Dissertation

Organizing Collaborative Research

The dynamics and long-term effects of multi-actor research programs

Tjerk Wardenaar

Rathenau Instituut

The **Rathenau Instituut** promotes the formation of political and public opinion on science and technology. To this end, the Institute studies the organization and development of science systems, publishes about social impact of new technologies, and organizes debates on issues and dilemmas in science and technology.

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Rathenau Instituut
Anna van Saksenlaan 51

Postal address:
Postbus 95366
2509 CJ Den Haag

Telefoon: +31 (0)70 342 15 42
E-mail: info@rathenau.nl
Website: www.rathenau.nl

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Tjerk Wardenaar
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promotor: prof. dr. P.A.A. van den Besselaar

Thesis committee:
Prof. dr. S. Kuhlmann (Universiteit Twente)
Prof. dr. E.H.M. Moors (Universiteit Utrecht)
Prof. dr. A.C. Petersen (University College London)
Prof. dr. P.C. van der Sijde (Vrije Universiteit)
Dr. I.C.M. van der Weijden (Universiteit Leiden)

Content

1 Introduction

1.1 Working together on the grand challenges of our time

Societal relevance, valorization and the usability of scientific research are central concepts in contemporary science systems. Researchers are encouraged to strive for societal relevance by science policymakers and research funders who include relevance requirements in their mechanisms for agenda-setting and funding. The requirement for societal relevance is especially salient in large-scale, multi-actor research programs. These increasingly popular organizational forms link research agendas to the challenges that contemporary societies face. Emblematic of this development is the use of grand societal challenges, such as climate change and healthy aging, as strategic rhetoric and or a guiding principle in the new EU Horizon 2020 program.

At present, a shared definition of these increasingly popular research organizations is lacking. In this dissertation, the concept of a multi-actor research program[1] is used to refer to research programs that: (1) consist of a large collection of research or other projects with a certain degree of substantive coherence and organizational delineation, (2) have a thematic rather than a disciplinary focus, (3) bring together participants from different disciplinary, organizational and sectoral backgrounds, (4) focus on the production of both scientifically excellent and societally relevant knowledge, and (5) are often – but not always – funded by both public and private research money.

Multi-actor research programs are implemented with the belief that the grand challenges of our time can only be addressed successfully when relevant actors work on them together (Lyall and Fletcher 2013). Influenced by concepts such as Mode-2 and transdisciplinary research, these programs aim for collaborative research practices by participants with different disciplinary, organizational and sectoral backgrounds (Boon et al. 2014; Pohl 2008). These collaborative research practices not only focus on the production of new fundamental knowledge but also on knowledge that is societally relevant and readily applicable in practice (Hegger et al. 2012b).

However, the ambition of multi-actor research programs goes beyond influencing current research practices and the production of societally relevant output.

1 In the literature, many concepts have been used to refer to these programs, e.g. 'multidisciplinary research programs' (Roelofsen et al. 2011), 'interdisciplinary research programs' (Kloet et al. 2013; Lyall and Fletcher 2013; Lyall et al. 2013), 'transdisciplinary research programs' (Pohl 2008; Roux et al. 2010), 'large research programs' (Hegger et al. 2012b), 'multi-actor programs' (Hegger et al. 2012a), 'multi-actor, multi-measure programs' (Baumann et al. 2004), and 'knowledge and innovation programs' (Bressers 2011). In this dissertation, the concepts of 'multi-actor research program' and 'public-private research program' are used for these organizations to emphasize their collaborative research approach.

In pursuing collaborative research practices, they strive for long-term effects on scientific knowledge production. The Dutch funding scheme Bsik (Besluit subsidies investeringen kennisinfrastructuur) is an illustrative example. This 802 million euro funding scheme introduced 37 multi-actor research programs into the Dutch science system with the intention to create high-quality, *sustainable networks* of knowledge producers and knowledge users (SenterNovem/Bsik 2005). Collaborative research practices in the context of these programs should therefore not only occur during their own lifespan, but become integral to future scientific knowledge production processes.

Multi-actor research programs are enjoying growing popularity and have far-reaching ambitions, but there is not a lot of clarity on the organization, dynamics and results of these programs. To fill this knowledge gap and to strengthen the use of these programs as policy instruments, this dissertation raises two central questions:

- *How do multi-actor research programs organize collaborative research practices?*
- *Do multi-actor research programs have long-term effects on scientific knowledge production?*

1.2 Collaborative research practices in nested organizational structures?

Multi-actor research programs aim to organize collaborative research practices. Starting from a certain challenge, the program brings together a diverse group of actors around a more or less explicit program logic, on the basis of which sub-programs with more specified aims are derived from the central challenge. The research or other work is subsequently organized into smaller work packages, and the individual projects are situated within them (De Jong et al. 2012; Merkx et al. 2012). Within such a nested organizational structure, multi-actor research programs are expected to induce collaborative research practices across (1) organizational and (2) sectoral boundaries.

With regard to the first, the consortium approach of these programs is seen as a means to organize collaborative research practices between organizations.[2] As consortia of different organizations, multi-actor research programs are regarded as a manifestation of an increasingly popular research coordination mode that has been dubbed 'delegation to networks' (Braun 2003; Lepori 2011). At present,

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2 In this dissertation, a distinction is made between the 'program' and the 'consortium'. The term 'program' refers to a collection of research activities with a certain degree of substantive coherence and organizational delineation. The term 'consortium' refers to a set of partners committed to a 'program'. To refer to the set of partners committed to a multi-actor research program we use the concepts of 'strategic research consortium' and 'public-private research consortium'.

little or no attention has been paid to the programs' actual approaches to agenda-setting and coordination of collaborative research practices. Delegation to research networks has subsequently been treated as an undifferentiated coordination form, quite similar to what has been argued with regard to network governance in organization studies (Provan and Kenis 2008). A more in-depth understanding of the ways in which multi-actor research programs coordinate participating organizations is a first step in answering the question of how these programs organize collaborative research practices.

In relation to the second, collaborations across sectors are expected to be induced by giving non-academic stakeholders a role in the knowledge production process. The arguments for involvement are: (1) collaboration with stakeholders could help close the gap between the supply of and demand for scientific knowledge (McNie 2007), (2) making use of stakeholders' creative potential and experimental – or practical – knowledge could enhance the social robustness of the knowledge produced (Caron-Flinterman et al. 2005; Edelenbos et al. 2011) and (3) interactions between individual participants across the science-society boundary are associated with higher levels of information use (Kirchhoff et al. 2013; Knapp and Trainor 2013; Weichselgartner and Kasperson 2010). However, studies of stakeholder involvement have revealed a rich diversity in roles and activities (Boon et al. 2014; Hegger et al. 2012a; McNie 2012; Pohl 2008). At present, it is subsequently not clear how stakeholder involvement – and thus cross-sectoral collaboration – is fleshed out in the context of these programs.

1.3 Long-term effects: a new generation of PhD holders?

As discussed above, large-scale multi-actor research programs are introduced to sort out effects beyond their own lifespan. By stimulating collaborative research practices across organizational and sectoral boundaries, they aim to affect future knowledge production processes. However, the assessment of the long-term effects of R&D programs is a difficult endeavor (Arnold 2012; Rogers 2012). In the absence of a working crystal ball, we are dependent on indicators of changing research practices. In this dissertation, we focus on the PhD students who are working on their dissertations in the context of these programs.

Studies on research socialization have shown that developments during the PhD period can have long-lasting effects on future research practices (Slaughter et al. 2002; Verbree 2011). A study on management styles of Dutch medical research group leaders, for example, found early career socialization effects on their work practices. The cohort of leaders that obtain their PhDs after the introduction of a national research evaluation system and when project funding had become important, spent: (1) less time on education, (2) more time on conducting research and (3) acquired more external funding from a wider range of sources than the older cohort of research group leaders (Verbree 2011).

Although not primarily implemented as PhD training trajectories, large numbers of PhD students participate in multi-actor research programs. The programs' challenge-driven research approach, their interdisciplinary focus and the involvement of non-academic stakeholders provide participating PhD students with a different training trajectory. We expect that such a training trajectory will affect their skills and in turn their future work practices. PhD students who, due to training in a collaborative research setting, gain skills allowing them to interact closely with knowledge users and are used to working on societally relevant research output are more likely to be involved in such collaborative research practices later in their careers. The effects of multi-actor research programs on the skills of these PhD holders would consequently be an indication that these programs have long-term sustained effects beyond their own lifespan.

1.4 Climate (adaptation) research

The aim of this dissertation is to provide insight into the organization and long-term effects of multi-actor research programs. The main empirical focus is on the organization and effects of climate (adaptation) research programs. Consensus is growing that a changing climate can have adverse effects on contemporary society. Climate change invariably features on the lists of grand societal challenges. For example, roughly 40 percent of the budget of Horizon 2020 – the new EU framework program – has been assigned to seven grand challenges: of the program's total R&D budget of 72 billion euros, about 60 percent is related to sustainable development and about 35 percent specifically to climate (EuropeanCommission 2013).

The importance of climate change to the policy agenda provides relevance to a study on the organization of research programs in this scientific discipline. More importantly, from a methodological perspective, there is a rich history of collaborative research in climate and environmental research. Environmental scholars have argued for years that they can only contribute to addressing challenges such as climate change by working across disciplinary boundaries and by collaborating with non-academic stakeholders (Funtowicz and Ravetz 1993; Hegger et al. 2012b; Pohl 2008). Climate (adaptation) research programs are subsequently on the forefront of the trend towards challenge-driven research. Understanding the organization and dynamics of climate adaptation programs can provide lessons for programs on themes without a history of collaborative research practices.

At the start of this study an explorative inventory of climate research programs was conducted to take stock of multi-actor research programs in 16 countries (Australia, Austria, Canada, Denmark, Finland, France, Germany, Ireland, Japan, the Netherlands, New Zealand, Norway, the United Kingdom, the United States of America, Sweden and Switzerland) (Wardenaar 2012). The exploratory analysis resulted in a long list of 56 climate research initiatives. After a screening of the initiatives on program aims, research activities and science-society collaborations, 26 initiatives (in 14 countries) were selected for further analysis. In a second step, questionnaires were sent to the program directors of the 26 initiatives. Eighteen program directors were willing to participate and provided information on their program's mission, objectives and organization. Based on the survey response, 14 programs were identified as multi-actor research programs (Table 1.1):

Table 1.1 Overview of 14 multi-actor research programs

Name	Country	Period
CSIRO flagship	Australia	Continuous
ACRP	Austria	Continuous
GICC	France	Continuous
KLIMZUG	Germany	2008-14
Klimazwei	Germany	2006-09
Climate changes Spatial Planning	Netherlands	2004-11
Knowledge for Climate	Netherlands	2008-14
Living with Water	Netherlands	2004-11
NORKLIMA	Norway	2004-13
CLIPORE	Sweden	2004-11
ProClim	Switzerland	Continuous
UK CIP	UK	2005-11
Tyndall Centre	UK	2000-10
NOAA RISA	USA	Continuous

Source: Wardenaar (2012)

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The explorative inventory provided valuable cases for more in-depth analysis on research coordination, stakeholder involvement and PhD training. In the relevant chapters of this thesis, case selection per topic is explained in more detail. In table 1.2, we provide some background information on the five most important cases in this dissertation.

Table 1.2 Description of most important cases

Program	Chapter	Description
Climate changes Spatial Planning	2 & 5	Dutch climate (adaptation) research program with the objective to "provide an operational knowledge infrastructure in the field of climate proof spatial planning for governmental and industry organizations." The program was funded by the abovementioned Bsik-scheme and ran between 2004 – 2011 with an annual budget of 10 million € (50% subsidy, 50% co-funded).
KLIMZUG	4	German climate adaptation research program with the objective to "develop innovative strategies for adaptation to climate change and related weather extremes in regions." The program is funded by the German Federal Ministry of Education and Research (BMBF). It started in 2008 and ends in 2014. Annual budget of the program is 17 million €.
NOAA RISA	4	Climate adaptation program of the US' National Oceanic and Atmospheric Administration (NOAA). The program runs since 1995 and has the mission to "help expand and build the US' capacity to prepare for and adapt to climate variability and change." The budget of the program changes yearly, but lies around 7 million € per year.
Knowledge for Climate	4 & 6	Dutch climate adaptation program that started in 2008 and will end in 2014. The program is funded by a follow-up funding scheme of Bsik (FES). Mission of the program is to "develop applied knowledge, through cooperation between the Dutch government, the business community and scientific research institutes, in order to ensure that long term decision making takes into account the impacts of climate change." The program has an annual budget of 13 million € (50% subsidy, 50% co-funded).
Tyndall Centre	6	British climate research program that brings together scientists, economists, engineers and social scientists to "research, assess and communicate from a distinct trans-disciplinary perspective, the options to mitigate, and the necessities to adapt to current climate change and continuing global warming, and to integrate these into the global, UK and local contexts of sustainable development". The program was funded between 2000 – 2010 by three UK research councils. Since 2010, the program is funded by its core partners (host universities) and by some additional research grants. The program has an annual budget of 2 million €.

