary distances may offer new perspectives one's own discipline, this of course being part of a more general interdisciplinary learning process that will later facilitate the more tangible integration, e.g.

> Yes, just listening to and trying to understand people that have deep knowledge in other disciplines is of course really rewarding. Listening to these physicists, sometimes they just ask what are really silly questions in biology. But then you have to answer and you have to think deeply about your own discipline. And of course, looking at the problems from a completely new perspective is extremely educating. **(CeMEB)**

Discovery and verification

The change of mindset has several effects that pertain to interdisciplinary work processes. One of these is the identification of 'problem spaces' between the disciplines that become intellectual niches for new research:

> There has not been an expansion because we started very broadly. It's more like we have created new niches in between the different fields, that we were not aware of before. We have found more connections between them. **(UCEG)**

The proximity and network effects between different specialisms also facilitate this integrative process, and speeds up new initiatives:

> The cross-disciplinary nature of the network has allowed people to take new initiatives more rapidly […] I think it has increased the speed of the progress and the readiness to try new things. It reduced the threshold for starting novel projects, because of the personal vicinity. **(STARGET)**

An example of such an integrative outcome is when one research area draws verification for some research from another field, e.g.

> We have had a lot of collaboration with the group that is [using] electron microscopy on material and devices. They have spent a lot of time analysing the devices we made. And this is now starting to be very valuable, but it has taken a long time. **(LINNEQS)**

Results transfer

One way of transferring results is when method developed in a basic discipline is adopted by clinicians. The following quote illustrates how this process can be facilitated by proximity:

> These two people started collaboration around this new method. […] Normally the basic science people would stay where they are and talk to some mouse people, and then eventually the mouse people maybe will need clinicians. But here we have this emerging methodology being reported in […] seminars where this clinician was present. This is an example of sort of rapid integration of new methodology for clinical studies. **(STARGET)**

In order to facilitate this kind of transfer results must be of cross- and interdisciplinary relevance. That is, they have to facilitate insight and discovery for some group outside the areas of inquiry (3.9), e.g.

> When we had the first preliminary sequence DNA from this snail, we asked a medical researcher who work with Alzheimer's disease to look into the sequences. And he immediately found five of the genes that are involved in Alzheimer in humans […] What is interesting for medicine is of course understanding what these genes are doing in a completely different organism. In humans, we know them because they produce this disease. But what do they do in snails? What do they do in fish etc.? **(CeMEB)**

A more radical form of interdisciplinarity is created when in such cases as the above, results are transferred from one domain to another and starts affecting the processes of inquiry as well as the explanatory models there:

> So now when we are working with marine organisms we will actually present completely new models for medical research, explaining existing models and how these are land related. These [results] are important in order to understand the human and how things work on the cellular, genetic level. **(CeMEB)**

This concludes the results section of this article. Table 2 summarizes the main results, as well as key phrases that capture the content of the derived categories. In what follows we will look closer at what insights can be derived from this in terms of governing interdisciplinary research at CoEs.

Discussion and conclusions

A central aim of the Linnaeus Grant was to create organizational structures for sustaining cross-cutting research on a high international level. As we saw in the research overview, previous studies agree on the connection between excellence and interdisciplinarity (e.g. Martin, Allwood, and Hemlin 2004; Heinze et al. 2009; Hellström 2011; Langfeldt et al. 2015; Borlaug 2016; Gläser and Laudel 2016). The two central assumptions guiding this aim are that (i) certain intellectual issues are too complex for single disciplines to solve on their own, and that (ii) epistemic governance can facilitate the interdisciplinary capacities and outcomes necessary to achieve excellence (here understood as new scientific advances). In the research overview, we also observed that studies converge on a set of contextual precursors to interdisciplinary outcomes. First, continuity in funding is considered important for engaging in interdisciplinarity (e.g. Pfirman and Martin 2017). Second, independent, interdisciplinary research units are the preferred organizational form for pursuing interdisciplinary research (e.g. National Academies Committee 2005; Sá 2008). Third, institutional support from the immediate academic setting to interdisciplinary endeavors can be a determinant of their success (e.g. Lattuca 2002; Porter et al. 2006).

While such factors certainly were present in the respondents' accounts, and perceived as important precursors to interdisciplinary outcomes, our results also put the focus on how the internal governance of the centers promote such effects. Some previous studies emphasize the connection between leadership activities, or broadly governance, in collaborative research environments, and significant research contributions (Hollingsworth and Hollingsworth 2000; Hemlin, Allwood, and Martin 2004; Heinze et al. 2009). In the present study, we find that the governance of CoEs is largely about creating and ensuring that certain conditions and processes are present in the research environment, the idea being that these conditions will eventually lead to interdisciplinary outcomes. Center directors seem to be of the mind that one should stimulate and not force interdisciplinary

Table 2. Overview of results.

	Factors and categories	Examples
Governance	*Training/nurturing*	Joint supervision and funding of juniors. Integration activities on the junior level. Nurturing connections between basic and applied perspectives.
	Organizational structure	Cross-boundary department structure. Permeable but distinct organizational boundaries. Interdisciplinary meeting structure.
	Informal epistemic environment	Long-term perspective. Open-ended line of inquiry. Maintaining energy and collaboration. Complementary disciplines.
Conditions	*Time availability*	Time to cooperate. Time to decide on direction between specialisms. Develop respect between epistemic orientations over time.
	Shared interests and complementary expertise	Researchers share sets of intellectual problems and opportunities Practical challenges that require complementary disciplines. Shared knowledge base for a diversity of applications. Balance strong center identity and good relationship to the disciplines. Strength of disciplinary identities. Younger researchers to make the connection between disciplines.
Outcomes	*Closing disciplinary distances*	Fruitful interdisciplinary encounters. Identifying disciplinary similarities and complementarities. New perspectives on own discipline.
	Discovery and verification	Identification of 'problem spaces' between the disciplines. Proximity and network effects between different specialisms speed up new initiatives. Verification of research from another field.
	Results transfer	Method developed in a basic discipline adopted by clinicians. Results of cross- and interdisciplinary relevance. Results transferred from one domain to another.

Table 3. Synthesis of actions, conditions and outcomes for interdisciplinarity.

Network governance →(activities)	*Capacities for interdisciplinary research →(conditions)*	*Epistemic effects (outcomes)*
Ensuring and nurturing a base of cross-cutting specialisms	Shared interests/complementary expertise	New niches
Creating proximity and promoting slack	Collaborative mindsets	Verification/result transfer
Encouraging open-ended lines of inquiry	Lower thresholds to start collaborations	New lines of inquiry

outcomes. This is represented in the empirical accounts by the tripartite division between governance, conditions and outcomes. The challenge for the analysis is to identify the pathways from governance to outcomes via mediating conditions. Luckily, the results offer accounts of several such pathways, which we will now discuss in the light of some of the literature. Table 3 is an attempt to summarize/illustrate these pathways/mechanisms.

Governance of a network of specialisms

The result section outlined three areas of typical governance interventions, perceived by the respondents to support conditions for interdisciplinarity. These were training/nurturing, organizational structure, and informal epistemic environment (Table 2 offers some examples of each). A general observation is that all of the governance interventions seem to relate, largely, to managing a network of specialisms. In fact, the idea of network governance is a reoccurring theme in the respondents' accounts. Three such general network promoting activities appear to support conditions for interdisciplinarity. These are activities that: (i) ensure and nurture a base of cross-cutting specialisms in the CoE's network, (ii) create proximity and promote slack, and (iii) encourage open-ended lines of inquiry. The first refers to activities related to organizational structure. They include recruiting from different specialisms and building on cooperation between departments. Related to this are training/nurturing activities, aimed at vitalizing the network. Here, setting up joint-supervision and socializing junior researchers into interdisciplinarity, were important in bridging between different specialisms (cf. National Academies Committee 2005). Younger researchers typically played that role.

The second governance activity, termed 'creating proximity and promoting slack' relates to informal encounters between the specialisms. In order to encourage this, directors made organizational choices such as promoting permeable center boundaries. They were nevertheless clear to members about the general direction and expectations, and institutionalized physical platforms for interaction (e.g. seminars, coffee meetings, colloquia, etc.). The platforms served to promote collaboration towards these ends. Slack and proximate meeting places certainly served to facilitate informal interactions (cf. Pfirman and Martin 2017). However, the final aspect of network governance, 'encouraging open-ended lines of inquiry', seems to be the main driver of an informal epistemic environment. Activities here were described in terms of maintaining long-term research perspectives, flexible fund allocation across the network, and maintaining energy within the network by balancing focus and spontaneity. The result was a risk-tolerant environment that mitigated the higher transaction costs associated with interdisciplinarity (van Rijnsoever and Hessels 2011)

In the next two sections, we will first discuss how the respondents linked these three governance activities to conditions for interdisciplinary research. We will then move on to showing how conditions were perceived by the respondents to yield certain epistemic outcomes.

Conditions for interdisciplinary research

Shared interests/complementary expertise and time availability were the two main conditions directors perceived as facilitating interdisciplinary outcomes. Some of the most emphasized aspects of these conditions were: 'shared interests/complementary expertise', which in turn can be seen as

supporting 'collaborative mindsets', and 'lower thresholds to start collaborations'. According to the interviews, shared interests/complementary expertise resulted from governance activities promoting cross-specialisms and slack (cf. Pfirman and Martin 2017). For instance, the accounts show that complementary expertise was discovered when researchers from different backgrounds met on unconditional terms. Shared interests were developed when intellectual problems were discussed. Researchers started to understand each other, see parallels between their specialisms, and reflect about their own specialisms.

Time availability supported these initial, collaborative steps. Governance that promoted open-ended lines of inquiry gave members time and space to agree on epistemic problems (cf. the notion of 'creating common ground', Lattuca 2002; Öberg 2009; König et al. 2013). While these conditions depended on slack and time, they also depended on favorable access between the specialisms. The respondents linked such access or proximity to lower thresholds for turning interactions into actual collaboration. This observation is supported by Klein and Porter (1990), who suggest that physical proximity is an important facilitator of informal interactions.

In the next section, we look at the outcomes of these conditions.

Epistemic outcomes

From the narratives, we derived three main categories of outcomes: closing disciplinary boundaries, discovery and verification, and result transfers. In this final section, we focus on the latter two. Closing disciplinary boundaries is an epistemic outcome that refers to decreasing the cognitive distance between specialisms. However, unlike the other categories, it can also be framed as a process that begets more interdisciplinary effects downstream. From this perspective, one may want to consider it an epistemic condition as much as an interdisciplinary outcome. Discovery seems to be mainly associated with the condition of shared interests/complementary expertise. In the interview accounts, we find that developing shared interests and discovering complementary skills led to the discovery of new problem areas. Such discoveries laid the ground for developing new niches and new lines of inquiry. Similarly, the respondents related verification and transfer of results to lower collaboration thresholds. The latter seems to have prompted a faster transfer and integration of results and instruments between specialisms. In some cases, such transfers were expected to open new lines of inquiry in their new adoptive disciplines/specialisms.