Source: Wardenaar (2012), www.tyndall.ac.uk, www.climatechangesspatialplanning.nl, www.klimzug.de, cpo.noaa.gov, www.knowledgeforclimate.nl

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1.5 Structure of this dissertation

This dissertation consists of five analytical chapters (Chapters 2–6) and a concluding chapter that addresses the central research questions of the dissertation (Chapter 7). Below, we briefly introduce the scope, focus and research questions of the individual chapters.

Chapter 2: Coordinating organizational collaborations in consortia

The focus in this chapter of the dissertation is on how multi-actor research programs coordinate organizational collaborations. Being seen as 'network organizations', it is often assumed that multi-actor research programs rely on what is called 'network coordination' to achieve their objectives. In this context, network coordination is usually defined as: (1) a greater distance from the state, resulting in a higher level of self-organization and (2) a governance style that relies on the participants' shared interests and their mutual dependency, resulting in informal governance mechanisms (Braun 2003; Klerkx and Leeuwis 2008a, 2008b; Lepori 2011; Potì and Reale 2007). As mentioned above, delegation to networks has been treated as an undifferentiated coordination form. The organization studies literature shows, however, that network coordination can take many different forms (Provan et al. 2007). To fully understand multi-actor research programs as research coordination structures, it is crucial to focus on the actual coordination approaches that they develop. Chapter 2 addresses the following sub-questions:

1. *What actual coordination approaches do multi-actor research programs develop?*
2. *How can we explain the development of a certain coordination approach?*

To answer these questions we built on insights from organization studies on different governance forms of network organizations. We performed a systematic comparison of the coordination approaches of two Dutch research programs: Climate changes Spatial Planning (CcSP) and Next Generation Infrastructures (NG Infra).

Chapter 3: An illustrative prelude to stakeholder involvement
Collaboration beyond sectoral boundaries is a key feature of multi-actor research programs. Non-academic stakeholders are expected to play a central role in these programs in order to increase the practical applicability of the knowledge produced. To illustrate that scientific excellence does not automatically result in practical applicability, the attention in this chapter briefly shifts away from multi-actor research programs. The chapter provides an illustrative prelude to this salient aspect of such programs by presenting a research study from – rather than about – the environmental sciences. The chapter describes a case study on the consequences of allocation choices in bio-energy policies. It contrasts the use of life-cycle assessment (LCA) methodology in academic research with the use of this methodology in policy directives. By calculating the differences in climate change score of the same bio-electricity chain (rapeseed to electricity) in various directives, the article shows that methodological issues can have severe policy consequences. The chapter builds on insights from LCA studies and has a technical character, but in this way it provides insight into the sometimes subtle barriers to societal relevance. The chapter concludes with a plea for more cross-sectoral dialogues in order to increase the practical applicability of LCA methodology.

Chapter 4: Stakeholder roles in challenge-driven research practices
In this chapter the focus shifts back to multi-actor research programs as a response to such pleas for more cross-sectoral dialogues. Studies on stakeholder involvement in multi-actor research programs have revealed a rich diversity in stakeholder roles and activities, ranging from limited consultation rounds to extended knowledge coproduction projects (Boon et al. 2014; Hegger et al. 2012a; Kloet et al. 2013; McNie 2012; Roelofsen et al. 2011). However, understanding multi-actor research programs, as a means to organize challenge-driven research requires a more systematic understanding of the diversity of stakeholder roles in the context of these programs and the effect of such involvement on knowledge production processes. Chapter 4 thus raises the following two sub-questions of this dissertation:

3. *What roles do stakeholders play at the different levels of multi-actor research programs?*
4. *How are these different roles linked to the research activities in multi-actor research programs?*

The chapter starts by defining stakeholder roles along three dimensions that have been studied separately in the literature but have not yet been combined: (1) the direction of flow of information between scientists and stakeholders, (2) the phase of the research process in which stakeholders are involved and (3) the nature of their contribution to the research process. The typology is subsequently tested empirically in three multi-actor research programs in the US (NOAA's RISA program), the Netherlands (Knowledge for Climate) and Germany (KLIMZUG).

Chapter 5: Stakeholder involvement in agenda-setting

The analysis of stakeholder roles in multi-actor research programs confirms the rich diversity of stakeholder involvement in these programs. This diversity adds additional complexity to the already significant policy challenge of selecting a consortium that will carry out collaborative research activities that will contribute to the overall policy goal of addressing grand societal challenges. The aim of the fifth chapter is to explore to what extent ex ante evaluation of multi-actor research programs enables policymakers to select consortia that will carry out programs in which stakeholders are indeed involved. The chapter raises the following two sub-questions:

5. *How are stakeholders involved in the design phase of a multi-actor research program?*
6. *To what extent is such involvement a predictor of their later involvement and financial contribution?*

To answer these questions we studied the 37 Dutch multi-actor research programs that were funded by the above-mentioned Bsik funding scheme.

Chapter 6: Training a new generation of PhD holders?

After the previous chapters have provided insights into the organization and dynamics of multi-actor research programs, in this chapter the focus shifts to their long-term effects. Long-term effects are difficult to assess due to attributional and temporal aspects. In this dissertation, the skills of participating PhD students serve as an indicator of long-term effects on research practices. Previous studies have shown that socialization effects during the PhD phase can have long-lasting effects on research practices (Slaughter et al. 2002; Verbree 2011). In the case that PhD students participating in multi-actor research programs actually develop a different set of skills from PhD students in traditional trajectories, it can be assumed that the rising popularity of these programs (with large numbers of participating PhD students) will have effects on future research practices. The chapter addresses the last three sub-questions of this dissertation:

7. *Is the set of skills developed by PhD students in multi-actor research programs different from the set of skills developed by PhD students in traditional trajectories?*

8. *Are differences between training trajectories in skill development related to individual characteristics and to training context?*
9. *What is the relationship between individual characteristics and training context characteristics and the development of different types of skill?*

To answer these questions a survey among 438 sustainability PhDs in the UK and the Netherlands was conducted. Approximately half of the PhDs were involved in a multi-actor research program, the other half followed a traditional trajectory. The survey gathered data on: (1) characteristics of individual participants, (2) characteristics of their training context and (3) their obtained set of skills. We distinguish between four types of skill: (1) academic research skills, (2) academic communication skills, (3) translation and dissemination skills, and (4) transferable skills.

Chapter 7: Conclusion, discussion and recommendations
The closing chapter of this dissertation presents the conclusions of this study. It discusses the scope and limitations of the main findings and provides recommendations for policymakers, program directors and individual program participants.

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2 Varieties of research coordination: A comparative analysis of two strategic research consortia[3]

Abstract

Strategic research consortia as policy instruments for research coordination have been on the rise for more than a decade. Despite their rising popularity as coordination structures, there has been little comparative analysis of the actual coordination approaches such consortia develop. In order to enhance our understanding of consortia as coordination structures, this paper makes a systematic and in-depth comparison of the coordination approaches of two Dutch consortia. The analysis shows that research consortia coordinate their activities in very different ways. A consortium's coordination approach turns out to be strongly influenced by its internal characteristics. The observed influence of internal consortium characteristics implies that the eventual coordination approach of consortia will not always match the rationale behind a policy measure to support these consortia. We recommend policy-makers to foster strategic research consortia with a heterogeneous composition that have organised sufficient flexibility for reacting to unforeseen developments.

2.1 Introduction

Governments are keen to encourage scientists to respond better to societal knowledge needs and to address societal challenges such as ageing, climate change and resource scarcity. They use a variety of policy instruments and approaches in their attempts to do so. The past few decades have seen the emergence of a trend whereby governments fund consortia, centres or programmes that organise and conduct research in areas of strategic importance to society or the economy (Gray 2011; Kloet et al. 2013; Turpin et al. 2011). Such research consortia are a strong coordination tool to involve both knowledge users and research performers in agenda-setting for public research activities (Lepori 2011). Delegation of decisionmaking to strategic research consortia as a tool for research coordination has been readily understood as a form of 'network coordination' (Braun 2003), which implies that self-organisation on the basis of shared interests and mutual dependency are central factors in the steering of relationships and activities.

The organisation studies literature shows, however, that network coordination takes many different forms (Provan et al. 2007). Three governance forms have

3 This chapter has been published as Wardenaar, Tjerk, Stefan P.L. de Jong and Laurens K. Hessels (2014). Varieties of research coordination: A comparative analysis of two strategic research consortia. *Science and Public Policy*, Advance Access (March 21, 2014).

been identified in empirical studies of network organisations (Provan and Kenis 2008). Building on these insights from organization studies, this paper aims to increase our understanding of the coordination approaches of strategic research consortia, addressing the following two questions:

- *What actual coordination approaches do strategic research consortia develop?*
- *How can we explain the development of a certain coordination approach?*

To answer these questions we performed a systematic comparison of the coordination approaches of two Dutch research consortia that were funded under the same funding scheme (Climate changes Spatial Planning (CcSP) and Next Generation Infrastructures (NG Infra)). The scheme Investment Grants for Knowledge Infrastructure (*Besluit subsidies Investeringen Kennisinfrastructuur* (Bsik)) funded a total of 37 strategic research consortia. The Bsik scheme only provided a very general institutional framework for the consortia, with no organisational mould or blueprint for coordinating research activities. This provided us with an excellent opportunity for a comparative analysis of the actual coordination approaches adopted by consortia. In the comparison we study several characteristics that have a possible influence on the governance form and coordination approach of a research consortium.

2.2 Theoretical framework

2.2.1 Strategic research consortia in the literature

Strategic research consortia are regarded as a manifestation of an increasingly popular research coordination mode that has been dubbed 'delegation to networks' (Braun 2003; Lepori 2011). Braun's description of 'delegation to networks' in science policy is closely related to the general concept of network coordination (Powell 1990). The notion of network coordination has been introduced as a viable alternative coordination mode which is based on values like friendship, reputation, altruism and reciprocity, subsequently going beyond the classic hierarchy–market continuum (Fisher et al. 2001; Powell 1990).[4]

In science policy studies, 'delegation to networks' is often put forward as a solution to the problems of 'traditional' coordination modes.[5] In this context, network coordination is usually defined as: first, a greater distance from the

4 Network coordination is used in the literature to describe both an ideal-typical coordination mode and the coordination activities of network organisations. In this paper, we use the first meaning of the concept.

5 In the case of science policy studies these are known as the problem of adverse selection and the problem of moral hazard (Braun 2003). The problem of adverse selection revolves around the question of how you can be sure that you have selected the right scientist for a research job. The problem of moral hazard concerns the question of how you can be sure that a selected scientist does his best to fulfil a given research task.

state, resulting in a higher level of self-organisation; and secondly, a governance style that relies on the participants' shared interests and their mutual dependency, resulting in informal governance mechanisms (Braun 2003; Klerkx and Leeuwis 2008; Kloet et al. 2013; Lepori 2011; Potì and Reale 2007).

The growing presence of consortia as research performers and coordination structures in science systems since the 1990s has been reflected in an expanding body of literature on the rationales behind the funding of such consortia, their policy design and their outcomes. However, in this body of literature, little or no attention has been given to the actual coordination approaches adopted by consortia. We argue that 'delegation to networks' in science has often been treated as an undifferentiated coordination form, as has been argued (Provan and Kenis 2008) with regard to network governance in organisation studies. A quick glance at the 37 Dutch Bsik consortia indicates that, in practice, consortia differ widely in the way they coordinate. They vary in their funding allocation models, organisational structures and degree of hierarchical steering (Hessels and Deuten 2013b). Moreover, studies of network organisations have shown that they often rely on coordination mechanisms such as control (Kenis and Provan 2006) and can even—contrary to their own goals—turn into hierarchical organisations (Oberg and Walgenbach 2008). For these reasons, we argue in this paper that, to fully understand consortia as research coordination structures, it is crucial to focus on the actual coordination approaches that they develop.

2.2.2 Research coordination approaches

In drawing an initial distinction between strategic research consortia, we borrowed a typology of network governance types introduced by Provan and Kenis (2008). Their typology is based on two considerations: first, whether governance is brokered; and secondly, whether the network is participant-governed or externally governed. The typology results in three governance models.[6] In the first form (participant-governed networks (PGNs)), governance is decentralised and not brokered. Network participants interact on an equal basis and make all decisions themselves. In the second form (lead organization governed networks (LGNs)), governance is brokered and all major network-level activities and key decisions are coordinated through and by a single participating member (the lead organisation). In the third form (network administrative organisation (NAO) model), a separate entity is set up specifically to govern the network and its activities. The typology is a good starting point to increase our understanding of differences between strategic research consortia. Since the typology only describes pure governance forms (Provan et al. 2007), we complemented it with additional theory.

6 There are three rather than four, because nonbrokered governance is by definition always participant-governed.

We take research coordination to mean establishing or strengthening a relationship among the activities in a system, with the aim of enhancing their common effectiveness (Hessels 2013). Consortia perform research coordination in two phases of their life cycle: the selection phase and the implementation phase (Meulen and Shove 2001; Shove 2003). During these phases consortia can rely on a large diversity of coordination 'attributes', such as informal agreements and incentives. These attributes can be linked to and are often explained in terms of 'ideal types' of coordination, i.e. the market, hierarchy and networks (Lepori 2011; Powell 1990; Williamson 1991). In this paper we use these ideal-types to characterize coordination approaches (see table 1). A coordination approach is understood in this paper to be the combination of coordination attributes that a consortium applies in its attempts to achieve its goals. Combining coordination attributes means a coordination approach will resemble an ideal-typical coordination approach to some extent or other. It should be noted that the ideal-types cannot be expected to be found in their pure form (Stokman 2011).

The examples provided by Provan and Kenis (2008) suggest that consortia with different governance forms are likely to develop coordination approaches that resemble different ideal-types. In PGNs all partners participate voluntarily and on an equal basis. Power in the network is thus more or less symmetrical. PGNs for research are most likely to develop ideal-typical network coordination. Participants establish relationships with partners they expect to complement themselves (Powell et al. 1996; Stokman 2011). Selection of participants and projects in such a coordination approach will be based on knowledge about reputation and research and managerial skills. Because a distinct administrative entity or lead organisation is lacking, informal agreements seem most effective in the implementation phase.

Table 2.1 Ideal-typical coordination approaches in two life phases of research consortia

Coordination type	Selection	Implementation
Market	Open competition	Contracts / incentives
Hierarchy	Top-down (i.e. predefined programme)	Control mechanisms
Network	Network values (e.g. reputation)	Informal agreements

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In LGNs governance becomes highly centralised and brokered, with asymmetrical power (Provan and Kenis 2008). The lead organisation's control over the financial resources of the network makes it attractive for other partners to invest more in relationships with the lead organization than in relationships with other participants. The lead organisation in a research consortium can use its control over funding to coordinate, just like a research council. In that case, the selection of participants and projects will take place via open calls. During the implementation phase, the lead organisation will hold participants accountable for the formal agreements they have made. If necessary, the lead organisation can provide additional steering through financial incentives.

In the NAO model, a separate entity is established, either by mandate or by the members themselves. The introduction of a separate entity will be accompanied by other more formal structures like an executive director, staff and a board (Provan et al. 2004; Provan and Kenis 2008). As such, the NAO model is most likely to develop a coordination approach that resembles the ideal-type of a hierarchy with formal and bureaucratic agreements. In the selection phase, we would expect a designated body to select projects and participants in a top-down manner, based on a pre-defined research programme. It can subsequently exert control over research activities, using control instruments.

2.2.3 Possible influences on a consortium's coordination approach

Given the principles of network delegation, governments will give strategic research consortia a great deal of autonomy to choose their own coordination approach. As illustrated by the case of the 37 Dutch Bsik consortia, this can result in a wide variety of coordination approaches (Hessels and Deuten 2013b). The second aim of this paper is to improve the understanding of how such differences evolve. We have explored several characteristics that might possibly influence the governance form of a strategic research consortium and the development of a coordination approach, drawing a distinction between two types of factors: the factors related to the institutional environment of the network, and the factors related to internal consortium characteristics.

2.2.3.1 Institutional environment

Since networks and institutions mutually influence or even co-constitute each other (Owen-Smith and Powell 2008), institutional characteristics may help to explain the differences between the coordination approaches of research consortia. In our analysis of the influence of the institutional environment we distinguished between two dimensions: the scientific discipline and the organisational field. Scientific disciplines vary in terms of their social organization and communication culture. These differences relate partly to their objects of study but are also a product of historical contingencies. The first relevant variable with regard to strategic research consortia is strategic task uncertainty, the degree of consensus about intellectual priorities (Whitley 2000). In a field with high strategic uncertainty, more stringent coordination measures may be required to ensure collective action. This is also the case for interdisciplinary consortia, which bring together actors between whom there is a large cognitive distance. Secondly, due to differences in cognitive content, fields also vary in their communication styles, with an emphasis on monographs, papers in academic journals or conference proceedings (Becher and Trowler 2001). One important variable in the current context is the degree to which research outputs can be quantified and systematically evaluated. Bibliometric indicators are most valid in natural science disciplines, with a relatively high throughput of publications and a strong emphasis on scientific journals as the standard communication medium.

The second dimension to consider is the 'organisational field' of the consortium (DiMaggio and Powell 1991; Owen-Smith and Powell 2008). Institutional theory suggests that organisations are under various pressures to model themselves after important organisations in their environment or 'organisational field' (DiMaggio and Powell 1983, 1991). This organisational field consists of those organisations that constitute, in the aggregate, a recognised area of institutional life (DiMaggio and Powell 1991). This means that isomorphic pressures do not merely exist among competing organisations, but also, for example, between resource supplier and consumer. In addition, the different participants in the consortium from non-academic organisations bring with them certain beliefs regarding appropriate behaviour that influence the consortium's coordination approach (Oberg and Walgenbach 2008). Because of the strategic focus of the research consortia under study, non-academic organisations play an important role. Given the differences between the dominant coordination mechanisms in firms, governments and universities, their relative proportions may be a decisive factor in the coordination approach manifested in the consortium.

2.2.3.2 Internal consortium characteristics

The second set of factors that might influence the governance form of a strategic research consortium concern the internal characteristics of the consortium. Many studies have shown that structural characteristics influence dynamics and further development of networks (Padgett and Ansell 1993; Powell et al. 1996; Stokman 2011) and can also be expected to influence networks' coordination approaches. We analysed the possible influence of three internal consortium characteristics: the shared history, the size, and the power distribution.

The first characteristic we studied was shared history. Inter-organisational research consortia are often formed in the wake of a new funding scheme. In some cases an entirely new consortium is formed, while in other cases the consortium builds on an existing collaborative arrangement between organisations. If a shared history exists, Provan and Kenis (2008) suggest that the direction of such an evolution is towards more a formal governance, i.e. towards the NAO model.

The second network characteristic we took into consideration was consortium size. We considered consortium size in two dimensions, in terms both of the number of participants and of geographical distance covered. In a small consortium it is possible for all partners to know each other and communicate with each other directly. An increase in the number of participants makes such direct communication more difficult. A large consortium will tend to have brokered governance and more bureaucratic control (Provan and Kenis 2008). In our analysis we also considered consortium size in terms of the geographical area covered. Geographical proximity among potential partners has been shown to strongly influence the probability of collaborations (Boschma 2005).

Third, we considered the power distribution in a network. Most network organisations consist of partners of different sizes with unequal access to strategic means such as funds, information or relations. It has been shown that such differences between network participants strongly influence the dynamics of the network (Padgett and Ansell 1993). In an inter-organisational consortium differences between partners are likely to result in an unequal power distribution (Provan and Kenis 2008). For example, if one consortium partner has disproportionate access to strategic means, it may start acting as the lead organisation. In our study, we focused particularly on differences in access to the funding awarded.

2.3 Data and methods

2.3.1 Research context and cases

Because our research questions were exploratory in nature, we opted for a case study approach. Our research questions deal with different types of coordination approaches taken by research consortia and the factors influencing these approaches. These exploratory questions, focusing on uncontrollable contemporary behavioural events, justify a comparative case study (Yin 2003). We selected two cases that: first, shared sufficient characteristics and at the same time differed sufficiently in institutional environment and internal consortium characteristics to allow a meaningful comparison; and secondly, provided sufficient information to allow an in-depth analysis.

The two consortia were funded under the same funding scheme. We present this research context of our study, before introducing our cases. In 2002 the Dutch government introduced the 'Investment Grants for Knowledge Infrastructure' scheme (*Besluit subsidies Investeringen Kennisinfrastructuur* (Bsik)). Before any consortia were selected, a governmental working group conducted a broad survey of universities, research institutes, industry and government to identify relevant knowledge themes. In a second step, the working group organised a 'call for expressions of interest'. Based on the survey and the responses to this call, the working group defined five interdisciplinary themes.

The funding scheme subsequently made €802 million available for 37 strategic research consortia that were commissioned to foster more science–society collaborations in one of the five themes. The government introduced a novel structure to select and monitor the consortia. It believed that the focus on science–society collaborations and the interdisciplinary character of the scheme made existing, permanent organisation structures (e.g. the research council) less suitable for this coordination task (Hessels and Deuten 2013a), so it opted for special temporary coordination structures.

A Committee of Wise Persons (*Commissie van Wijzen*) that reported directly to the government played a crucial role in selecting and monitoring the consortia. This committee was assisted in its task by the Royal Netherlands Academy of Arts and Sciences (on matters of scientific quality) and the Netherlands Bureau for Economic Policy Analysis (on matters of economic relevance). However, the committee did not have standardized criteria, and it evaluated the consortia in a comparative way. Monitoring was based on annual reports and a midterm evaluation of all consortia by the committee.

The temporary nature of the scheme and the unconventional selection and monitoring structure resulted in a large degree of autonomy for the consortia. They were required to provide matching funding and produce an annual review, but the scheme set no guidelines for consortium size, goals, composition or governance form. Moreover, the consortia were not evaluated in terms of organizational aspects such as the division of tasks, responsibilities and power in the consortium. The large degree of autonomy provided us with an interesting research context, with 37 research consortia in the same national, institutional landscape but with a very large variety in terms of their organizational structure (Hessels and Deuten 2013b). Within this context we selected two cases for our comparative analysis.

CcSP was launched in 2004 by Wageningen University and Research Centre (WUR), VU University Amsterdam (VU), the Royal Netherlands Meteorological Institute (KNMI), and the National Institute for Public Health and the Environment (RIVM). NG Infra originated at the Faculty of Technology, Policy and Management (FTPM) of Delft University of Technology (TU Delft) and was closely related to an interfaculty research program on Design and Management of Infrastructures (1998–2003).

CcSP (€80 million) and NG Infra (€40 million) are comparable in size to the other Bsik consortia[7] and are both interdisciplinary consortia dealing with a complex societal problem (respectively, climate adaptation and public infrastructure systems and services). However, while CcSP combines various areas of environmental science, NG Infra focuses on engineering in combination with public administration. Secondly, the main stakeholders engaged in CcSP are governmental organisations, while for NG Infra industry is at least as important. Third, CcSP is based on collaboration between four different organisations, but NG Infra is founded on collaboration within a single organisation. In short, the two consortia represent the potential variety of strategic research consortia in a number of dimensions and thus allowed us to explore the relative importance of the characteristics included in the framework presented in Section 2.2.

7 The total budgets of the two consortia consists of 50% Bsik funding and 50% matching from the members of the consortia.

2.3.2 Data

Before we describe our case studies in more detail in Section 2.4, we should briefly mention our data collection techniques and methodology. The data for the study were gathered via semi-structured interviews and document analysis. The interviews form the core of this analysis and cover the broad spectrum of topics in this study. We carried out 37 interviews with an average duration of 1.5 hours. The interviews were conducted while the programmes were still running (between 2010 and 2011), which implies that their coordination approaches may have changed by the time of publication.