The identified epistemic outcomes mirror the variations of interdisciplinarity identified in the literature. For instance, the establishment of new niches resonates with the notion that interdisciplinarity serves to cover knowledge areas unaddressed by established disciplines (cf. Stember 1991). Verification and results transfer evoke the instrumental aspects of interdisciplinarity raised by Salter and Hearn (1996). According to their take on instrumental interdisciplinarity, ideas and methods are borrowed from one discipline or specialism into another to improve their problem-solving capacity, while the boundaries between disciplines tend to be maintained. In our case however, we find that disciplinary borders can be crossed: the transfer from one discipline or specialism can affect processes of inquiry and explanatory models in others.

This is most likely due to a number of factors found in the governance and conditions columns in Figure 3, which specifically relate to qualities of the CoE funding instrument, such as long-term proximity of specialisms, and slack from base funding. The present study shows how these can sustainably foster the types of novel intellectual encounters that interdisciplinarity is associated with. By providing a detailed qualitative account of interdisciplinary governance, conditions and outcomes in CoE settings, we have been able to analyze some of the mechanisms that support interdisciplinary cooperation. In this study we have illustrated how the CoE setting can enable researchers to move beyond a merely interactive, borrowing epistemic relationships, to integrative relationships, where new cross-cutting specialisms develop. We believe that the above account can aid in understanding organizational/social correlates for interdisciplinary research, as well as contributing insight to academic leadership in these contexts.

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Street-level priority-setting: The role of discretion in implementation of research, development, and innovation priorities

Erik Brattström[b,*], Tomas Hellström[a]

[a] School of Economics and Management, Lund University, 221 00 Lund, Sweden
[b] Department of Business Administration, School of Economics and Management, Lund University, P.O. BOX 7080, 221 00 Lund, Sweden

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ABSTRACT

Research on priority-setting for research, development, and innovation (RDI) often does not take into account the many challenges associated with translating priorities into RDI programs and projects. Such implementation challenges are typically handled by RDI program officers at funding agencies i.e. those officers that manage RDI programs and projects. To address this challenge, this paper utilizes a 'street-level bureaucracy' approach to understanding how RDI priority-setting is enacted by program officers in the course of translating general RDI priorities into actual funding. This is done through a study of how program officers at the Swedish Energy Agency exercise discretion in the course of implementing RDI priorities. The results suggest four general dimensions of program officer discretion in priority implementation, viz. (i) regulating inflow of new knowledge and ideas, (ii) interpreting the relationship between strategy and program design, (iii) tweaking and applying selection criteria, and (iv) determining the portfolio's balance between basic research and application/innovation. The results suggest that discretion can act as an important mechanism mediating between the formulation of RDI priorities and de facto RDI investments by funding agencies. By explicating some variations of this mechanism, the study contributes new insights into the governance of RDI funding processes.

1. Introduction

Political commitment is a basic condition for building agendas for research, development, and innovation (RDI). Yet, how commitments are fulfilled depends on how agendas are implemented, and RDI funding and commissioning agencies play a significant role as implementers (OECD, 1991). In many cases, the details of implementation are delegated to agency administrators, e.g. its RDI program officers (Hellström et al., 2017). Their tasks include translating strategic priorities into RDI programs, to which researchers respond with project proposals. As a result, such program officers may exercise considerable discretion over how strategic priorities are realized.

Lipsky (1980) developed the concept 'street-level bureaucracy' to capture the discretion exercised by public administrators at the lower levels of formal governance structures. In short, the concept refers to the decisions, routines, and devices that administrators make, establish, and invent in order to cope with uncertainties and work pressure (p. xii). The result – de facto policies, made 'on the street' – may offset as well as reinforce or redirect what was initially intended by the original policy. This study explores the phenomenon of 'street-level priority-setting' in RDI, by focusing on how program officers implement strategic priorities for RDI and in the course of doing so, make discretionary decisions, typically on the program level.

The paper will explore this issue through a case study of the Swedish Energy Agency (SEA). The SEA is the main funding agency of energy relevant RDI in Sweden. Its RDI portfolio covers basic as well as applied sciences, and extends into funding commercialization of energy relevant research. In a specialized RDI commissioning agency such as SEA, where expert administrators are involved in defining, identifying, and procuring relevant knowledge and research, one can anticipate a high level of discretionary problem-solving with regard to priority implementation. In many cases, agency goals may be difficult to relate to specific decisions, and there might be a lack of top-down communication/instructions on how to handle such situations. Criteria may be vague and program design and funding decisions may depend on the agency's/RDI program officers' ability to rally and use external expertise. This stresses the importance of understanding how funding agency conditions and activities bear on how RDI priorities are implemented. Such perspective is generally lacking in traditional notions of priority-setting research, which instead tend to focus on priorities as

Abbreviations: RDI, research, development, and innovation

* Corresponding author.
E-mail address: erik.brattstrom@fek.lu.se (E. Brattström).

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a result of various types of strategic, participatory processes e.g. foresight and/or forecast exercises (e.g. Martin and Irvine, 1989; Martin, 1995; Van der Meulen, 1998; Georghiou and Harper, 2011; European Science Foundation, 2013).

The present account, on the other hand, is intended to illustrate the various ways in which 'flexibility' or 'tweaking' of priorities are inserted or enacted by administrative staff in the course of implementing strategic RDI priorities. By focusing on street-level priority-setting, the paper aims to contribute to the research policy literature concerned with governing RDI funding processes by contributing insights into some of the mechanisms that mediate between policy formulation and actual outputs in terms of projects for research, development and innovation. Of particular interest here is how 'street-level priority-setting' reaches beyond mere content of priorities, or their 'thematic' aspects, such as the area of technology targeted. In the course of the study we will observe how discretionary decisions/strategies enacted by program officers also establish new organizational forms, criteria and routines for (re)directing priorities, or what has been referred to as setting 'functional priorities' (OECD, 1991).

The paper will proceed by outlining a number of insights from previous research relevant to the topic. Secondly, the method will be presented followed by case background and the results of the interview study at SEA. The paper finishes with an explication of street-level priority-setting in terms of how it relates to thematic and functional priorities in different discretionary modes, and how managing RDI program officer discretion may be a relevant issue for research policy-making.

2. Literature review

2.1. Priority-setting for RDI

Priority-setting, is a natural and necessary part of any policy-process. Prioritization can be a device for policy-makers to realize political ambitions, or to signal policy shifts (Barré, 2008). However, prioritization is also typically embedded in policy processes, either in a routinized fashion, or as responses to triggering events (Bosin, 1992). In terms of priorities for research, development, and innovation (RDI), OECD (1991) considers two general types. The first refers to thematic priorities, such as scientific fields and disciplines, technologies, and societal goals. The second type – functional priorities – is about the conditions for effective knowledge production, including capacity-building, communication and interaction between the actors in research and innovation processes. It extends from investing in research training to balancing the national portfolio of funding instruments (OECD, 2009).

Long-term priorities may be institutionalized, e.g. converted into specialized agencies or agency units, and research fields. Shorter-termed priorities are typically translated into time-limited programs or projects. In this regard, RDI priorities do not differ significantly from priorities in other policy domains such as labour, health or environment. In fact, RDI priorities too aim at improving welfare, increasing competitiveness and sustainability, etc. However, in addition to such social ends, priorities for RDI also aim to achieve certain scientific goals, such as creating critical mass and facilitating new discoveries (e.g. Weinberg, 1963; Moravcsik, 1988). This dual aim of RDI priorities relates to how science ought to be governed; centrally by government (e.g. Bernal, 1939) or by the researchers themselves (e.g. Bush, 1945; Polanyi, 1962). Today we see a how these styles of governance increasingly mix and institutionalize. In such contexts, RDI priorities are subjected to a number of interpretations and adjustments along the way from political enunciation to scientific results (e.g. Salo and Liesio, 2006; Hellström et al., 2017). In this way priority-setting may be described as an activity or process involving several actors and phases of implementation.

As an activity, priority-setting is about practically choosing between competing alternatives and acting towards their realization by, for example, distributing resources, communicating, and organizing. Priority-setting can be described in terms of its directionality of influence (Gassler et al., 2004, 2007). As traditionally understood, a bottom-up approach is taken when responsibility for RDI prioritizing is delegated to the scientific community (cf. The Haldane Report, 1918; OECD, 1991; Gassler et al., 2004). Today, bottom-up priority-setting also include a wider range or societal actors, such as small and medium sized enterprises (SMEs) and community representatives such as civil society organizations (OECD, 2009). Conversely, top-down priority-setting is when governments decide on the allocation of resources.

One may view the bottom-up and the top-down approaches as occupying ends of a continuum. Actual priority-setting typically falls somewhere between the ends. From that perspective, priority-setting is not simply a matter of top-down and bottom-up; rather it is a complex process which involves multiple actors and interfaces of contact (OECD, 1991). Stewart (1995) stresses such a 'systemic perspective' on priority-setting, and emphasises the interconnection between user-demand (market forces), institutions (enabling/disabling structures), and political bargaining (balance of policy/epistemic interests). She suggests that priority-setting for public sector research is best approached as a problem of system design, where institutional processes and structures set priorities by determining the actors' action space.

2.2. Priority-setting in the context of implementation

Research has traditionally focused how strategic priorities emerge through selection techniques such as Delphi method, foresight/forecast exercises (e.g. Linstone and Turoff, 1975; Irvine and Martin, 1984, 1989; MacLean et al., 1998). Prioritization as an implementation issue is not much dealt in research on RDI priority-setting. There are of course some exceptions. Salo and Liesio (2006), for example, distinguish between two phases of priority-setting. The first refers to determining the relative importance of different research themes and deciding on topics within the themes. A list of priorities is produced through, for example, foresight exercises. Here priorities are formed in the absence of complete information about how they will be implemented through programs and projects. The second phase involves implementing priorities by, for example, formulating project calls and deciding on project proposals. Here selection criteria are elaborated to elicit, and adequately assess project proposals (Salo and Liesio, 2006). While Salo and Liesio (2006) treat the two phases as related but fairly separated, one may want to consider how they are linked. Hellström et al. (2017) views the move from forming priorities to implementing them as a process of translation. In this process, priorities are "dissolved, shifted, and re-specified" (p. 607), according to procedural and structural conditions found in the implementing agency. Such conditions are typically a result of how past priorities have transformed into organizational capacities within the agency. Naturally, new priorities may conflict with such 'path dependent' structures, and raise tensions between organizational capacities and knowledge production that aim at novelty (see also Rip and Nederhof, 1986; Van der Meulen, 1998; Coombs and Georghiou, 2002).