Table 2.2 Overview of interviewees

Programme	Role	Organisation
CcSP (18)	Board & Management (3) Sub-programme leaders (5) Scientists (3) Stakeholders (7)	WUR (4) VU (4) KWR[8], PBL[9], KNMI (1) Ministries (2) Regional authority (3) Consultancies (2)
NG Infra (19)	Board & Management (2) Sub-programme leaders (5) Scientists (2) Stakeholders (10)	TUD (9) Ministries (2) Regional authority (2) Utilities (1) Industry (5)

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The interviewees played various roles in the programmes, ranging from scientific directors to stakeholders. We tried to achieve a balanced set of interviewees for CcSP and NG Infra (see table 2.2). The interviews were fully recorded and transcribed by an external organisation under the supervision of the researchers. The transcribed interviews were subsequently coded using a structured code-book. This codebook was developed on the basis of a theory-driven approach, that is, codes were generated from the theoretical framework as discussed in Sections 2.2.2 and 2.2.3. Following DeCuir-Gunby et al. (2011), we assigned names to codes and gave an explicit description and an example from the interviews for every code. One researcher coded all the interviews. His coding was checked in three ways: first, one of the other researchers coded two randomly selected interviews and compared his results with the coded interviews of the first researcher; secondly, the coding results were discussed at team meetings; and finally, two members of the consortia management boards were asked to check the results of our analysis for factual inaccuracies.

8 KWR Waterrecycle Institute
9 Netherlands Environmental Assessment Agency

In addition, we used information from an internal database based on archives on the Bsik scheme at Agentschap NL (Hessels and Deuten 2013b). This organization played a supporting role in monitoring the consortia, archiving their proposals, annual reports etc. We also analysed programme websites and extensive documentation on both programmes. Finally, thanks to evaluation studies we had rich datasets on the two consortia—including two surveys—that provided valuable background information on the cases (de Jong et al. 2012; Merkx et al. 2012).

2.4 Case characteristics

2.4.1 Internal consortium characteristics

CcSP and NG Infra were created specifically for the Bsik scheme and had no predecessors funded by earlier Dutch funding schemes. Still, the consortia had very different origins. CcSP was based on good contacts between individuals working at WUR and VU, as its scientific director explained. Starting from these informal relationships – which were later expanded to include RIVM and KNMI – a formal consortium of organisations was developed. In the case of NG Infra the main driver was a group of people working at the same organisation (i.e. the FTPM at TU Delft). As explained by a member, this group had built up the new faculty shortly before. Building on these relationships, the group worked as the driving force behind NG Infra, generating ideas for the consortium and formalising its position. As a management board member explained, other organisations were not brought in until later on and on the basis of the group's existing relationships. The proposals of the two consortia show that their initial networks were of a similar size in terms of the number of organisations at the start. CcSP reported 65 partners in its proposal, while NG Infra reported 62 partners. In geographical terms, the proposals show that both consortia are relatively small, as the majority of partners are Dutch. However, NG Infra has a more international character with a number of partners outside the Netherlands (Stichting Next Generation Infrastructures, 2003). There is a difference in the financial scope of the programmes (€80 million for CcSP versus €40 million for NG Infra). Analysis of the compositions of key bodies like management boards confirmed that there was an unequal distribution of power in the consortia. In the case of CcSP, six of the ten board members (two ex-officio) are affiliated to the four initiators of the consortium (WUR, VU, RIVM, KNMI); these four organisations also have a majority in the programme council, with eight out of 13 members; and four of the five theme coordinators are affiliated to the same organisations (Klimaat voor Ruimte, 2007). In the case of NG Infra, two of the five members of the supervisory board are affiliated with the TU Delft; four of the five members of the management board are affiliated with the TU Delft, while all theme coordinators are affiliated with the TU Delft (Next Generation Infrastructures, undated).

2.4.2 Institutional environment

Both consortia are interdisciplinary, in the sense that they combine natural science approaches with social science research. In CcSP various areas of environmental science are combined, ranging from atmospheric science to social geography. NG Infra combines various branches of engineering with fields like complex systems research and public administration. The interdisciplinary profile of both programmes suggests a relatively high degree of strategic task uncertainty, as there is usually much less consensus about intellectual priorities in new interdisciplinary fields than in established disciplines (Whitley 2000). In both cases, the programme opens up a new area of research building on several distinct research traditions. This implies that there is probably no stable research community with widely shared values and common goals as yet.

In terms of publication culture, the emphasis in CcSP seems to be more on the natural sciences and engineering, while NG Infra seems to build slightly more on social science approaches. The members of the scientific advisory boards of the two programmes illustrate this difference.[10] The Scientific Advisory Council of CcSP is geared towards the natural sciences and engineering, with seven natural scientists or engineers (64%) versus four social scientists (36%). The disciplinary backgrounds represented on NG Infra's Scientific Advisory Board (with eight members) are 12% humanities, 25% natural science or engineers, and 63% social science. The stronger natural science and engineering component in CcSP suggests more trust in the validity of bibliometric quality indicators, which would make it easier to steer the programme on the basis of quantitative output criteria.

The institutional setting of the two consortia consists of two groups of organisations, (i.e. academic and stakeholder organisations). In terms of the academic organisations, the programmes were selected in such a way that the most important ones (the consortia founders) have a similar organisational culture. These organisations (WUR Alterra (CcSP), VU Institute for Environmental Studies (CcSP), and TU Delft FTPM (NG Infra)) all have a relatively strong focus on applied research and contract research. The summary of the goals, audiences and dominant output in table 2.3 illustrates this overlap.

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10 This analysis is based on the membership of the boards as presented on the websites <http://climatechangesspatialplanning.climateresearchnetherlands.nl/organisation/international-scientificadvisory-council-%28isac%29> and <http://www.nextgenerationinfrastructures.eu/index.php?pageID=23> both accessed 5 July 2011. Data about individual members were found on the websites of the research consortia, supplemented if necessary with information found on the websites of their main employer. We used education as a first indicator of disciplinary background; if unavailable or unclassifiable we used current research interests; if this information was unavailable we based our classification simply on the current affiliation. Given the interdisciplinary profile of most council members we often had to choose the discipline most clearly visible in their education or research activities.

Table 2.3 Characterisation of the main research organisations involved in CcSP and NG Infra[11]

		CcSP		NG Infra
		Alterra	**IVM**	**TPM**
1	Goals / mission	Research and education to contribute to sustainable environment	Research and education to contribute to sustainable environment	Research and education to contribute to sustainable solutions
2	Audience / stakeholders	Governments; the 'water market'	Governments, firms, NGOs, NWO, KNAW	Firms, public authorities
3	Dominant output	Emphasis on professional publications	Scientific publications	Scientific publications

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When it comes to the other group of important organisations (the stakeholder organisations) there is a clear difference between the two consortia. The stakeholder organisations engaging with CcSP are mainly governmental organisations. These organisations also feature in the institutional setting of NG Infra, but to a lesser extent. Organisations in industry, and especially utilities, are the most important for NG Infra. Analysis of the stakeholder organisations that play a role either on the board or on one of the councils of the programmes confirms this difference.[12] In the case of CcSP, 23 stakeholder organisations play such a role with 56.5% coming from government, 30.4% from industry, and 13.0% from non-profit organisations. In the case of NG Infra, ten stakeholder organisations play such a role with 30% coming from government and 70% from industry.

2.5 Observed coordination approaches

2.5.1 Governance form

To characterise the governance forms of the two cases, we first assessed whether or not governance in the consortia was brokered. The limited number of organisations in the governance bodies (such as the management board and programme council) suggests that the partners do not interact on an equal basis in the consortia. To deal with the large amount of money awarded, both CcSP and NG Infra created a foundation at the Dutch Chamber of Commerce shortly before their programme started, in 2004 and 2003, respectively (see <www.kvk.nl> accessed 20 June 2013).

The four initiators of CcSP signed an official collaboration agreement on 29 November 2004 (Klimaat voor Ruimte 2005). In this agreement, the four

11 Sources: <www.alterra.wur.nl>, <www.ivm.vu.nl> and <www.tbm.tudelft.nl> all accessed 1 July 2011

12 Sources: <www.klimaatvoorruimte.klimaatonderzoeknederland.nl> accessed 21 June 2011 and Annual Report Next Generation Infrastructures 2009 (Next Generation Infrastructures, undated).

organisations explicitly mandated the foundation to coordinate and administer activities within the consortium. This entity is formally and physically separate from the partners. Thus, CcSP neatly fits the description of an NAO governed consortium. The exclusive role of the NAO (Stichting Klimaat voor Ruimte) is to govern and administer the activities of the consortium. As defined in the collaboration agreement, CcSP's NAO has been assigned a relatively large number of staff to perform this role.

The NG Infra consortium also established a foundation to perform coordination activities. In the case of NG Infra, the foundation created an entity that was formally distinct from the FTPM group but in practice (and visibly), the distance is small. A member of the management board explained how the foundation was created:

> *"Eventually when TPM was granted the* [Bsik] *funding* [. . .] *we decided to create a separate foundation to manage the money. However, it was really born from within the faculty'"* (management board member, NG Infra).

The TU Delft, that is the FTPM, is clearly the leading organisation in NG Infra. Because of its administrative and facilitative activities NG Infra fits the description of a LGN. However, NG Infra is not a pure LGN because the establishment of the foundation did create an entity that was formally responsible for managing the funds and the quality of the research.

CcSP and NG Infra can thus be seen in terms of the governance typology as different forms of strategic research consortia. In the next two sections, we shall analyse the differences in their actual coordination approaches. We would expect CcSP (as an NAO governed network) to lean in its coordination approach towards the ideal-type of hierarchy, and would expect NG Infra (as a LGN) to be geared more towards market coordination.

2.5.2 Selection phase

Three main steps can be distinguished in the procedures of both consortia: setting the scene, collecting proposals, and evaluating proposals (see also table 2.4). However, the nature of these steps differed between the consortia. Moreover, the interviews revealed that the main rationale behind the selection procedures of the networks differed significantly. CcSP had opted for a strong top-down approach, while NG Infra had decided on a bottom-up approach.

Table 2.4 Three main steps in selection phase

Procedure	CcSP	NG Infra
Setting the scene	Definition of terms of reference	Issuing of open call
Collecting proposals	Invitation to potential participants	Screening phase (i.e. contact between candidates and programme)
Evaluating proposals	Scientific and societal review	Scientific and societal review

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The interviews on CcSP indicated that the consortium had started with a very clear vision of the form and content of its activities. Consequently, the selection procedure had a relatively strong hierarchical character. The main rationale behind this approach was clearly expressed by the scientific director of the consortium:

> *"If you want to build a house from dozens of products, you have to make sure that those products contain elements which can be combined"*
> (scientific director, CcSP).

The first step in the selection procedure for CcSP was therefore to establish terms of reference. The consortium management (representing the NAO) set out in these terms of reference what they wanted to achieve with a certain project. In some cases potential project leaders were invited to comment on the terms of reference. Once the board had approved the terms of reference, the road was clear for an actual proposal to be submitted. This first step enabled the consortium management to keep a firm grip on the form and content of the project proposals.

After the terms of reference were defined, the consortium management approached potential project leaders. So instead of issuing an open call, the network opted for a more top-down approach in this step. The way this step worked in the CcSP case comes close to the ideal-type of network coordination (see table 1). The consortium directors and theme coordinators selected candidates from within their own network, based on trust. As one theme coordinator explained, they searched for individuals who were known to be able to handle such a project in both intellectual and managerial terms.

The third main step was a review procedure including both a scientific and a societal component. In CcSP, these two reviews were performed separately. The scientific review was performed along conventional lines. All proposals were sent to the Dutch Research Council (NWO) for academic peer review. For the societal review the consortium management selected societal actors with a possible interest in the outcomes of the study. So in the case of a study on (and with) a certain municipality, the management sent the proposal to policy-makers at another municipality with similar problems.

In contrast to the relatively hierarchical approach at CcSP, NG Infra took a bottom-up approach to selecting new projects and people. At the launch of the consortium, a group of people working at the FTPM drafted a proposal for the programme. The proposal consisted of an initial six sub-programmes and it formulated key questions, thus defining the main direction in a top-down manner. However, as one theme coordinator explained, the questions were worded in an abstract way, leaving enough room for interpretation and creativity in project proposals. The idea behind the relative freedom in the project was clearly described by one of the theme coordinators:

> *"We have never made the step to becoming really directive towards the projects. That just won't work. These projects are written from a certain vision, from a context"* (theme coordinator, NG Infra).