While path-dependencies in priority-setting, like the ones suggested above, can be organizational/social, there are also those that are cognitive/epistemic. For instance, some suggest that conceptual dichotomies such as between basic and applied research, distract funders from genuinely diversifying their RDI portfolios (Wallace and Rafols, 2015). Other suggested examples of cognitive path dependencies are biases against novelty in traditional peer-review systems (e.g. Boudreau et al., 2016). One reason for such biases is that peers promote proposals that align with their own intellectual interests as opposed to those that are novel (Nicholson and Ioannidis, 2012). Peer-reviewing is an integral part of the priority process, since it is often central to selecting amongst competing RDI proposals. Gibson et al. (2004) observe that there generally is a measure of disagreement on what criteria that should be

applied to make fair allocations. Non-transparent processes for prioritizing proposals risk creating frustration amongst stakeholders – especially if projects, in hindsight, are perceived as failures (Gibson et al., 2004; Chalmers et al., 2014).

What emerge are two perspectives to complement traditional thematic priority-setting: (i) the systemic, and (ii) the process-oriented. The systemic perspective stresses how institutional structures frame RDI priorities. The process perspective emphasises how priorities are translated from the political to the program level, and how they, over time, form organizational/professional structures. Each of the perspectives places agency/organizational level implementation at the core of priority-setting. It is a natural step from these insights to emphasize decision making actors on the agency level, who manage these processes, as necessary for understanding how priority-setting de facto comes about. Putting the emphasis of explanation on these actors and the structure of their discretionary decisions/actions is what we mean by a street-level perspective on priority-setting.

2.3. The 'street-level'

Street-level bureaucracy (SLB from hereon) is the concept developed by Lipsky (1980) to refer to a quality of administration of public services where agency workers, who are close to the client in the chain of implementation, exercise a substantial amount of discretion in allocating effort, dispensing of benefits, interpreting rules and regulations, etc. Local discretion exercised in this way can be seen as adding and subtracting from policy to the point where actual, *de facto,* policies, can be viewed as locally made, on the 'street-level'. Lipsky (1980) suggests under such circumstances, policies are enacted by the routines that agency officers establish, and the methods they develop to handle uncertainties and conflicting demands. Since there is a limit to how much a policy can be adapted to specific circumstances, bureaucrats need to develop routines to fit policy goals to a greater number of instances, but also fixes and adaptations to fit general policy to local needs (Lipsky, 1980). These local adaptations reflect workers' assessments of political and organizational constraints and, of course, what their own desire, ability and ingenuity allow. Bureaucrats naturally want their organizational context and its requirements to conform to, or at least be consistent with, their own preferences (Lipsky, 1980).

Where demand exceeds supply bureaucrats often enjoy substantial autonomy vis-à-vis their agencies in allocating resources (Hudson, 1989). Lipsky (1980) identifies three types of modifications of the task environment, that are available when allocating scare resources among clients. These modifications amount to a form of control over an ambiguous work situation. Bureaucrats can *modify client demand* by controlling clients, including symbolizing their relationship in various ways, pacing and timing interaction and adjust the content of interactions. They may *modify their job conception* by changing their own activities, for example by changing their objectives to their ability to perform. Finally, they may *modify client conception* by separating clients into categories thereby making it easier to motivate allocation decisions which may or may not be dictated by policy expectation. This could include making divisions between 'deserving' or 'undeserving' clients on the basis of locally developed distinctions. In these ways bureaucracies typically come to favor some types of clients at the expense of others (Lipsky, 1980).

Strategies such as the above are enabled because organizations often do not have the resources and overview to steer activities in consonance with policy goals, and are therefore often obliged to permit substantial discretion (Hudson, 1989). Lipsky (1980) argued that in cases where discretion is needed to a high degree (e.g. in expert agencies such as the one studied in this paper), accountability by necessity is very low. Even immediate supervisors may have little influence if the work is not rule bound (Maynard-Moody and Musheno, 2000). In the context of expert agencies that regulate via technical rules, and that often need high levels of expertise to develop solutions for their domain, it is useful to separate the *professional* and the *administrative* bureaucrat (Adler and Asquith, 1981; also Evans, 2011). While administrators are often officials who are assigned various tasks regardless of substantial domain knowledge (and who can therefore be easily replaced), the professional is usually a member of a group defined by their expertise, who make decisions with reference to an esoteric (in the economist's sense), usually academic, body of knowledge. They may therefore enjoy considerably more autonomy and discretionary influence than an administrator. It is likely that most street-level bureaucrats exist on a spectrum between these ideal types, and their level of discretion is probably partly explained on the basis of where on this spectrum they reside vis-à-vis a particular set of tasks or their formal organizational role.

In the context of expert agencies, and in particular where experts are involved in defining/identifying relevant knowledge and procuring research, one might expect a high level of discretionary problem solving to take place, as well as a confluence between the goals of the target communities (e.g. researchers and policy makers). In a study of 1300 health care professionals, Tummers and Bekkers (2014) demonstrate that bureaucrats use their discretion to positively pursue policy goals when their activities are perceived to be meaningful to clients. If these clients' activities and goals are of a creative nature, such as is the case in research (as well as in many instances of sector policy for 'technical' sectors such as energy), this should be reflected in discretionary creativity. Piore (2011) suggests that instead of the traditional way of seeing discretion emerging in conflict with policies and rules, a negative view, policy ambiguity can also be viewed as a source of creativity and motivation. He proposes that the absence of directives as well as the proliferation of rules and goals can open up the possibility of discretion as a 'creative necessity' leading to adaption and flexibility among street-level bureaucrats (also Silbey et al., 2009).

3. Method

3.1. Design

The ambition of the study was to identify ways in which RDI priorities are implemented as a function of discretionary choices made by RDI program officers i.e. those officers that manage programs and projects of energy relevant research, development, and innovation. The Swedish Energy Agency was selected as a case organization for this study, because this organization has had substantial experience with priority-setting over an extended period of time, and is operating a large part of its RDI mission though research commissioning and funding. The case study employed an inductive design (Yin, 2014) focusing on the case Agency, and the policy landscape for energy R&D makes up the case context. The units of observation were the program officers, and unit of analysis being the discretionary strategies they employ. While the study focuses on program officers, some complementary information was gathered from higher managers in order to properly account for the case context and the strategic aspects of the Agency (see case background).

3.2. Data collection

The main source of data for this study was interviews with RDI program officers. Interviewees were selected according to their administrative and executive role in programs, on program boards and in selection processes for RDI projects. In addition, personal referral was employed to locate individuals, central to the Agency's internal priority processes (Biernacki and Waldorf, 1981). The typical interviewee was an employee who was responsibility for program calls, had worked with developing priorities for the agency and/or interpreting and executing priorities within programs and calls for his/her area of expertise (e.g. energy systems, power distribution, transport etc.). In total 17 semi-structured interviews were conducted over a period of 12 months. Interviews were conducted face-to-face or over phone, and lasted on

average for about one hour. Questions covered the main topic of the study, including background questions regarding position, work tasks and time in the organization. Substance questions focused on priority-setting activities, implementation of priorities and discretionary possibilities, actions and activities, as well as barriers and facilitators for implementation of priorities and their effect on administrative actions. Interviewees were free to decide in what direction the interview would go, however the general topic was kept in focus throughout the interviews. Interviews were recorded and transcribed verbatim.

3.3. Analysis

A general inductive approach was applied to analyse the interviews. The purpose of the approach is to "allow findings to emerge from the frequent, dominant, or significant themes inherent in raw data" (Thomas, 2006, p. 2). In doing this a standard qualitative coding procedure was followed which involved going through the interview protocols in detail, identifying statements and motivations which denote activities explicitly or implicitly connected to discretionary considerations and interventions. These statements were captured by assigning codes in the form of short descriptive labels or simple keyword summaries to the relevant parts of the text. Codes were then clustered into broader themes based on commonalities identified by the researchers. These themes were re-interpreted and broken down into lower level categories according to the same method of identifying similarities and co-extensive qualities in the themes. The typology created through this approach (Table 1 below) was inductively derived, but yet circumscribed by the researchers' interests, in this case with regard to conditions, activities and outcomes of discretion in priority-setting.

4. Case background: priority-setting at the Swedish Energy Agency

Prompted by the oil crisis, The Swedish Government started making focused investments in Energy research and development 1975. From the beginning these investments targeted technological solutions to the energy crisis, alternative sources of energy and solutions to disturbances in the energy system. In the last decades however, concerns have moved towards the environment, viz. global warming and sustainability (SOU 2012/13:21, 2012). Since 1998, the Swedish Energy Agency (SEA) has had the overall responsibility for energy issues in Sweden. The agency, which operates under the Ministry of Energy and Environment, is tasked to promote the development of a sustainable energy system, which includes RDI, to support long-term energy and climate goals, the goals of national energy policy and energy related environmental goals. Most of this is done through priority-setting, programming and funding of RDI, stretching from energy relevant basic research, applied research and technological development, to demonstration projects and business support. The agency is responsible for preparing the National Energy Bill, which includes energy research priorities, for parliamentary consideration every fourth year. This bill is enacted by parliament, and an official mandate is handed down from the ministry level to the agency. In this process agency goals for RDI might be tweaked in the direction of political and current social challenges. In addition to this four-year priority cycle there are yearly government instructions to the agency regarding new tasks and lower level priorities.

Since 2003 the agency has pursued priority-setting according to a thematic framework, focusing on a number of areas of the energy sector, and specific technological fields. Here they have utilized expert committees to select focus and formulate challenges for each area. Over the years these areas have been fairly stable and included e.g. transport, biofuels, buildings, energy systems, power systems and energy intensive industry. Stakeholder representatives from academe, industry and the public sector have been invited to participate in the expert committees attached to each area, or what has been referred to as 'development platforms'. The committees outline current and future challenges in their respective area, and draft a report, which is then synthesized into the agency's main strategy document for RDI priorities. This document forms the basis for the energy bill that is submitted for parliamentary consideration and, if passed, is used to steer agency RDI for the next four years. The areas outlined in this strategy document are mirrored in the agency's various organizational units, which are devoted to realizing the strategic priorities via programming, project calls and project funding. In some cases there is a need to cooperate cross agency, for example with the research council as basic research is concerned or with the transport agency with regard to that sector. This cooperation usually takes place on unit and program level.