This characteristic of the selection procedure is most visible in the first step of selection, the decision to rely on open competition. The consortium directors made the decision to use open calls to see what themes merged from the wider national and international scientific community. By relying on this market approach, the network directors tried to harvest as much creativity as possible. In a later phase of the network, it was decided to also issue targeted calls. By adding these to the existing open calls, the consortium was able to bring some focus to its project portfolio.

Between the open call and the review of proposals there was a period in which aspiring project leaders and the consortium liaised on the content of the proposal. In this screening period, the NG Infra management was able to steer the direction of the project. One theme coordinator referred to this as a period of 'invisible steering'. This comment makes it clear that in this phase of the selection procedure freedom for the individual project was important, but that the consortium also tried to coordinate the content of the various projects.

As in the case of CcSP, proposals were reviewed in terms of both scientific and societal aspects. The scientific review was performed by an international scientific advisory board. However, the societal aspects received less attention than in the case of CcSP. NG Infra did not organise an external review for the societal aspects of the proposals. The societal review consisted of a check on letters of commitment by the management to see whether the stakeholders were actually committed to a project proposal.

A comparison of the selection procedures of the two strategic research consortia shows two important differences between them. First, CcSP took a relatively hierarchical approach, starting with a clear vision of the form and content of the programme, while NG Infra tried to facilitate as much creativity as possible by taking a bottom-up approach to selection. Secondly, the selection mechanism of CcSP corresponds with the theoretical notion of network coordination while NG Infra relied on a market-like selection mechanism.

2.5.3 Implementation phase

After the selection of projects and project members, coordination focused on the implementation of the actual research activities. We compared the governance coordination approaches of the consortia in terms of their resemblance to ideal-typical coordination attributes (see table 2.1). The comparison will show that the consortia also differ in terms of these attributes (see also table 2.5).

Table 2.5 Use of governance coordination attributes

Attribute	CcSP	NG Infra
Contracts	Moderate	Moderate
Incentives	Weak	Strong
Control mechanism	Strong	Weak
Informal agreements	Weak	Strong

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The coordination approach taken by CcSP in the implementation phase relied mostly on control mechanisms and, to a lesser extent, on formal agreements in contracts. This choice can be illustrated by the following quote from the scientific director, which highlights the downside of a market approach in this phase:

> *"People have to understand that it is about the programme. Not about that project which happens to be their project. That is a big problem with these Bsik programmes. It all falls apart the moment the money has been allocated"* (scientific director, CcSP).

He believes CcSP did not 'fall apart' thanks to close interaction between projects and the management office. As mentioned above, the collaboration agreement between the partners (that established the NAO) stated that a relatively large consortium management office would be established. This enabled the consortium to apply strict control mechanisms. Scientific project companions played a key role in monitoring the progress of the projects. Each project was assigned to a project companion who worked for this separate entity and was well informed about the progress and content of the project. It was also the project companion who raised the difficult questions:

> *"The role of the project companion was partly administrative, but he also raised questions with project leaders like 'you promised us this and that, but did you actually do it?'. Sometimes it was clear, but in other cases it brought to the surface where work had actually been done to achieve certain promises"* (theme coordinator, CcSP).

Incentives and informal agreements did not play a large role in CcSP's coordination approach. The network opted for large-scale projects (minimum of €1–1.5 million) and allocated most of its funding at the start of the actual activities. One consequence of this decision was that little money was left to create additional incentives that would work as a coordination mechanism during the implementation phase. The consortium was not able to steer itself in new directions by rewarding new, innovative suggestions. Various interviewees remarked that the consortium did not have enough flexibility later in its life cycle to respond to new questions in its environment.

In contrast with CcSP, control mechanisms played only a marginal role in the coordination approach adopted by NG Infra. This relates to the dominant position of the FTPM and a conscious decision to only set up a small management office, in order to reserve as much funding as possible for research projects. This made it difficult for the management office to monitor and evaluate the progress of projects very strictly. It should be noted that some theme coordinators did try to exercise control over the progress and content of the projects. In the absence of a general framework with for example explicit milestones, these attempts mainly used soft control mechanisms. One of the coordinators remarked:

> *"It is not that we have these milestones of which we can say: 'now we shut off the money flow, or you have to stop with the project'. The only thing we can do is encourage, stimulate, and bring people together"* (theme coordinator, NG Infra).

The dominant position of the FTPM enabled the management and theme coordinators to use informal agreements to keep a grip on the research activities. As one coordinator explained, a sort of 'gentlemen's agreement' based on trust with project leaders at the FTPM gave NG Infra's management some influence over activities. Finally, formal contracts were signed with participating organisations, but the interviews indicate that these formal contracts have not been applied in the consortium's coordination approach.

NG Infra's management used its control over funding to actually steer the programme in new research directions. The NG Infra management board decided at an early stage to spread the allocation of its funding over several years. The rationale behind this decision was that the relatively long lifetime of the consortium made it impossible to predict what all the relevant questions would be. So the NG Infra management set aside part of its money to use as incentives for new projects. Using this market-like mechanism, NG Infra was able to revamp its programme on several occasions.

2.6 Explaining differences in coordination approach

Our comparison of the coordination approaches of CcSP and NG Infra shows striking differences. CcSP, an NAO governed consortium, relied predominantly on hierarchical coordination attributes combined with some network attributes (especially in the selection phase). NG Infra, resembling the lead organisation governance model combined market attributes (open competition and incentives) with network coordination attributes (informal agreements). Since both operate within the same policy framework, their differences provided an excellent opportunity for us to gain an understanding of how consortia develop a coordination approach. Thus, we now explore those characteristics of the consortia that may have influenced the development of their coordination approaches.

The first possible explanation concerns the influence of the cognitive characteristics of the consortia. We expected that the stronger natural sciences background of CcSP would imply a lower level of strategic task uncertainty and a greater emphasis on publishing in scientific journals. The interviews showed, however, that this assumed difference did not exist. Both networks turned out to be highly interdisciplinary and in both cases strategic task uncertainty appeared to be relatively high. In both consortia the emphasis on publishing was felt to be an obstacle to science–society collaboration, but it was perceived as a surmountable obstacle. The similarity in these cognitive characteristics between the two consortia rules them out as a possible explanation for the differences in coordination approaches.

The second possible explanation concerns the influence of isomorphic pressures from important stakeholders. The key stakeholders for CcSP were governmental organisations, while NG Infra's key stakeholders were businesses and utilities. A superficial look at the consortia suggests that this might have influenced their coordination approaches. For example, the relatively strict hierarchical organisation of CcSP resembles the bureaucratic nature of its most important, governmental, stakeholders. The interviews with consortium directors did not, however, indicate that the consortia had mirrored themselves on their stakeholders. Moreover, it turned out that stakeholders only really became influential after a critical midterm review, by which time the coordination approaches of the consortia had already been defined.

A third possible explanation lies in the internal consortium characteristics. As described above, the consortia had different histories and different distributions of power. CcSP was based on good contact between people working at four different organisations, who acquired central positions in bodies such as management board and council. Analysis of the CcSP-project database shows that these organisations (especially WUR and VU) also provided a large share of participating researchers (see <www.klimaatonderzoeknederland.nl/projecten/projectendatabank> accessed 05 July 2011). NG Infra was initiated by a group of people within one organization (TU Delft), which strongly dominated the consortium and supplied almost all management board members and theme coordinators. Half of the NG Infra funding was allocated to researchers at TU Delft's FTPM (Next Generation Infrastructures, undated).

It appears that these organisational characteristics also influenced the governance form and subsequently, the coordination approaches of the consortia. In the case of CcSP, the people who launched the consortium worked at four different organisations, so their collaboration required the establishment of an NAO with an explicit description of its size, tasks and responsibilities. The people who started NG Infra all worked at TU Delft, which gave this organisation a lead role in the consortium.

These differences partly explain the different approaches in the selection phase. The top-down approach of CcSP is in line with the agreements made between the four partners. The NAO subsequently played an important role in implementing the selection procedure. The use of open calls in the case of NG Infra is in line with the leading role of TU Delft. The proposal of NG Infra reflects the leading role of the TU Delft in this respect:

> *"The TU Delft cannot realize the full ambition of the Next Generation Infrastructures initiative without involvement of new disciplines and without active involvement of practitioners for access to empirical data and tacit knowledge in the infrastructure sectors"* (Stichting Next Generation Infrastructures, 2003).

By taking the lead in the proposal and being granted the funding, the TU Delft was able to bring in partners and build a consortium to realize the ambition of the initiative that was rooted in its interfaculty research programme. However, it is important to note that the members of the management board emphasized that they used an open call approach because they were convinced that it enable them to harvest as much creativity as possible (see also Section 2.5.1).

The different distributions of power and the consequences described above resulted in two different approaches in the implementation phase. Because different organisations were expected to work together, the preparation phases for projects were longer and more explicit:

> *"With most of these projects you had to deal with multiple organisations. In the end, they all had to put their signature to a contract. They all have to agree and give approval. They all have to commit themselves and promise for example to provide matching funding"* (theme coordinator, CcSP).

The project companions at the NAO used the agreed milestones to monitor the progress of the projects and to exert control over them:

> "[Monitoring] *occurred on the basis of those milestones. Not in the sense that you threatened to cut off the money flow if a milestone was missed. But it was used as an instrument to check whether a project was still on track"* (theme coordinator, CcSP).

At NG Infra the implementation phase has been characterised by a combination of two different coordination attributes. On the one hand, the directors, coordinators, and TU-related project leaders know each other very well, resulting in coordination by informal agreements.

> *"What we see at present is that outside parties deliver reports far more conscientiously. For them the programme is an entity that makes certain demands about project progress while people at the faculty think: oh well, he's a friend, so it will be fine if . . ."* (theme coordinator, NG Infra).

On the other hand, however, NG Infra had decided to spread the allocation of funding. In the implementation phase of the consortium, as described above, it used this funding to fill any gaps in the research. By setting out targeted calls and providing funding, it was able to bring organisations that could perform such specific research activities into the consortium.

2.7 Conclusions and recommendations

Strategic research consortia as a policy instrument for research coordination have been on the rise for more than a decade (Potì and Reale 2007). A systematic comparison of the actual coordination approach of two Dutch strategic research consortia shows that such 'delegation to networks' is not an undifferentiated form of coordination. We identified two different dominant governance forms in our case studies, i.e. an NAO governance form (CcSP) and a lead organisation governance form (NG Infra). As theorised, our comparison revealed considerable differences between the cases' coordination approaches CcSP relied more on hierarchical coordination attributes (i.e. top-down programming and control mechanisms), while NG Infra's coordination approach relied on market attributes (open competition and incentives). However, it is important to note that the coordination approaches of both consortia also included other coordination attributes.

Internal consortium characteristics appear to have the greatest influence on the coordination approach of the consortia. We found various indications that the consortia's network compositions at the outset influenced the coordination approach. The cooperation between different and equal partners in the case of CcSP triggered the establishment of an independent NAO with formal agreements and an explicit allocation of tasks. The dominant position of TU Delft in the NG Infra consortium made it an obvious lead organisation that was able to use its funding to steer research activities, rather like a research council. The shared history of a group of people within the same faculty subsequently resulted in an informal character and the high level of trust among NG Infra participants led to gentlemen's agreements and soft control mechanisms.
CcSP and NG Infra were both successful strategic research consortia and were positively evaluated by the Committee of Wise Persons. Our study confirms, however, that the Bsik funding scheme provided insufficient guidance and requirements to individual consortia (Hessels and Deuten 2013b). Without such

guidance, strategic research consortia develop divergent coordination approaches. These findings have important policy implications, because such coordination approaches do not necessarily reflect the policy goals behind the implementation of strategic research consortia. After all, strategic research consortia are often introduced on the basis of the rationale that they are the best means to harvest the expertise, diversity and creativity of the (research) community. LGNs and NAOs are not necessarily in contradiction with this idea, but might develop particular coordination approaches that are.

Our findings suggest that policy-makers should stipulate requirements that safeguard the openness of consortia, in two different dimensions. Consortia with internal characteristics that reflect the diversity of a network's community are the first candidate to benefit from funding support. In the case that parts of the community are not willing or are unable to participate fully in the consortium, consortia are vulnerable to becoming vehicles for the interests of one dominant partner (LGN) or a clique of dominant partners (NAOs). In these cases, only consortia that have organised supportive arrangements to include the full network's needs should benefit from funding support. Finally, openness also has a temporal dimension. Policy-makers should demand phased and flexible funding to allow a consortium to react to unforeseen developments while safeguarding outcomes.

Since this paper is one of the first to investigate the actual coordination practices of strategic research consortia, we approached our research questions with a comparative case study which enabled an in-depth analysis of the causal relationships that lead to a certain coordination approach. Given the inherent limitations of this research approach we close with some suggestions regarding the generalisation of our findings. First, because CcSP and NG Infra were both interdisciplinary and had a high level of task uncertainty, the potential influence of cognitive characteristics may have been suppressed in our analysis. Similarly, the influence of institutional characteristics might be greater in other cases. After all, the dominance of academic research organisations in both programmes limited the influence of important stakeholder organisations. Finally, the national context may play an important role in shaping a consortium's coordination approach but this has not been tested because of our empirical focus on the Netherlands. Further research on network programmes in different scientific fields, with different stakeholder relationships and other national contexts, is needed before general conclusions can be drawn about the decisive factors that shape research coordination in strategic research consortia.

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3 Differences between LCA for analysis and LCA for policy: a case study on the consequences of allocation choices in bio-energy policies[13]

Abstract

Purpose The increasing concern for adverse effects of climate change has spurred the search for alternatives for conventional energy sources. Life cycle assessment (LCA) has increasingly been used to assess the potential of these alternatives to reduce greenhouse gas emissions. The popularity of LCA in the policy context puts its methodological issues into another perspective. This paper discusses how bio-electricity directives deal with the issue of allocation and shows its repercussions in the policy field.

Methods multifunctionality has been a well-known problem since the early development of LCA and several methods have been suggested to deal with multifunctional processes. This paper starts with a discussion of the most common allocation methods. This discussion is followed by a description of bio-energy policy directives. The description shows the increasing importance of LCA in the policy context as well as the lack of consensus in the application of allocation methods. Methodological differences between bio-energy directives possibly lead to different assessments of bio-energy chains. To assess the differences due to methodological choices in bio-energy directives, this paper applies three different allocation methods to the same bioelectricity generation system. The differences in outcomes indicate the importance of solving the allocation issue for policy decision making.

Results and discussion The case study focuses on bioelectricity from rapeseed oil. To assess the influence of the choice of allocation in a policy directive, three allocation methods are applied: economic partitioning (on the basis of proceeds), physical partitioning (on the basis of energy content), and substitution (under two scenarios). The outcomes show that the climate change score is assessed quite differently; ranging from 0.293 kg to 0.604 kg CO_2 eq/kWh. It is argued that this uncertainty hampers the optimal use of LCA in the policy context. The aim of

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policy LCAs is different from the aim of LCAs for analysis. Therefore, it is argued that LCAs in the policy context will benefit from a new guideline based on robustness.

Conclusions The case study confirms that the choice of allocation method in policy directives has large influence on the outcomes of an LCA. With the growing popularity of LCA in policy directives, this paper recommends a new guideline for policy LCAs. The high priority of robustness in the policy context makes it an ideal starting point of this guideline. An accompanying dialog between practitioners and commissioners should further strengthen the use of LCA in policy directives.

3.1 Introduction

The increasing concern for possible adverse effects of climate change, has spurred the search for alternatives for conventional energy production systems. Biomass based energy (fuel, heat and electricity), or bio-energy, has in this respect been promoted as a promising alternative. Bio-energy is believed to be more sustainable than the conventional energies obtained from fossil fuels (Chum et al. 2011).

Moreover, it is believed that bio-energy increases countries' energy security and to create opportunities for rural development. As a consequence bio-energy is stimulated via environmental and energy policies in both developed and developing countries (Worldwatch Institute 2007; United States Department of Energy 2010; Van der Voet et al. 2010).

Despite these advantages, bio-energy is increasingly linked to adverse effects on the environment and on society. Questions have been raised with respect to impacts on food, land and water availability (Bindraban and Pistorius 2008; De Fraiture et al. 2008). Another criticism concerns the alleged impacts on land use changes and the destruction of tropical rain forest (Searchinger et al. 2008). Also the presumed reductions in greenhouse gas (GHG) emissions are questioned (Reijnders and Huijbregts 2008). In a response to these more critical stances to bio-energy, governments have introduced directives with the intention to stimulate sustainable bio-energy (SenterNovem 2008; UNEP 2009). Life cycle assessment (LCA) plays an important role in these directives and it often serves as the main tool to assess alternative energy production systems' reductions in GHG emissions. In this way, policymakers are faced with methodological decisions central to LCA, e.g. with respect to the allocation method. This article reviews various bio-energy directives and discusses how their differences with respect to the recommended allocation methods may influence the assessment of bio-energy systems. It does so in order to stimulate the discussion on distinguishing LCAs for the purpose of analysis (finding hotspots, monitoring, process optimization, etc.) and LCAs for policy purposes (banning, subsidizing, certifying, etc.).

This paper is organized as follows. Section 3.2 sketches the issues of allocation and how it has been dealt with in policy guidelines on bio-energy. Section 3.3 describes a case study on electricity with rape seed, using several allocation principles. Sections 3.4 and 3.5 discuss and conclude.

3.2 Allocation: practice, policy and problems

3.2.1 Allocation methods

During the inventory phase of an LCA the problem of multifunctional processes, and thus of allocation, is often encountered. Following Guinée et al. (2002), a multifunctional process is considered as "*a unit process yielding more than one functional flow, i.e. co-production* [more than one product outflow], *combined waste processing* [more than one waste inflow] *and recycling* [one or more product outflows and one or more waste inflows]".

Multifunctional processes are a problem for LCA because usually not all the functional flows are part of the same product system. Thus, a multifunctional process is part of the product system studied and also of other systems. The question is then, how to allocate the environmental impacts of this multifunctional process to the different product systems, i.e. to the different functional flows.

The LCA community has come up with various ways to address the multi-functionality problem. The on-going debate on allocation triggers the question whether there actually is a 'correct' way to address this problem. It can be argued that by focusing on the physical relationships behind the process this question can be answered positively. However, this argument has so far not been able to bring the allocation debate to an end (see also Weidema et al., 2010 for a summary of recent discussions on allocation). Three types of reasons for this can be identified; 1) there are always various physical relationships to choose from for a multifunctional process, 2) different co-products can be expressed in different physical quantities (e.g., mass and energy), and 3) physical relationships don't necessarily reflect properly the ground for existence of a process (like mass for processes co-producing medicines in small amounts and fodder in big amounts).

In this article, the on-going debate on allocation is seen as a sign that the question above should be answered negatively. It follows in this respect the assertion of Guinée et al. (2004) that "the multi-functionality problem is an artefact of wishing to isolate one function out of many. As artefacts can only be cured in an artificial way, there is no 'correct' way of solving the multi-functionality problem, even not in theory." The most frequently used methods to solve this problem are shortly introduced below. The introduction discusses not only the rationales behind the methods, but also discusses their advantages and flaws:

Subdivision: disentangling a process that has been recorded as a multi-functional unit process into the constituent mono-functional unit processes;

System expansion: avoiding the multi-functionality problem by broadening the system boundaries and introducing new processes and several functional units;

Physical partitioning: the artificial splitting up of a multifunctional process into a number of independently operating mono-functional processes, based on physical properties of the flows (e.g. mass, energy, carbon content, etc.);

Economic partitioning: the artificial splitting is based on economic properties of the multifunctional process, such as the gross sales value or the expected economic gain.

In order to come to a standardization of LCA, ISO introduced a hierarchical approach for dealing with multi-functionality. The ISO 14044 allocation procedure (clause 4.3.4.2) prescribes subdivision or system expansion as a first step in order to avoid actual allocation. In case allocation cannot be avoided ISO prescribes physical partitioning as a second step. The procedure emphasizes that this type of partitioning should reflect the underlying physical relationship between the different products or functions. As a third step, when physical partitioning cannot be established, ISO prescribes allocation in a way that reflects another (e.g. economic) relationship between the different products or functions (ISO 14040, 2006).
In addition to these allocation methods mentioned in the ISO standard, there is the often used approach of substitution:

> *Substitution*: the concept behind substitution is that the production of a co-product by the system studied causes another production process in another system to be avoided. This avoided production process results in avoided emissions, resource extractions etc. that should be subtracted from the studied product system.

Several authors have argued that substitution is conceptually equivalent to system expansion (e.g. Ekvall et al., 1997; Finnveden et al., 1998). Conceptually equivalent does not mean that system expansion and substitution provide the same results, but that they provide results that are compatible.[14] The two allocation methods share subsequently some advantages and disadvantages. Both methods, for example, increase the level of complexity by adding extra processes, either to be added, or to be subtracted. A consequence of the conceptual equivalency between the two approaches is that it is used as an implicit argument to choose for substitution, while still claiming compliance to ISO.

14 In order to compare System I that produces products A and B simultaneously with System II that produces product B, it is the same to add to System II the production system of product B (system expansion) or to subtract from System I the same production system (substitution).

It is important to note, however, that there are also large differences between these methods. An important drawback that is particular for system expansion concerns the fact that the system provides more than one function, so that a multiple functional unit is used. It can be questioned whether an LCA that aims at studying the environmental burdens of one specific function, achieves this aim when it gets an answer for several functional units. Drawbacks specific for substitution are related to the various assumptions that have to be made. For example, it has to be argued which production process is actually avoided.

Physical partitioning is one of the simplest allocation methods to apply, and if one carefully chooses the physical characteristic used as basis for the method, it is quite straightforward to apply. However, determining the physical characteristics to be used as a basis for allocation can be challenging. Potentially relevant characteristics should relate to the purpose or use of the product. But co-products often have different purposes (or uses) and thus different characteristics may be relevant in understanding why they are sold. In many cases the LCA practitioner can overcome this problem by selecting a physical characteristic that make sense for both product and co-product. However, such a common denominator cannot always be identified e.g., a system that produces both meat and leather, or a waste incinerator that fulfills the function of waste processing and the function of energy production.

Economic partitioning is another often applied allocation method. By taking the economic value of different processes as a basis for allocation, economic partitioning addresses the economic motivation behind a multi-functional process. While some practitioners see this as a strength, it can also be seen as the main drawback to economic partitioning. Another argument against economic partitioning is that prices can fluctuate independently from the long term economic value of a process. Also the fact that prices can vary between different locations is sometimes seen as a disadvantage of economic partitioning (Ayer et al., 2007).

3.2.2 Allocation in policy guidelines

Early political visions included high level of biofuel incorporations into transport fuels with no restrictions of origin or production pathways (CEC, 2007). However, in a response to the more critical stances to bio-energy, governments have introduced directives with the intention to stimulate *sustainable* bio-energy only (RTFO, 2007; Directive 2009/28/EC, 2009; LCFS, 2007; EPA, 2010). LCA plays an important role in these regulations as it often serves as the main tool to assess alternative energy production systems' reductions in GHG emissions.

The European Union and the United States have led the way in using LCA in regulatory schemes. The first schemes appeared in individual European Member States. The UK implemented the Renewable Transport Fuel Obligation (RTFO) in 2007, which requires transport fuel providers to report the sustainability level of the fuels provided in the UK (RTFO, 2007). For the GHG criterion, the scheme required that reporting parties calculate the carbon intensity of their fuel based on a specified LCA methodology, including using a "restricted" substitution method for allocation. The RTFO restricted the substitution method by only allowing some uses for specific co-products (e.g., rapeseed cake could only be used for animal fodder). However, for certain chains, it was not possible to identify the use of the co-product. In these cases, economic partitioning was used, as it was felt to be the closest allocation method to substitution (RTFO, 2007).

Having set ambitious targets for the use of biofuels in Europe (10% renewable in the transport sector by 2020 (CEC, 2007), the European Commission published, in 2009, a directive with the goal to ensure the sustainability of biofuels and bioliquids (Directive 2009/28/EC, 2009). The Renewable Energy Directive (RED) defines a minimum threshold for GHG emission savings that must be achieved by bio-fuels to be considered renewable energy. The calculation methodology for GHG savings is also defined in the directive. The directive imposes to use energy content as basis for allocation, except for electricity that is co-produced with biofuel or bioliquid, and which, under certain conditions, should be allocated applying substitution (Directive 2009/28/EC, 2009). As a European directive, the RED will be transposed into national legislation in European member states. In case of the UK this means that the guidelines of the RED are being implemented in the RTFO.