In order to increase the flexibility of this system the thematic areas are now intersected with four cross-cutting themes: general energy systems, sustainable society, business development and commercialization, and international cooperation. In addition, the main strategy document is now updated on a yearly basis, using stakeholder and internal agency consultation, to reflect changes in the energy landscape

Table 1
Overview of results.

Discretionary dimensions	Examples
Broadening and narrowing scope	• Allowing researchers to inform the agency by new, interesting ideas/knowledge fields **(broadening)** • Expanding the agency's/program's base of research performers **(broadening)** • Maintaining or decreasing epistemic investments based on routine assessments of the market's internal capacity to stimulate certain fields/applications **(narrowing)** • Identifying RDI niches of potential national relevance and steering research/epistemic competencies towards such new niches **(narrowing)** • Targeting desirable researchers in order to diversify/complement RDI portfolios **(narrowing/broadening)**
Downward and upward programming	• Dictating the work process of how strategic priorities translate into RDI programs **(downward)** • Formulating the content of RDI programs on the basis of strategic priorities **(downward)** • Steering the selection of project proposals in the direction of strategic priorities **(downward)** • Starting from the base of RDI projects when designing programs **(upward)** • Collapsing existing portfolios **(upward)**
Criteria flexibility and selectivity	• Relaxing the use of criteria **(flexibility)** • Making subjective but adequate interpretations of criteria **(flexibility)** • Legitimizing choice, ex post, by referring to criteria **(flexibility)** • Formulating criteria that support assumptions of what benefits the RDI program **(selectivity)** • Tweaking general criteria to support the program officer's personal interest/field **(selectivity)** • De-selecting/removing criteria when perceived as obstacles **(selectivity)**
Epistemic trade-offs between basic and applied research	• Creating funding categories/quotas to steer content **(basic/applied)** • Formulating new requirements **(basic/applied)** • Creating new conditions for the researchers, or engaging in steering groups to reverse the orientation of programs **(basic/applied)**

and lessons learned. In what follows below we will explore, specifically, how in such a context, 'street-level priority-setting' takes place in the form of discretionary choices made by program officers.

5. Results

The result section is divided into four main dimensions of discretion: (i) scope, (ii) programming, (iii) criteria, and (iv) epistemic trade-offs. Scope refers to how program officers decide how to regulate (broaden or narrowing) the inflow of new knowledge and ideas to the agency. Programming refers to choices regarding the relationship between strategy and program design. Criteria refer to how program officers tweak and apply selection principles to support programming. The final dimension, epistemic trade-offs, refers to how program officers balance between projects oriented towards basic science and application/commercialization.

The separation of the dimensions is an analytical construct. In reality they not only overlap, the sequence as a whole is iterative rather than linear.

5.1. Scope: broadening and narrowing

Program officers (referred to as 'PO' below) perform a range of discretionary choices in order to regulate the inflow of knowledge to the agency's RDI programs. These choices can be grouped into two general types of activities: (i) broadening and (ii) narrowing scope of the agency's energy relevant RDI. Sometimes, the activities occur simultaneously.

Program officers broaden the scope in order to find new RDI areas for the agency to venture into. They approach this by formulating project calls in a fashion that allows programs to be informed by new, interesting ideas/knowledge fields by the researchers themselves:

> "Since the project calls are broad, realization that knowledge in a new area is needed, usually comes via the proposals. We try to keep our options open. We leave it up to the researchers to suggest what knowledge we need – to define what is interesting to us" (PO1)

Broadening scope also refers expanding the base of research performers. Here, program officers use calls to reinforce existing programs/knowledge fields, where there already is a fruitful display of interests. They design the calls to appeal to new actors with new ideas, within an, a priori, prioritized area/theme:

> "As we witnessed a growing interest, we increased the level of investment. Interest in the calls were always high. I believe the calls were a good way of getting ideas from actors we did not know of. Before, we just worked with the people we knew." (PO2)

Instead of trying to expand the agency's portfolio in terms of knowledge areas, program officers maintain or even decrease it. One approach of 'narrowing' the scope is to routinely assess the market's internal capacity to stimulate certain fields/applications. From the assessments, the program officers decide if agency ought to venture into certain areas or not.

> "One continuously tries to assess whether this is something that should be handled by the market. We don't hand out project grants by default just because we have an energy consuming industry within that specific field. […] There are also other instruments that promote increased efficiency and reduced energy consumption." (PO3)

Some activities of the agency refer to steering national research/epistemic competencies towards new niches of potential relevance. However, as a first step, program officers have the discretion to identify such niches:

> "We tried to identify where Sweden could find a niche. We have good researchers, and we know that given their competencies and knowledge, they could venture into new markets. We worked on finding a niche where we have knowledgeable and where potentially there is a bigger market in the future – one that is not already covered by another investor." (PO4)

Sometimes, program officers need to combine choices of both broadening and narrowing scope. In order to diversify/complement RDI portfolios with new perspectives, program officers may decide to target desirable applicants, and clarifying the agency's interest to them. In this way, the program officers avoid proposals from 'the usual suspects':

> "[I]n some cases, one has to be clear with the applicants on what one wants, or else one receives only conventional energy projects. If one has the ambition of getting new angles on an issue, then one must conduct a dialogue and be clear." (PO5)

5.2. Programming: downwards and upwards

Programming refers to the act of developing, using, and refining RDI programs. The quotes distinguish between two types of choice/acts in this regard: (i) downward and (ii) upward programming. The next section will deal with them in this order.

Downward programming occurs when program officers at the Energy agency departs from existing strategic priorities and translate them into programs. One aspect of this type of programming emerges when program officers dictate the *process of how* the priorities/themes translate into outputs such RDI programs:

> "The programs are our primary tool to realize the strategy, and because of that the program areas that we focus on come straight from the strategy. It would have been strange if we had a different focus. However, what the strategy doesn't tell us, was how we should work. That we needed to figure out on our own." (PO4)

Another aspect of downward programming refers to when program officers translate strategic themes into *program content*. For example, program officers may decide to focus on specific technologies within an a priori prioritized theme:

> "[The strategic report] prioritized the thematic area [x], but it was up to the program officers to create the content of the actual program. [The report] did not say anything specific about the future-oriented technologies that we actually invested in. Those were the conditions, and we continued [investing] where there were good researchers." (PO2)

Program descriptions are typical instrument of programming both process and content. For instance, program officers formulate programs in a fashion that steer the selection of project proposals in the direction of general agency priorities:

> "I write program descriptions […] Program descriptions are what I use in my daily work to assess if calls and proposals align with the priorities [set by the strategic reference groups]." (PO3)

The downward approach can be contrasted to upward programming. The latter occurs in the absence of top-down pressures of enforcing agency priorities. Here, program officers use strategy at their own discretion and typically start from the base of RDI projects when they form programs. An illustrative quote describing this:

> "There is no top-down pressure on program officers to use the reports from the strategic reference groups. We're never asked from the top if a specific project aligns with the reports and the general strategy […] Connections between the reports and individual research programs comes from below, from the level of the program officer, and is highly voluntary." (PO6)

Program officers will for instance build new RDI programs by

collapsing existing project portfolios. This can have cross-fertilizing effects, establish new processes of selecting projects, and give rise to novel de facto priorities:

> "We realized there were several different concepts, and that these researchers were also amongst the best in the world in their fields. There were plenty of tracks and we began thinking it would be wise to collecting all the tracks in one program. […] That prompted the new direction and a new program within the prioritized theme [x]. Already from the start we knew we wanted a new program […] and subject the researchers to competitive calls." (PO2)

5.3. Criteria flexibility and selectivity

The Energy agency has a standard set of internal criteria for project selection. In order to receive funding, projects must for instance, a priori, show evidence of energy relevance, scientific quality/excellence, and social relevance. In addition to these, the agency is obliged to impose a set of state rules for funding research and innovation. To aid their assessments, program officers typically appoint and instruct expert reviewers. Yet, the ultimate interpretation of such decisions resides with the program officer;

> "As long as we do not find reason to prioritize differently, we run with the expert panel's decision. Our role is instead very much about designing the calls, instructing the panels and reviewers, and assessing whether we can follow their recommendations. We focus mainly on strategy, and program and project design." (PO4)

From the quotes, we can distinguish between two main choices related using criteria: (i) flexible interpretation and (ii) selective use. A first case of flexibility is when program officers relax the use of criteria and gradually apply them more intuitively than rigorously:

> "When we create criteria, we initially tend to use them as a checklist […]. However, after some time we start to use the criteria differently, more as a general guide for project selection." (PO7)

Secondly, program officers may rely on subjective but adequate understandings of general agency criteria, and formulate calls based on their interpretations:

> "The notion of 'energy relevance' is not made explicit in the call. Other programs state that projects must have the potential to reduce energy use in kWh, but since we started calls for social science projects it is difficult to make our criteria that concrete." (PO8)

A third type of flexibility relates to how program officers use criteria not as selection instruments, but instead as devices to legitimize their choices ex post:

> "[U]ltimately, we don't seem to use the criteria as a guide for which project to invest in. Rather we use them to motivate a choice once the decision is made, as tools to concretize what we consider valuable in a project." (PO7)

On top of imposing general agency criteria, program officers can also formulate sub-criteria for programs and projects. This gives rise to a type of discretion which we refer to as 'selectivity'. Selectivity relates to how program officers develop and use criteria to support assumptions of what benefits their portfolios:

> "We want the program to be network-oriented, to add value to several actors, and to be a knowledge platform. It is all about developing success criteria for that purpose, for example by saying 'we want X number of projects to collaborate'," (PO9)

Selectivity also relates to instances where the program officer tweaks general criteria by formulating a set of sub-criteria that serves his/her personal interests. This is illustrated by the following quote:

> "When one formulates a call, it is not very useful just to say that projects 'should display energy relevance'. Lately, we have tried to explicate what we are looking for. In my case, it is about trying to articulate what is interesting from the perspective of climate negotiations." (PO5)

Finally, program officers may also opt to de-select criteria when they consider them as obstacles to efficient portfolio-building:

> "Program [x] did not benefit from requiring applicants to co-fund projects. We removed that requirement in the new program because we considered it to put certain type of projects at a disadvantage." (RA4)

5.4. Epistemic trade-offs: Basic and applied research

Epistemic trade-offs refer to the discretionary choice between investing in projects oriented towards basic research and those closer to application and commercialization. Choice, in this case, affects the level of uncertainty of an RDI portfolio. Higher levels of uncertainty may be a consequence of a project portfolio mainly oriented towards basic research and vice versa.

As the following quote shows, trade-offs link to the values that program officers are expected to realize. These may sometimes pull in different directions, viz. towards basic scientific understanding or industrial utility:

> "At some point, one needs to decide what is important. Unconventional research cannot be expected to be industry relevant. Instead one may wish to invest in something of industrial relevance, but that is not very unconventional. It's a choice one has to make; one cannot have it all." (PO8)

To secure space for investments in basic science, program officers may create funding categories/quotas (e.g. research, innovation, demonstration) and then begin to top them up:

> The call covered three categories of funding: one focused on research, another on innovation, and a third on infrastructure […]. In allocating between the categories, we decided to prioritize that of research. For doctoral students enrolled in the research projects, it is good to have funding for the entire PhD." (PO4)

Another way of making trade-offs relates to program officers' discretion to formulate demands. For instance, a program officer can change the direction of ongoing programs by formulating new requirements, in this case to the benefit of basic science projects:

> "We were going to re-design the program from being focused on company [x] and commercialization, to be more general, and produce more generalizable results. That was the point of departure. We made these requirements explicit in the goals of the program and in the grant decisions." (PO2)

However, program officers may instead opt to reverse the direction of programs from basic to applied sciences. A way to do this is by creating new conditions for the researchers. The quote below shows how program officers connected previously separate projects to achieve synergies perceived beneficial for applied, commercial purposes:

> "We wanted more collaboration between company [x] and company [y], because we hoped for company [y] to be more commercially successful. That it would get support from the excellent researchers involved with company [x]. That was our strategy" (PO2)

Another way of achieving similar types of re-orientation occurs when program officers get engaged in steering groups. By doing so they are in a good position to influence directions:

> "We took a new approach. The researchers within this area of basic

Table 2
Social and epistemic aspects of discretions.

Discretion	Social aspect	Epistemic aspect
Scope		
Broadening	Finding and funding new epistemic partners	Evaluating the market of ideas
Narrowing	Steering competencies towards new RDI niches of national relevance	Finding scalable, epistemic niches
Programming		
Downward	Creating (new) process to implement strategic priorities	Creating new content e.g. investing in future-oriented technologies or write program descriptions
Upward	Creating new program structures e.g. collapsing research and introducing competition	Changing/modifying content of earlier programs, but remaining within the prioritized theme
Criteria		
Selectivity	Creating criteria for collaborations or removing institutional requirements in order to diversify the epistemic portfolio/level the playing field	Creating new sub-criteria for specific fields
Flexibility	Using criteria for ex-post justification	Interpreting existing criteria to fund new epistemic fields
Epistemic trade-offs		
Basic and applied	Enable social choice (e.g. steering funding towards commercialization) by creating (new) conditions for interaction	Enable epistemic choice (e.g. steering funds away from innovation and demonstration towards basic science) by creating new funding structures/ categories
Basic and applied	Enable social choice (e.g. steer funding towards applied sciences) by creating new governance structure	Enable epistemic choice (e.g. steering funds away from commercialization towards basic science) by modifying the epistemic/social orientation of the program

science are world-leading, and we wanted to push them towards applications. […] We were very active in the project's reference group, and shifted the orientation of the project towards application by influencing their proposals." (PO2)

6. Discussion

This study has focused on how RDI program officers develop and perform discretionary activities in implementing priorities for energy RDI. Single program officers at the Swedish Energy Agency (SEA) have limited influence over the agency's formal RDI priority process, and therefore the practical concerns and opportunities they identify are rarely included in the Agency's strategic priorities. Instead, program officers address such concerns/opportunities during the phase of implementation. For instance, in the present study, program officers had few possibilities to direct thematic priorities (e.g. deciding how the agency should prioritize between general RDI areas such as transportation, solar, or bio energy). However, they did have more discretionary control over how the organization carried out general priorities, and in that regard they were able to counter stale historical commitments and path-dependencies that operate in strong legacy fields like energy (e.g. Hellström et al., 2017). In this context, creativity in content and process design at the lower organizational levels appears to have been an essential ability/coping mechanism for achieving appropriate RDI outcomes (e.g. Gibson et al., 2004; Chalmers et al., 2014). The way de facto priorities unfold during the process of implementation resonates with the notion of street-level bureaucracy (SLB); that policy formation stretches into the lower levels of public organizations, via a range of discretionary activities of civil servants (Lipsky, 1980). For instance, the absence of clear instructions for how to convert strategic priorities into content and process, or the deficiency of top-down communication about strategic priorities in the first place, appear to trigger discretion among the program officers (e.g. Piore, 2011; Silbey et al., 2009). In addition, the considerable degree of freedom from immediate supervisors enjoyed by RDI program officers at SEA is likely due to their relatively high level of technical expertise (e.g. Maynard-Moody and Musheno, 2000). This allows them, in a way predicted by SLB research, to engage in modification of client demand by, for instance, creating new social conditions for interaction between research performers, developers, and innovators. Program officers also modify client conception in various ways, for example by creating new structures for funding and new categories of research. This refers to the development of social conditions for RDI, such as steering actors towards cross-collaboration by, for example, setting up an interactive platform or creating a new program structure. As we saw in the above, such actions facilitate discretionary steering of RDI between basic and applied programs/projects. One may refer to this as the epistemic aspect of SLB priority-setting, where criteria are developed, program niches are identified and new categories of research are developed, all in order to affect the content of the research itself.

However, program officers' discretionary reach extend further than that. For instance, program officers inserted themselves in the RDI projects' reference groups in order to add value. As reference group members, the program officers needed a good command of the research content/process. This in turn required an ability to combine social/organizational capacities with technical/academic skills/epistemic capacities. In addition to the epistemic aspect suggested above, the former ability relates to the social aspect of a discretionary activity.

In these ways research program officers can complement thematic priorities (e.g. transportation, solar, and bio energy), by tweaking or simply adding new governance structures, criteria and routines to the priority implementation process, or what may be called new 'functional priorities'. Such functional priorities refer to the conditions for an effective process of knowledge production (capacity-building, communication, interactions) (e.g. OECD, 2009).

Important to note is that each discretionary category summarized in Table 1 can involve activities that relate both to the social and the epistemic. It is not a matter of 'either or' but rather how an activity (such as 'broadening scope') can be understood to enact both aspects. Program officers broaden and narrow scope of programs, refer upwards to strategic considerations or downwards from existing activities, tweak criteria and trade-offs between applied and basic concerns, and these strategies can apply to epistemic and social conditions alike.

Table 2 presents the discretionary activities from the results section in terms of their social and epistemic aspects. The main point of creating this division is to bring home a central insight from this study, namely that the implementation of priorities concerns both content (epistemic) and form (social organization). Street-level priority setters can tweak priorities on content as well as form, depending on circumstances and interests, using the strategies elaborated above, and the significance for the agency's RDI will differ substantially depending on these choices.

7. Conclusions and policy implications

This study builds on previous research on street-level bureaucracy,

and extends it to the area of implementation of priorities for energy research, development, and innovation (RDI). It demonstrates that program officers at the Swedish Energy Agency exercise a range of discretionary activities that significantly influence how strategic RDI priorities yield RDI programs and project. Placing the program officer at the centre of such a process of translation gives him or her opportunity to directly affect the direction and content of knowledge production. Some broader implications of this for energy relevant RDI priority-setting can be identified.

One uncontroversial aim of energy RDI priority-setting is that it ought to be well-defined and transparent. In some ways street-level priority-setting, while clearly able to unleash creativity in the implementation of priorities, might get in the way of these aims. This can play out, but also be handled, in a number of ways. National energy RDI priorities and corresponding budget allocations are set on the political level. However, street-level priority-setting indicates that discretionary decisions play a significant role for the outcome of these priorities, thereby creating a possible tension between the political and the agency level. It is therefore important to actively determine/establish the limits of discretion given already established national actions plans and international commitments. That being said, political commitments are seldom enough to settle issues of actual selection. For the program officer as RDI decision-maker such high level commitments are often simply a context for street-level priority-setting. Advocates from industry, political leaders, NGOs, contractors and experts chime in, and policy drivers from outside of parliament such as court decisions, regional policy and industrial needs also play a role, and need to be interpreted and weighted. In this ambiguous context it is important to make sure that RDI discretion does not fall prey to stakeholder expectations and local benefits or 'investment optima', e.g. when program officers move resources from basic to applied problems within a given area of technology because it makes sense for a particular stakeholder constellation. This is especially important where there is a need for balance between research, development and innovation. In our study we saw how moving resources between more basic research and more innovation oriented activities was common. In fields such as power generation and transport, where the RDI needs exists almost uniformly along the basic science, applied R&D, demonstration, deployment and commercialization continuum, such discretions can create undesirable biases if not checked. In immature fields, steps should be taken to prevent program officer discretion from creating untimely lock-ins and over/under-nurturing of interfaces between key-actors. In priority-setting the issue of lock-ins is usually handled by stakeholder elicitation, policy coordination (in this case e.g. EU policies) and international benchmarking. Governing discretion can mean controlling it against these activities

Declarations of interest

None.

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Paper IV

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Facilitating collaborative priority-setting for research and innovation: a case from the food sector

Erik Brattström

School of Economics and Management, Lund University, Lund, Sweden

ABSTRACT

Policy for science, technology, and innovation is increasingly supporting bottom-up approaches to setting strategic agendas for research and innovation (R&I). These processes are designed to bring industrial needs of R&I intensive sectors to the fore, while at the same time stimulating engagement of other relevant stakeholders, such as public and private research performers. This paper addresses the question of what conditions best facilitate the main activities of this type of 'collaborative priority-setting'. It does so through a case study of the creation of a strategic R&I agenda in the Swedish food sector. The paper concludes that local conditions such as government resources and time availability, mixed bottom-up and top-down process steering, and complementary expertise, facilitated the priority-setting. They did so by facilitating the main activities of adjusting scope of prioritised research areas, and mapping out the R&I themes' expected impacts, desired outcomes, and initial activities/investments. The paper suggests that insights into these 'intermediate/micro-level relationships' of priority-setting can assist policy-makers as well as managers aiming at creating sector consensus on R&I priorities.

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Introduction

This paper addresses the question of how the activities involved in research and innovation (R&I) priority-setting in an industrial sector may best be facilitated. It does this by focusing on how a bottom-up priority-setting process in the Swedish food sector evolved, and the conditions that facilitated the activities of what the participants ultimately considered a successful process.