Table 3.1 *Overview of bio-energy directives*

Legislation	Region covered	Allocation method
Renewable Transport Fuel Obligation	United Kingdom	Substitution whenever possible, if not allocation based on economic value
Renewable Energy Directive	European Union (all 27 Member States)	Allocation based on energy content except for electricity co-production for which it is substitution
Low Carbon Fuel Standard	California	Substitution whenever possible, if not allocation based on energy content
Renewable Fuel Standard 2010	United States of America	Substitution

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The US have also recently seen the development of two schemes regulating the GHG emissions of their transport fuel. The first, the Low Carbon Fuel Standard (LCFS, 2007), was set in place in California. This scheme defines an average maximum carbon intensity target for the mix of transportation fuels used in California. Transport fuels that have lower carbon emissions than the target are awarded credits, which they can sell to compensate fuels that are too carbon intensive. The credits and debits are awarded based on the life cycle GHG emissions of transportation fuels. The LCFS requires substitution to be used as allocation method (LCFS, 2007). However, in practice some chains use physical partitioning on the basis of energy content (CEPA, 2009).

A federal regulation is also under preparation in the USA, the Renewable Fuels Standard 2010 (EPA, 2010), which requires the U.S. EPA to calculate the carbon intensity of the biofuels becoming available most likely in the USA. EPA's results will then be used to classify the fuels into four different categories (cellulosic biofuel, biomass-based diesel, advanced biofuel and renewable fuel), which each have different volume targets. EPA performed their LCA calculations applying a substitution method in case of multi-functional processes.

3.2.3 Discussion

The schemes presented in this section are not only distinguishable by their geographical scope. Their reporting requirements have led them to implement different allocation methods. Most European schemes require industries to calculate and report their GHG emissions themselves, so the allocation methods applied have to be simple. And indeed, even the RTFO only employs a "restricted" substitution. In the American schemes, calculations are performed with support of given default values that industries have to use. These default values can only be changed under specific conditions, and only by the scheme's implementation body. Therefore, the American schemes can use somewhat more complex allocation methods.

This diversity in reporting requirements is confusing for bio-energy producers and users. As most modern markets, the bio-energy market has a global character and consists of international actors and relationships. Moreover, the use of different allocation methods in different schemes is not only confusing but also disturbing. After all, different allocation methods potentially lead to different assessments of a single bio-energy stream (Kim et al., 2002; Wang et al., 2004; Guinée et al., 2007; Thomassen et al., 2008; Bier et al., 2011). To assess whether it can be expected that the different requirements in the schemes above result in different assessments, they are applied on a case study below. To serve its purpose of illustration, a real life case study has been selected that is relatively simple and straightforward, focusing on GHGs only and leaving out of the analysis other impacts (including direct and indirect land use change that may obviously be an important issue) and further methodological discussions. In this way, the case serves as a suitable test on whether the problem is real or only hypothetical.

3.3 Case study on rapeseed

3.3.1 Goal and scope

The discussion above shows that different countries promote different guidelines with respect to addressing multifunctional processes. The goal of this LCA study is to assess the influences of the choice of allocation on the outcomes of an LCA. Previous studies have already used a similar approach using a hypothetical case (Guinée et al., 2009; Luo et al., 2009). In the present study the allocation methods are applied on an existing bio-electricity chain. The chain selected is the rape-seed to bio-electricity chain.

The electricity production for the Dutch mix was used as a reference chain and renewable energy resources were not considered to contribute in this mix. This comparison took place only for one impact category: Climate Change.

The selected functional unit for the case study was: The production of 1kWh low voltage electricity at the Dutch grid. For the case study main data sources were Hamelinck et al. (2008) and Van der Voet et al. (2008). To check data from these sources and when additional data was needed the ecoinvent database was consulted, especially for agriculture (Nemecek et al., 2000). The CMLCA 5.0 software, accessed via www.cmlca.eu, was used as a calculation platform.

3.3.2 Life Cycle Inventory Analysis

The chain consists of five main life cycle stages: the feedstock production, the feedstock transport, the conversion, the oil transport and the electricity generation. For the *system boundaries definition*, two main assumptions were made:

1. A distinction between "negative" and "positive" CO_2 emissions. All CO_2 emissions from the feedstock production phase (rapeseed cultivation) were considered (positive) emissions to the environment, while CO_2 fixation in the same phase was considered a negative emission (or extraction from the environment). For all other emission, this distinction was not made and the carbon emissions are still accounted for (including that released upon combustion).

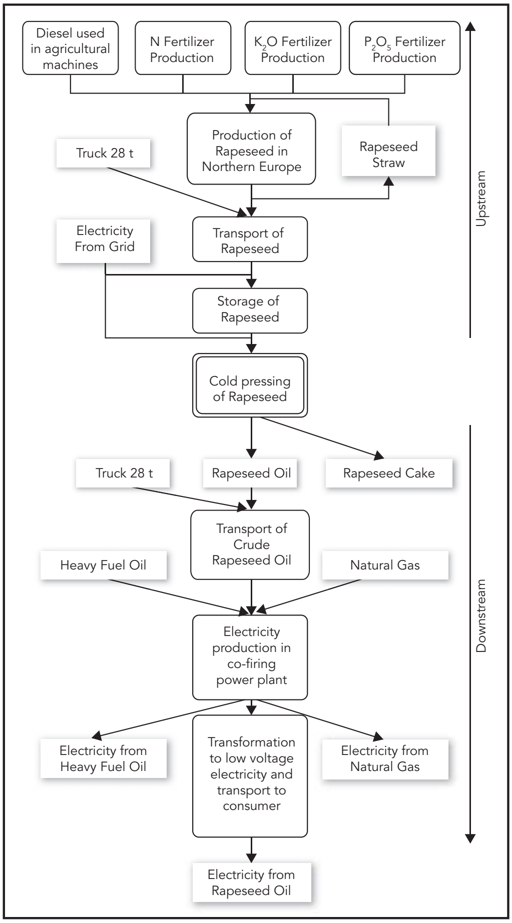
2. Emissions from electricity production are included as well as emissions from the production of input materials and energy to all other processes (e.g. fertilizers production, electricity used for conversion processes, among the main ones).

The *flow diagram* in figure 3.1 provides an outline of all the major unit processes in the system. The flow diagram is based on the flow diagrams of Hamelinck et al. (2008) and of van der Voet et al. (2008). It is remodelled and specified for the present case study.

It was assumed that rapeseed is cultivated and produced in Northern Europe as well as it was assumed that the rapeseed straw generated during the harvesting process is ploughed back to the ground replacing part of the nitrogen fertilizer. The rapeseed is then transported to the conversion plant where the oil will be extracted. The estimated requirement for this transportation is 150 tkm (tonne-kilometres) within the Netherlands or between Germany and the Netherlands.

Once the rapeseed is at the conversion plant, two main processes take place in order to extract the oil: 1) storage and 2) cold pressing of the rapeseed. Out of the pressing process two products are obtained: the rapeseed oil and the rapeseed cake. This was the process for which the multi-functionality problem was solved by applying the different allocation methods. Hence special focus is given to this process. Afterwards, the oil is transported from the conversion plant to the power plant where it is combusted in order to produce electricity. It was estimated again that transportation requirements were 150 tkm. Co-firing with heavy oil and natural gas was the chosen technology in the chain for the bioelectricity generation process. This process involves also another multi-functionality problem due to the three economic inflows it has (heavy oil, natural gas and rapeseed oil). In order to concentrate on the multi-functionality problem from the conversion process (pressing process), the energy production was allocated on the basis of the energy content: 37% to the rapeseed oil, 37% to the natural gas and 46% to the heavy oil. Two more processes take place in order to deliver the electricity to the consumer: the conversion of the electricity produced from high voltage to low voltage and the transportation of the electricity to the consumer.

Figure 3.1 Flow Diagram Rapeseed to Electricity Chain



Source: Hamelinck et al. (2008), van der Voet et al. (2008)

Since the core point of the case study is to analyze the difference in the results when using different allocation methods, the allocation methods used in the bio-energy directives were applied to the multifunctional process in the conversion phase (pressing process). The *allocation methods* applied were thus: substitution, physical partitioning (on the basis of energy content) and economic partitioning (on the basis of proceeds).

As mentioned above, a difficulty for the substitution method is to determine which product is replaced by the co-product of the studied system. The case study includes two alternative cases of substitution: 1) substitution of soybean meal and 2) substitution of peas.

In the case of substitution of soybean meal a loop is created: soybean meal is obtained together with soybean oil and soybean oil substitutes rapeseed oil. To deal with such a loop practitioners can rely on two different approaches. First, ignore the fact that soybean meal and oil are coproduced and close the loop by including soybean meal alone. Second, extent the system by including the co-produced soybean oil and apply a form of partitioning. The use of the first approach implies a less realistic assumption, as these products are indeed co-produced. The use of the second approach is simpler and more realistic and still serves the illustrative purpose of the case study. Therefore, the second approach was chosen and economic partitioning was applied to the extraction process when substituting with soybean meal. It should be noted however that this is a simplification of the substitution method.

Therefore an alternative – and less realistic – case of substitution of peas has been added. This application is straightforward as peas production is not associated with any co-products requiring allocation. The substitution in terms of protein can be considered as a simplification but it serves the illustrative purpose of the case study and is in line with energy policies.

The resulting substitution ratios are shown in table 3.2. They are calculated based on the protein content of rapeseed cake, soybean meal and peas (Brookes, 2001; Corbett, 2008).

Table 3.2 Substitution ratios

Substituted Product	Protein content (mass %)	Substitution Ratio (Rape./Subs.)
Soybean meal	45%	0.75
Peas	24%	1.5

Table 3.3 shows the allocation ratios used for the partitioning methods.

Table 3.3 Allocation ratios used in case study

Method	Rapeseed Oil	Rapeseed Cake
Economic partitioning	0.70	0.30
Physical partitioning	0.55	0.45

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With the allocation ratios, it is possible to allocate the burdens (emissions to air) between the rapeseed oil and rapeseed cake from the pressing process.

Table 3.4 Partial inventory table for upstream part of bio-electricity chain

Elementary flow	Upstream emission to air (kg CO_2-eq)
Carbon dioxide	0.246
Nitrous Oxide (N_2O)	0.00199
Methane	0.000324

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The emissions generated in processes taking place before the pressing process (i.e. upstream of the multifunctional process), are the ones allocated to the two products that result from pressing rapeseed (i.e. rapeseed oil and rapeseed cake) with the different allocation ratios from different allocation methods. The downstream emissions (those being emitted in processes after the pressing process) correspond to the total emissions of the chain calculated with a surplus method and subtracting the upstream emissions. The upstream and downstream emissions are shown respectively in table 3.4 and 3.5.

Table 3.5 Partial inventory table for downstream part of bio-electricity chain

Elementary flow	Downstream emission to air (kg CO_2-eq)
Carbon dioxide	0.012
Nitrous Oxide (N_2O)	0.00
Methane	0.000019

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3.3.3 Life Cycle Impact Assessment of the Case Study

The only impact category analyzed was the climate change category. The inventory results of GHG emissions to air in kg were transformed to kg of CO_2 equivalents. The Global Warming Potential for a 100-year time horizon (GWP100) developed by the Intergovernmental Panel on Climate Change (IPCC) was used as the characterization factor (IPCC, 2007).

The climate change profile obtained for the rapeseed oil to bioelectricity chain by using different allocation methods is shown in table 3.5. The results are compared to a reference chain and the improvement is also calculated. The reference chain is the Dutch production mix based on fossil fuels and nuclear energy (Van der Voet et al., 2008). The composition of the Dutch electricity mix is given in Table 3.6 (Seebregts et al., 2005; CBS, 2007):

Table 3.6 Reference chain: Dutch electricity mix

Source	Mix (%)	Efficiency (%)	Remark
Natural gas	52.0	43	
Hard coal	43.6	39	
Nuclear	4.1		90% pressure water reactor, 10% boiling water reactor
Industrial gas	0.1	36	
Oil	0.1	44	

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The total GHG emissions of the reference chain are 0.715 kg of CO_2 equivalents. The percentage of improvement is calculated by subtracting the total GHG emissions of the bio-electricity chain from those of the reference chain and then dividing it by the total GHG emissions of the reference chain:

$$GHG_{reduction}\,(\%) = \frac{GHG_{emission,\,fossil\,chain} - GHG_{emission,\,bio\text{-}chain}}{GHG_{emission,\,fossil\,chain}} * 100$$

As table 3.7 shows, the allocation method used has a substantial influence on the results of the impact assessment. The method leading to the largest indicator of improvement is the substitution of peas (~ 60%); followed by physical partitioning on energy basis (~ 35%). Finally, the substitution of soybean meal and the economic partitioning lead to approximately 20% improvement.