Traditionally, governments shoulder the main responsibility of setting priorities for R&I of strategic importance to the nation. In a top-down fashion, governments typically coordinate and implement systematic approaches to prioritisation, such as national forecast and foresight exercises (e.g. Glod, Duprel, and Keenan 2009; Fisher and Maricle 2015). These approaches to priority-setting are by now well understood by policy-scholars and policy-makers (e.g. Linstone and Turoff 1975; Martin and Irvine 1989). However, national policies for science, technology, and innovation across Europe are converging on the notion that political goals related to e.g. societal challenges, economic growth, and competitiveness are best addressed when R&I needs are identified and implemented from the bottom-up (OECD 2016). This is one of several ways in which policy-makers are trying to enhance interaction between key actors in the innovation system. In particular,

CONTACT Erik Brattström erik.brattstrom@gmail.com School of Economics and Management, Lund University, Lund 221 00, Sweden

the approach aims at getting stakeholders from industry to develop a strong interest in implementing priorities (OECD 2015). The policy shift has caused a proliferation of strategic research and innovation agendas, in which priorities are negotiated, as well as implemented by various stakeholders. In many cases, the main responsibility for carrying out this type of 'collaborative priority-setting' is delegated to firm representatives and other stakeholders, and takes place within a time-bounded government initiative, often funded by public agencies. The process typically includes negotiations of converting political goals, such as increased competitiveness, sustainability, and cross-sectoral collaboration for certain industrial areas (e.g. mining), technologies (e.g. MedTech) or societal challenges (e.g. aging populations) into stakeholder consensus on relevant R&I investments.

It is clear that stakeholder choice in these priority processes have considerable impact on how political goals for R&I are operationalised and implemented. Yet, we know little about how these processes unfold and the local conditions that facilitate activities and choice. This paper explores this question through a case study of the creation of a strategic R&I agenda for the Swedish food sector. The priority process was initiated by the government and formed a part of a larger food policy initiative to strengthen the Swedish food sector. The priority process took place between 2017 and 2018 and was conducted by firms from the Swedish food sector's domestic value chain (e.g. primary production, food processing industry, and retail industry). It resulted in a strategic R&I agenda for the Swedish food sector, made public in May 2018.

The paper proceeds by first outlining a number of insights from previous research relevant to the topic. Next, the method used is presented, followed by a case background. The results of the analysis are then presented. The paper ends with a conclusion and discussion.

Literature review

The literature review starts by briefly describing general activities associated with setting priorities. It then proceeds to outline facilitating conditions for priority-setting, identified by previous studies.

Priority-setting typically includes the general activity of creating lists of research themes and choosing between them (Salo and Liesiö 2006). In a priority process that does not rely on special selection techniques (e.g. foresight exercises) various stakeholders usually press their case, negotiate, and agree on lists (Georghiou and Harper 2011). This is generally followed by determining the relative importance of themes, ranking them accordingly, and subsequently formulating promising topics within the themes (Salo and Liesiö 2006; Georghiou and Harper 2011). Priority themes and/or topics are commonly understood as being thematic (e.g. pointing out fields of science and technology), or functional (e.g. aiming at conditions for effective knowledge production) (OECD 1991, 2009).

A range of process conditions pertaining to successful priority-setting can be identified in the literature. They can be divided into three categories, viz. organisational, procedural, and cognitive conditions.

Organisational conditions

Priority-setting can be described in terms of its directionality of influence (Gassler, Polt, and Rammer 2007; OECD 2009). When responsibility for R&I prioritising is delegated to the scientific community, firms, and/or civil society organization/community representatives, one may refer to a bottom-up approach of organising influence. Conversely, top-down priority-setting is associated with governments (and large industry) deciding which scientific or technological fields to allocate resources to (OECD 1991, 2009). From a critical point of view, bottom-up priority-setting may promote short-sightedness/status quo as opposed to novelty (e.g. Salo and Liesiö 2006). Novel R&I goals derived top-down, on the other hand, can cause tension with existing structures and capabilities of implementing agencies (Hellström, Jacob, and Sjöö 2017). Studies suggest that a combination of bottom-up and top-down may reduce the risk of biases in priority-setting activities because more

actors and interests are involved (Martin and Irvine 1989). In fact, several studies argue that stakeholder diversity/inclusivity is a fundamental organisational condition for successful priority-setting (e.g. Gibson, Martin, and Singer 2004; Salo and Liesiö 2006; Sibbald et al. 2009). For example, priorities may gain greater visibility from policy-makers when they are co-produced by practitioners and researchers (e.g. Hernandez-Morcillo et al. 2017; Ockendon et al. 2018; Rudd 2011). Additionally, diversity/inclusiveness tends to facilitate local relevance and ownership of priorities, minimisation of research duplication, and creation of shared responsibility for implementation (COHRED 2000, 2006). However, diversity/inclusiveness depend on several other conditions, such as a representative composition of stakeholders and opportunities for all participants to be heard, involvement of top managers as participants, and access to resources (Salo and Liesiö 2006; Driessen, Glasbergen, and Verdaas 2001; Singer et al. 2000). Resource conditions include equal access to information, access to expertise, meeting material, and neutral facilitators/mediators. It also concerns time to negotiate, create consensus, and commitment (e.g. Martin and Irvine 1989; Rowe and Frewer 2000; Salo, Könnölä, and Hjelt 2004; Prager and Freese 2009).

Procedural conditions

Several studies suggest that transparency throughout a priority process is a fundamental procedural condition for success. Being reflexive about whose voice, views, and interests are advanced is part of a transparent process (e.g. Montorzi, De Haan, and IJsselmuiden 2010; Oxman, Schünemann, and Fretheim 2006; Rowe and Frewer 2000). So is having clear task definitions (e.g. Rowe and Frewer 2000; Gibson, Martin, and Singer 2004; Singer et al. 2000). For instance, a transparent process depends on participants being informed about the nature and scope of the exercise, what it intends to achieve (outputs) and how it intends to achieve it (mechanisms of the procedure) (Rowe and Frewer 2000; Singer et al. 2000). Others stress that success depends on having process procedures that are adaptable to the problems and positions of the involved actors, as well as their capacities and demands (e.g. Driessen, Glasbergen, and Verdaas 2001; Prager and Freese 2009). Some note that in the absence of such flexibility, priority-setters may have to exercise significant amounts of discretion in order to circumvent rigid rules and regulations imposed from the top (e.g. Brattström and Hellström 2019).

In case the process runs over a longer period, participants should be offered opportunities to revisit past choices/decisions, through, for example, iterative decision-making (Gibson, Martin, and Singer 2004). Similarly, Sibbald et al. (2009) argue for the importance of inserting revision or appeal mechanisms into priority processes. There are at least two good reasons for this. First, in the light of new developments, priorities may need adjustment (Driessen, Glasbergen, and Verdaas 2001; Gibson, Martin, and Singer 2004). Second, priority-setting is fundamentally a learning process characterised by the exchange of knowledge and insights between participants. Learning may prompt participants to realise that original objectives and methodological choices were inappropriate (e.g. Georghiou and Keenan 2000; Havas 2003; van der Meulen, de Wilt, and Rutten 2003).

Cognitive conditions

Successful priority-setting is facilitated by a number of cognitive conditions, such as the participants' willingness and ability to enter into open dialogues, respect diverting interests, trust each other, and maintain a constructive approach to problem-solving (Driessen, Glasbergen, and Verdaas 2001; Sibbald et al. 2009). These conditions can be created and sustained through frequent and informal contacts between participants, where they can exchange knowledge and insights (see also Salo, Könnölä, and Hjelt 2004). One approach to keep parties at the negotiation table is to widen the scope of the problem that the exercise aims to solve (Driessen, Glasbergen, and Verdaas 2001). Under such circumstances, the participants' ability to handle uncertainties becomes a condition for prioritising.

Studies also relate successful outcomes with the participants' ability to actively participate and learn throughout priority-setting, adapt to new circumstances, and capabilities to build consensus. For instance, the willingness of participants to make trade-offs/negotiate is considered an important condition for successful prioritisation. However, trade-offs/negotiations may generate agendas that are too comprehensive/general (e.g. Coenen et al. 2017) and/or lacking in innovativeness (Luoma 2001).

Material and method

Data collection and analysis

The main source of data for this study was interviews with participants involved in the process of developing a strategic agenda for R&I in the Swedish food sector (see background section below). The interview material covers the process from the end of 2017 to May 2018. The material covers a majority of the research areas and R&I themes elaborated in the process. Interviews were conducted with participants holding leadership roles in the priority process. They participated closely in the priority process. From their position, these respondents had a good opportunity to oversee the emergence of themes and sub-themes. Respondents include members of the steering group, research area leaders, and theme coordinators. The selection of respondents covers actors from the main parts of the domestic value chain (e.g. primary production, industry, retail). In addition to these respondents, the agency coordinator as well as a process consultant were interviewed. In total, the material covers 18 interviewees. Semi-structured interviews were conducted over the phone or face-to-face in May and June 2018. Interviews lasted 25–45 min. Questions covered the main topic of the study, including background questions regarding position, role in the process, and the time involved in the process. Questions focused on how the process had unfolded and included what the respondent considered decisive moments during priority-setting (e.g. emerging obstacles, critical choices made by the respondent, and what facilitated action/choice). The interviews also focused on the results of the process (e.g. expected/unexpected results and how the respondent related them to activities and circumstances of the process). The respondents were free to steer the direction of the conversation as long as it kept within the topic. The interviews were recorded and transcribed verbatim.

The transcripts were analysed using template analysis (King 1998). This is a criteria-driven coding approach where segments are identified based on the researcher's interests. In this case, the researcher searched for segments that explicitly or implicitly denoted (i) priority-setting activities, and (ii) facilitating conditions as expressed by the participants. The researcher attached short analytical summaries (key words and phrases) to the segments. These statements were captured by assigning codes in the form of short descriptive labels. Subsequently, codes were clustered into broader themes based on commonalities identified by the researcher. In the result section/findings below, these are described and explained using illustrative quotes from the interviews.

The researcher also observed priority-setting activities from December 2017 to May 2018. In total, the researcher joined six steering group meetings and 11 meetings on the level of research and thematic areas. Participation was a mix of face-to-face and phone/Skype participation. This approach, typically referred to as participant observation, may enable the researcher to get in-depth knowledge about how the people under study behave in their 'natural' setting (Schensul, Schensul, and LeCompte 1999). The researcher did not engage with the participants other than presenting himself and the purpose of his participation. The activities were documented by taking notes. Insights from observing the activities later aided the researcher in assessing levels of representativeness of the respondents' interview accounts.

Case background

In June 2017, the Swedish parliament adopted a national food Bill (*the Food Strategy*). The overall objective of the strategy was to improve the competitiveness of the Swedish food sector while at

the same time achieving national environmental objectives (Food Strategy 2017). The strategy was divided into three strategic areas, viz. Rules and Regulations, Consumer and Market, and Knowledge and Innovation. The third area makes up the immediate context of this study. The aim of the strategic area of Knowledge and Innovation was to 'support the knowledge and innovation system in order to contribute to increased productivity and innovation in the food chain as well as sustainable production and consumption of food' (Food Strategy 2017, 24). The government identified one of the sub-objectives of the strategic area as improving research and innovation collaboration among firms in the domestic value chain.

By the end of the spring of 2017, food sector firms were invited by the government to sign a letter of intent (LoI) by which they committed to identify areas/topics for collaboration (Avsiktsförklaring 2017). In June 2017, the government selected the Swedish Agency for Economic and Regional Growth to facilitate the initial phase of developing the collaboration. The government set the deadline for the agency's involvement to June 30, 2018.

During the fall of 2017, the signatories to the LoI elected a steering group. It consisted of actors from all the main parts of the value chain. The group proposed a number of general areas for future R&I collaboration and discussed them with the rest of the signatories. From the discussions, the following so-called *research areas* were formulated: Health and Taste, Circular Food, and Digitalization and Automation. At this point, the areas did not contain specified content. Three members of the steering group, referred to as *research area leaders* were assigned to each area. The rest of the signatories then joined the areas they found relevant. The responsibility of the three leaders was to coordinate prioritisation within each area. This study concerns that priority process. It started at the end of 2017. The process ended in May 2018 as the participants had come to an agreement on a set of priorities within each research area. The result, a strategic agenda for R&I, was made public on May 24, 2018.

Findings

This section is divided into two dimensions, viz. main activities and facilitating conditions. The first dimension includes the activities of (i) adjusting the scope of the research areas by making choices related to theme selection, and (ii) mapping out theme content components and their relation, i.e. to identify and connect a theme's expected impact, desired outcomes/outputs, and starting condition such as initial activities/investments.

The second dimension deals with conditions that facilitated choice-making within the main activities. Conditions cover: (i) government resources and time availability, (ii) mixed top-down/bottom-up steering, and (iii) complementary expertise. In the discussion/conclusions, the relationship between the activities and conditions will be further analysed. The dimensions and categories of activities and conditions are exemplified by illustrative quotes from the participants.

Main activities

In the activity of *adjusting scope*, participants made choices related to the widening and reducing of scope of the research areas.

The steering group opened up for firm participation from the entire domestic value chain. Broad participation widened scope by generating a range of ideas and possible themes. It also laid the ground for building consensus, e.g.:

> Firms from different parts of the value chain have their own ideas that needed to be aired and assessed in order for us to find common ground and proceed with a clear focus. (**Steering group member 1**)

To maintain a wide scope in the early phases of the priority process, the firms decided to exclude research performers (e.g. research institutes and academia) as formal members to the collaboration. A typical example of the rationale behind the decision:

> I believe it would have been more complicated to include the research performers in the process. It would perhaps have been an impediment and [the priorities] would have become too specific. (**Research area leader 1**)

As illustrated above, regulating participation was a way of widening scope. In addition, research area leaders widened scope by using general selection criteria, e.g.:

> I know my sector. If I mention the term 'R&I sophistication' [as criterion] to my colleagues, I would get as many definitions as participants. Hence, I have been very open and posed open questions such as: what are your needs? (**Research area leader 2)**

Subsequently, the participants began to reduce the scope of the research areas. This activity hinged on the participants' abilities to recognise overlaps between themes and collapse them, e.g.:

> [When we reduced the number of themes from 70 to 13] it was all about re-grouping them by looking at what connected to what. We had no selection criteria. We relied on intuition. (**Research area leader 2**)

A challenge that faced the participants during scope reduction was to, on the one hand, maintain commitment across the value chain, and on the other, to de-prioritise themes. As a way of managing the tension between commitment and selectivity, the research area leaders chose to create two theme categories, one that included themes with higher R&I sophistication, and one with a lower level, e.g.:

> When we had thirteen themes, we divided the themes into priority category one and two. They differed in how much they related to research and innovation. The distinction was not very strict but there was definitely a difference in that respect. (**Research area leader 2**)

The participants agreed that themes belonging to the first category should be included in the agenda and that the second category of themes should be put on hold.

Tthe second activity, *mapping*, began once prioritised themes were identified. Eleven theme groups were created and distributed equally over the research areas. Each group was led by a participant, here referred to as *theme coordinator*. Together with 3–5 other participants, the coordinator mapped out each theme. The most crucial choice involved in this type of main activity concerned selecting starting conditions, here understood as areas of future investments/type of activity perceived to yield desired outcomes/impact. To make the choice, participants assessed the supply of relevant R&I and prioritised accordingly, e.g.:

> We realized quite quickly that within certain fields, there are already high levels of research and innovation, and for that reason, we did not need to contribute with more resources. (**Theme coordinator 2**)

In some cases, the participants chose to focus on applied research as the appropriate starting condition to invest in (e.g. state of the art research in plant protein), e.g.:

> [W]e have focused on what is topical right now, that is the more generic that needs to be researched deeper, rather than something considered greatly innovative (**Research area leader 1**)

Alternatively, the participants opted for investments in existing knowledge expected to yield commercial results in the shorter term. Here is how one respondent framed it:

> For example, to develop a sugar free sugar is of course interesting to us but at the same time very specific. We must instead begin by identifying the low hanging fruit where we can reach success (**Theme coordinator 1**)

Facilitating conditions

This dimension concerns conditions that facilitated the activities/choice. It includes government resources and time availability, mixed bottom-up/top-down steering, and complementary expertise.

Government resources and time availability

Government resources, as a facilitating condition, can be divided into two categories: the national food strategy and funding. The firms saw the food strategy as a token of political support to

sector collaboration and increased public spending on food R&I. Throughout the process, the steering group used the perceived government message to maintain the participants' motivation. It also used the strategy to stress the importance of making timely choices in order to demonstrate to the government that the sector was able to collaborate. An illustrative quote:

> The national food strategy was a precondition, a decisive factor. The politicians were willing to back us but only if we did our homework and mobilize and coordinate. This message played an important role. In the discussions, I could argue: if we don't seize the opportunity it might take a while before we get a new one (**Steering group member 2**)

In addition, participants sometimes used the national food strategy during internal dicussions to defend their preferences, e.g.:

> A dialogue emerged about where to place the priority focus – on plant-based or animal products. I clearly said that we should not prioritize one over the other. The national food strategy is about increased growth and competitiveness, even if it talks about ecological products. Others agreed with me. In the end, we proceeded with a broad focus (**Research area leader 1**)

In other cases, re-interpretations of the food strategy prompted participants to change theme focus. This typically occurred when participants found difficulties to align desired outcomes with the perceived aims/expected impacts of the strategy, e.g.:

> We started with the entry point, how we can get Swedish consumers to eat healthier. But we gave it up since it doesn't fit the general aim of strengthening the competitiveness of the Swedish food sector. So, we made a turn and began looking at the competitive advantages the Swedish food sector and how we could market them in other countries (**Theme coordinator 1**)

In addition to the food strategy, government funding of the priority process was perceived as an important condition, e.g.:

> So far, one precondition for engaging in the process has been the state funding, and that we have not been required to add any funds. (**Steering group member 3**)

The funds financed a coordinator from the host agency and meeting facilities. While the coordinator was appreciated in general, the participants particularly valued that she represented a public agency with no historical ties to any specific part of the domestic value chain or to academia, e.g.:

> We have had a neutral actor, the Growth agency that has facilitated the process. That I think, was really important (**Steering group member 4**)

The funds also enabled the firms to procure various support services, e.g. an intelligence analysis, but more importantly for the process – an external process consultant from a food-oriented management consultancy. The consultant eased the participants' workload by, for example, providing organisational support, advising on how to integrate themes and map out content components and their relations, and facilitating internal communication, e.g.:

> [The consultant] has been a crucial factor. They have moved the process forward and helped us cope (**Theme coordinator 2**)

Having time to prioritise was also an important condition. Successful choice-making within the main activities hinged on time availability in at least three respects. First, the participants did not enter the process with a clear idea of *how* they would set priorities. Time compensated for the lack of preparations, e.g.:

> This was a process where the methodology developed over time. […] It is really great that the whole sector now can sit down in working groups and write documents (**Research area leader 2**)

The methodology first emerged in one of the research areas, was diffused, and adopted by the two other research areas. Secondly, time allowed the participants to make an inventory of ideas. For example:

> In an area such as this, where there are many different interests and perspectives, it would not have been possible to agree on something unless the process was allowed to take some time (**Steering group member 4**)

Third, it took time for the participants to learn from exchange and subsequently make informed choices e.g.:

> Eventually we agreed on a few suggestions to possible initiatives that were feasible and good and something that we can continue to work with. […] To my team, this was a learning process. (**Theme coordinator 4**)

Learning depended on the participants' willingness and ability to understand each other's perspectives on issues. The latter stimulated new understandings about how the sector was structured, e.g.

> The discussions [in the group] opened up for insights into how complex the various interfaces of the value chain are. From the group dialogue one now has a better understanding of the different actors' opportunities and challenges (**Theme coordinator 5**)

Mixed bottom-up/top-down steering

This condition relates to how a mix of bottom-up and top-down decision-making facilitated the process. In general, bottom-up decision-making enabled the participants to regulate participation and develop priority-setting procedures without much external interference. An illustrative quote:

> Having the mandate and freedom to work in a way that one prefers was important. It was a decisive factor to me. […] The most important choice I made concerned how the research area would organize its process (**Research area leader 2**)

A second aspect of the bottom-up approach concerns choice of theme content. Firms enjoyed high levels of discretion in choosing starting conditions, e.g.:

> We tried to avoid themes that were too technical or detailed. (**Theme coordinator 1**)

Although the priority process entailed significant levels of bottom-up discretion, it also included features of top-down steering. For example, top-down steering occurred when the steering group (the top) directed focus of the theme groups (the bottom), e.g.:

> We were setting priorities that stretched the chain from primary production to consumption and recycling. The feedback from the steering group was that we should focus on the industry part of the value chain. So we had to re-think. In the end, it turned out well. (**Theme coordinator 4**)

The government was also at times the source of top-down interventions. For instance, political leadership (the top) could intervene with instruction to which the firms adapted (the bottom), e.g.:

> [My research area] tried to include the start-up food-tech industry in the priority-process. But then we decided to postpone the collaboration. Now the government want us to include them, so we will have to reboot a bit. (**Research area leader 3**)

Complementary expertise

There are two aspects of this facilitating condition. The first refers to internal expertise and the second to external expertise. Internal, complementary expertise served to validate certain aspects of theme content, e.g.:

> We held a meeting with all the thematic groups within our research area where we cross-fertilized the themes by swapping group members. There we got the input from the other experts. The cross-fertilization resulted in a validation of one of our ideas. (**Theme coordinator 6**)

Internal expertise also shaped theme content by increasing the participants' understanding of how to solve mutual problems. One example:

> We discussed the topic of refrigerated and frozen foods products and needed a better understanding of how it worked regarding a certain process in the stores. I could look at it from a retail perspective while the producers

> used their perspective. The information that we generated was holistic and something which we could work within in our theme. (**Theme coordinator 5**)

The second aspect of complementary expertise concerns expertise that resided outside of the firms. For example, choice related to selecting starting conditions hinged on the expertise of research performers and R&D staff from related business sectors in at least two regards. First, in case the participants had little or no knowledge of the state of the art in their R&I theme, external experts could inform them, e.g.:

> None of us had any deeper knowledge about robotization. The input from [research performer S] increased our understanding of the research and development landscape, and what is feasible. Due to the contact it became clear to us what could be an initiative within our theme. (**Theme coordinator 4**)

Secondly, when participants had good knowledge of their R&I theme but wanted second opinions, external experts provided contrasting perspectives (in this case, on development of new materials from waste products):

> We sent out our priorities to the reference group that consisted of research performers. In some cases, we challenged the researchers. When we received feedback, we asked ourselves what we could do to make them agree with us. It improved the content. (**Theme coordinator 5**)

The third and final way of how external expertise facilitated priority-setting, concerned how research performers coordinated an entire R&I theme. This only occurred in one of eleven themes. Yet, it had a significant impact since the theme supported several other themes. The reason behind the delegated responsibility was that the participants themselves lacked sufficient expertise, e.g.:

> It was important to set the priorities without too much external influence. It was only within the theme [K] where we, due to needs, had to procure an external group leader from [research performer X]. (**Research area leader 2**)

This concludes the results section of this article. Table 1 summarises the main results.

Table 1. Summary of main results.

Dimension	Category	Examples
Activity/choice	Adjust scope of the research area	• Open up for broad sector representation and exclude research performers as formal members (widen scope) • Avoid narrow definitions of what are relevant needs and problems (widen scope) • Collapse themes based on intuition (reduce scope) • Create priority categories/de-prioritise (reduce scope)
	Map out theme content components and their relation	• Assess the supply of relevant R&I (research/commercialisation) • Connect expected impact/desired outcomes to production of applied research (research) • Connect expected impact/desired outcomes to use of existing knowledge (commercialisation)
Facilitating conditions	Government resources and time availability	• Motivate, pressure, and create room for interpretations (food strategy) • Neutral coordinator and process support (funding) • Develop routines for priority-setting (time) • Inventory of ideas (time) • Learn/new insights (time)
	Mixed bottom-up/top-down steering	• Discretion to self-organise (bottom-up) • Discretion to decide themes and content (bottom-up) • Adjust scope on instruction from steering group (top-down) • Add collaborators on instructions from government (top-down)
	Complementary expertise	• Support selection among ideas (internal expertise) • Complement perspectives on mutual problems (internal expertise) • New knowledge about state-of-the-art (external expertise) • Critical but constructive critique (external expertise) • Coordination of novel R&I themes (external expertise)

Discussion and conclusion

Bottom-up priority-setting is a trend in science, technology, and innovation policy that often aims to achieve the dual goal of setting R&I priorities and forging new relationships between participants (OECD 2015, 2016). From this perspective, the studied priority process was a success. The participants reached consensus on an R&I agenda and laid the foundation for increased sector collaboration. A theme coordinator captured this well by stating: 'The most important thing is that we together have formulated the priorities. […] It is the collaborative and cross-border work that is needed in order to take the big steps forward'.

The main results of the study are the identification of (i) the main activities and choices in setting the priorities, categorised as adjusting scope and mapping out content components and their relations, and (ii) the local conditions perceived to facilitate activities/choice, that is, government resources and time availability, mixed bottom-up/top-down steering, and complementary expertise.

The findings resonate with previous research on *organisational conditions* perceived to facilitate successful bottom-up decision-making processes. These include the importance of government funding, a neutral process host, and a process coordinator (e.g. Singer et al. 2000; Driessen, Glasbergen, and Verdaas 2001; Salo, Könnölä, and Hjelt 2004) as well as a combination of a bottom-up and top-down decision-making structure (e.g. Martin and Irvine 1989). Additionally, food sector firms from any part of the domestic value chain were invited to participate as formal members in the collaboration/process. This openness generated a diversity of participants (e.g. Gibson, Martin, and Singer 2004; Salo and Liesiö 2006; Sibbald et al. 2009). However, the firms also excluded related industries, research performers, and other stakeholders such as consumer interest groups as formal members. The exclusion seemed to have had positive effects on the activities but may have come at the cost of reduced R&I quality and external relevance of the priorities (e.g. Coenen et al. 2017). In terms of *procedural conditions*, methodologies for prioritisation emerged during the process (e.g. Prager and Freese 2009). Themes, content, and links between starting conditions and desired outcomes/expected impact were discussed during several rounds of negotiations/workshops in which participants sometimes engaged in revisions of earlier results (e.g. Gibson, Martin, and Singer 2004; Daniels and Sabin 2000; Sibbald et al. 2009). In terms of *cognitive conditions* highlighted in the literature review, the participants engaged actively, worked constructively with addressing emerging obstacles, and made clear efforts to understand each other's perspectives (e.g. Driessen, Glasbergen, and Verdaas 2001; Sibbald et al. 2009). The present study also demonstrates how the participants assessed the stock of R&I supply, interpreted policy texts, and hypothesised relations between starting conditions and desired outcomes/expected impacts. These activities resonate with what Brattström and Hellström (2019) refer to as cognitive aspects of discretion, i.e. those activities/choices of priority-setters that directly shape the content of priorities. However, the findings also imply that the participants felt pressure from the government to create consensus on content and seemed to assume that failure would result in a lost opportunity. Forced efforts to create consensus may have a negative effect on the innovativeness of R&I agendas (e.g. Luoma 2001). For example, several of the firms were already working within the prioritised themes. This may indicated that the firms resorted to finding overlaps between existing priorities as opposed to identify potentially novel ones.

The next sections illustrate how the main results of the study (see Table 1.) relate. It elaborates how the three identified conditions facilitated choice throughout the activities.

Government resources/time availability. The national food strategy, as a resource, enabled the participants to advocate for including certain themes (adjust scope) and to later assess and adjust starting conditions (mapping). The process consultant initially advised participants on how to merge themes (adjust scope), and subsequently supported theme coordinators to map out theme content and hypothesising causal links (mapping). Time, initially facilitated an inventory of ideas (adjust scope) and later a methodology for prioritising and learning between participants (mapping).

Bottom-up/top-down-steering. At the start of the process, bottom-up steering enabled the participants to regulate the intake of ideas and merge/rank themes (adjust scope). Top-down steering enabled the government to add collaborators to the process (adjust scope). As the process entered the phase of mapping out themes' expected impact, desired outcomes, and linking them to starting conditions, the mix of bottom-up/top-down steering continued to facilitate choice. From its position, the steering group had a good overview of the progress of all the research areas and could on that basis justify interventions in specific theme groups to correct perceived imbalances. Bottom-up steering, on the other hand, enabled participants of the theme groups to decide whether to focus starting conditions on research or on commercialisation/innovation, how to divide labour, and how to organise interactions (e.g. cross-fertilizing activities).

Complementary expertise. Complementary expertise facilitated the coordination of entire R&I themes (adjust scope). It also supported theme groups in validating interesting ideas/content, identifying solutions by addressing mutual problems, and facilitating new insights among the participants about the state of art within the themes (mapping).

To conclude, industrial sectors have their own history, culture, and challenges related to R&I collaboration. They may also differ in terms of R&I intensity/maturity. Hence, their susceptibility to steering by the interests of external actors such as research performers may vary. Factors such as these are embedded in the case context and affect the generalizability of the findings of the study. However, a qualitative case study like this can offer some insight into the basic variables, and their relation, that shape process outcomes of collaborative priority-setting for R&I. By taking a process perspective on prioritisation, this study has offered a view into the black box of collaborative priority-setting. It has unpacked some of the components, here understood as the activities and facilitating conditions, that mediate between inputs (e.g. the policy decision to fund the process) and outcomes (e.g. a strategic R&I agenda/sector consensus). The study has demonstrated what part of the collaborative priority process conditions support. The results should therefore be of interest to policy-makers and industrial actors who seek to create sector consensus on strategic agendas for R&I. What remains to be seen is how sector specific processes transfer across sectors. Future research in this area could profitably focus on the relation between activities and facilitating conditions of collaborative priority-setting from other sectors. Additional cases may provide a fertile ground for comparative studies and policy-learning.

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Notes on contributor

Erik Brattström is a researcher at the School of Economics and Management, Lund University. His research is focused on research and innovation policy.

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The Missing Link

The methods, processes, and conditions involved in implementing priorities for research, development, and innovation (RDI) on the 'lower' levels of decision-making in science policy have hitherto received limited attention in science policy research in general, and research on priority-setting in particular. Consequently, we know little about how implementers, such as funding agencies, industry, and research performers go about making RDI priorities implementable and what that means for the emergence of new conditions for RDI production.

The thesis explores this 'missing link' in the study of priority-setting for RDI, namely the processes of implementing RDI priorities, and the consequences of these processes. It does so by focusing on how choices, actions, and motivations of implementers of RDI priorities established elsewhere in the policy system enact, or carry out, the priorities, resulting in new conditions for RDI production. Such conditions can be understood as concretizations of the broader, prioritized themes for RDI and ways of organizing RDI within the themes.

The results of the thesis suggest that priority-setting as enacted can be understood as a sequence of socially and cognitively motivated discretionary choices that stimulate creativity and socialization during the implementation of RDI priorities. The thesis refers to this as a 'socio-cognitive approach to the implementation of RDI priorities'.

In their aggregated form, the discretionary choices, and the interactions they yield, shape new conditions for RDI production on content as well as form on the different levels of the policy system. This suggests that choices, interactions, and new condtions amount to a continuation of steering of RDI production after policy-decisions for RDI are made. It also raises some concerns about how discretion may undercut the legitimacy of RDI investments and negatively affect the 'optimal' trajectories of scientific fields (e.g. more significant discoveries and/or improved, complementary knowledge about observed phenomena, etc.). This begs the question if there is a need to govern discretion.

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