Table 3.7 Greenhouse gas emissions of bio-electricity chain

Allocation Method	GHG (in kg CO_2 eq)	Performance compared to reference chain	Improvement
Economic partitioning (on the basis of proceeds)	0.604	-0.111	+16%
Physical partitioning (on the basis of energy content)	0.477	-0.238	+33%
Substitution (by soybean)	0.567	-0.148	+21%
Substitution (by peas)	0.293	-0.422	+60%

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3.4 Discussion

The outcomes of the case study show that the choice of allocation method can have a considerable impact on the outcomes of an LCA, even for a system that is small, and where the allocation issue has been restricted to one process. The outcomes in this study range between a 16% and 60% improvement compared to a reference chain. And although substitution with peas tilts the picture with its extreme outcome, it should be noted that the other methods still produce outcomes that range from 16% to 33%.

Allocation methods are frequently required in LCA, especially when complex systems, like energy production systems, are involved. At this moment, directives regarding the assessment of bio-energy production still prescribe different allocation methods. As the case study shows, this poses a problem because the outcomes of LCA differ strongly, depending on which directive is followed. In the EU, the Renewable Energy Directive is likely to lead to standardization of national arrangements but differences between the EU and the US will remain. Also, transposition of the RED in national legislation might still result in diverse application of allocation methods due to differences in interpretation. And even when similar allocation methods are used within a single sector, different outcomes can be obtained due to methodological difficulties or a lack of reliable data.

As noted above, this diversity in policy directives is confusing and disturbing for bio-energy producers and bio-energy users. The resulting differences, due to methodological choices, in the assessments of countries are hard to justify in a policy context. Besides, this uncertainty adds on to other uncertainties for example those related to data issues. With the (economic) stakes high the uncertainty due to methodological choices might lead to legal problems. Bio-energy producers, for example, may consider a different assessment in another country as an indirect trade barrier.

To avert such a situation, we argue that it is important to discriminate between analysis and policy related LCAs. In the history of LCA important distinctions between LCA types have already been introduced, most notably attributional versus consequential LCAs, and recent attempts in the ILCD handbook (European Commission - Joint Research Centre - Institute for Environment and Sustainability, 2010). Our distinction focuses not on type, but on requirements on LCAs. Analysis-related LCAs are LCA-studies that are carried out for the purpose of understanding a certain system. They try to identify important impacts, main contributors to impacts, opportunities to reduce impacts or otherwise optimize the system, as well as to analyze the effects of data, assumptions, and choices. Understanding and presenting uncertainties and trade-offs in such an assessment adds to the aim of completeness. Policy-related LCAs, on the other hand, support the regulation of the production, trade and use of certain products. They try to support the governance of industrial systems through subsidizing or certifying desired products, or by taxing or banning undesired products. High levels of uncertainty in this context might lead to inconsistent policy, resulting in strategic behavior of involved actors or in legal disputes. We argue therefore that this difference in aims should be taken into account when setting up an LCA study. As the understanding of the system under study is the main aim of analysis related LCA, trade-offs and uncertainties that are encountered during the performance of such LCAs can be handled in line with the views of the involved researcher as long as choices are transparently displayed. The main aim of policy related LCA is to deliver comparable results. As differences in the handling of trade-offs and uncertainties in LCAs can impede the comparability of results, it is of great importance to present clear and straight-forwardly applicable guidelines for such choices in a policy context..

We argue that there is not an objectively correct way to solve the multi-functionality problem, but the problem can be solved in a way that serves the aim of the LCA best. In a policy context, LCAs should contribute to long term stability in the system, provide actors equal and full information, and create a level playing field. In other words, policy-related LCAs aim for consistency and robustness. This aim for robustness is not served by the existing guidelines of ISO. As discussed above ISO strives in the first place for completeness. In practice this turns out to be difficult due to methodological difficulties and problems with missing or unreliable data. The use of LCA in the policy context should therefore benefit to a great extent from a guideline based on robustness.

It is beyond the scope of this article to draw the outlines of such a guideline, but we foresee that the recommended allocation method within the bio-energy context will be physical partitioning based on energy content. After all, physical partitioning is relatively easy to apply, the data is unambiguous, the outcomes are stable over time and energy-content is the most common denominator of co-products in bio-energy LCAs. Although this choice will not be able to remove all uncertainty (it does not address for example data issues), the method's stability will increase the robustness of policy outcomes.

3.5 Conclusion

The aim of this article was to show to what extent a choice of allocation method can influence the outcomes of an LCA on bio-electricity production. The outcomes of a case study on a rapeseed-to-bio-electricity chain showed that variation between 16% and 60% reduction of GHG emissions in comparison to a reference chain can be obtained depending on the allocation method applied. These findings emphasize the urgency to develop a clear guideline for LCA practice as using different allocation methods can, intentionally or unintentionally, result in very different outcomes.

Current policies, originating from different regions, prescribe different allocation methods. The recent EU's Renewable Energy Directive introduces some uniformity for EU member states but differences with the US and other world regions will remain. Moreover, national governments can still end up with different regulations due to different interpretations of the EU directive. The undesirability of this situation lays in the uncertainty for bio-energy producers and consumers.

To overcome this situation, we focused on an important difference between scientific and policy LCAs. Whereas the former aims for completeness, the latter aims for robustness. The use of LCA in the policy context will benefit largely from the acceptance of this difference and by drawing up a guideline that is based on the aim of robustness. This paper serves as a starting point for realizing such a guideline. We think that in such a guideline physical partitioning on energy content is the favored allocation method. However, we do not deny the fact that physical partitioning on energy content has its own drawbacks. We urge therefore that the drafting of this guideline should be accompanied by an on-going dialogue between practitioners and commissioners to strengthen the use of LCA as a policy tool.

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4 Developing a typology of stakeholder roles in multi-actor research programs and its application to climate adaptation programs in the US, Germany and the Netherlands[15]

Abstract
Priorities in science are increasingly associated with grand societal challenges. Science policy makers and research funders are introducing new organizational forms to structure challenge-driven research. A key feature of these new organizational forms is the involvement of non-academic stakeholders. Multi-actor research programs support challenge-driven research by bringing together a diverse range of actors around a challenge with the intention of concentrating research activities and fostering relationships among participants. Understanding multi-actor research programs as means to organize challenge-driven research requires a systematic insight into the diversity of interactions in the context of these programs. A typology of stakeholder roles that does justice to this diversity is lacking, but the literature provides sufficient building blocks. In this study, we subsequently develop a typology of stakeholder roles based on three recurring themes in the literature on stakeholder involvement: (1) the direction of the flow of information between scientists and stakeholders, (2) the phase of the research process in which stakeholders are involved, and (3) the nature of their contribution to the process. The combination produces seven distinct stakeholder roles, labelled sponsors, shapers, informants, reviewers, recipients, reflectors, and centrals. The typology was applied to a study of three large multi-actor climate adaptation research programs in the United States (NOAA's RISA program), the Netherlands (Knowledge for Climate), and Germany (KLIMZUG). The empirical test verifies that the seven roles actually occur and can be identified as such and confirms that the typology is analytically useful. Our typology is more than an analytical instrument. Policy makers can use it as an instrument in shaping stakeholder involvement, making for a more effective approach to the grand challenges.

4.1 Introduction
Priorities in science are increasingly associated with grand societal challenges.

15 This chapter has been submitted for publication by Environmental Science and Policy as Wardenaar, Tjerk, Edwin Horlings and Peter van den Besselaar, "Developing a typology of stakeholder roles in multi-actor research programs and its application to climate adaptation programs in the US, Germany and the Netherlands"

Environmental and climate-related issues invariably feature on the lists of challenges. For example, roughly 40% of the budget of Horizon 2020 – the new EU framework program – has been assigned to seven grand challenges; of the program's total R&D budget of €72 billion, about 60% is related to sustainable development and about 35% specifically to climate (European-Commission 2013). On both sides of the Atlantic, science policy makers and research funders are introducing new organizational forms to structure this challenge-driven research (Diedrich et al. 2011; Foray et al. 2012). A key feature of these new organizational forms is the involvement of non-academic stakeholders.

Multi-actor research programs support challenge-driven research by bringing together a diverse range of actors around a challenge with the intention of concentrating research activities and fostering relationships among participants (Hessels et al. 2014). These programs are a popular organizational form in environmental research. For example, an inventory of climate adaptation research programs in 16 OECD countries produced a long list of 56 programs, 14 of which could be classified as multi-actor research programs (Wardenaar 2013). However, studies on stakeholder involvement in environmental multi-actor research programs have revealed a rich diversity in roles and activities ranging from limited consultation rounds to extended knowledge co-production projects (Hegger et al. 2012b; Hegger et al. 2012a; Kirchhoff et al. 2012; McNie 2012; Pohl 2008). Moreover, several authors have noted that many initiatives towards 'new', more interactive modes of research organization are not fundamentally different from 'traditional' research practices (Irwin 2006; Turnhout et al. 2013).

Understanding multi-actor research programs as means to organize chalenge-driven research requires therefore a more systematic insight into the diversity of interactions in the context of these programs. The aim of this paper is to produce a typology of stakeholder roles that does justice to the diversity of interactions between scientists and stakeholders in these programs. Our typology classifies the roles that stakeholders (can) play in multi-actor research programs. We take the work of Carney and colleagues on stakeholder roles in British research centers as a starting point (Carney et al. 2009). We embed these roles deeper in the existing literature by redefining them along three dimensions identified in previous studies on stakeholder involvement: (1) the direction of the flow of information between scientists and stakeholders, (2) the phase of the research process in which stakeholders are involved, and (3) the nature of their contribution to the process. In addition, our typology takes into account that multi-actor research programs are nested organizational structures that organize their work at different levels: from the program, to themes and regional subprograms, work packages, and individual projects (de Jong et al. 2012; Merkx et al. 2012). Stakeholders can be involved on one or several levels (Hessels et al. 2014). Since the levels of a multi-actor research program are interrelated, according to the program's (explicit or implicit) logic, involvement at one level potentially affects (research) activities at other levels.

The typology is subsequently tested empirically in order to verify that the roles in the typology actually occur and can be identified in a real-world situation, and to examine whether the typology can be applied to a practical analysis. It should be helpful in answering two substantive questions. (1) What roles do stakeholders play at the different levels of multi-actor research programs? (2) How are these different roles linked to the research activities in multi-actor research programs? The test concerns the roles of stakeholders in three large multi-actor climate adaptation research programs in the United States (NOAA's RISA program), the Netherlands (Knowledge for Climate), and Germany (KLIMZUG). Data on stakeholder roles were gathered in 63 semi-structured interviews with participants (around 20 interviews per program).

In section 4.2 we first discuss the organizational structure of multi-actor research programs and then develop a typology of stakeholder involvement by integrating three recurring themes from the literature: the direction of the flow of information, the phase of involvement, and the type of contribution. The integration produces seven distinct stakeholder roles. The typology is empirically tested in the next sections. In section 4.3 we describe the data and methods that were used. The results of the empirical test are presented in section 4.4 with respect to the organizational structures of the programs (section 4.4.1), the roles of stakeholders in the programs (4.4.2), and the links between stakeholder roles and research activities (4.4.3). We present our conclusions and discuss their implications in section 4.5.

4.2 Stakeholder roles and nested organizational structures

Multi-actor research programs aim for challenge-driven research by stimulating and facilitating interactions between scientists and stakeholders (Boon et al. 2014; Hegger et al. 2012b; Kloet et al. 2013; Pohl 2008). Studies on multi-actor research programs as coordination structures have shown that they are nested organizational structures (Klerkx and Leeuwis 2008; Wardenaar et al. 2014). To achieve their general objectives, consortia define within the program broad thematic and/or regional subprograms with more specific aims. Often, the work to be done is organized in smaller work packages, and within those, the individual projects are situated (de Jong et al. 2012; Merkx et al. 2012). In this way, the various levels of multi-actor research programs are linked to each other according to a more or less explicit program logic.

To understand multi-actor research programs as means to organize challenge-driven research, it is important to take these organizational levels in account. After all, the links between the levels within research programs make that stakeholder involvement at one level potentially affects (research) activities at other levels. Klerkx and Leeuwis' case study of an agricultural multi-actor research program – although not focusing explicitly on stakeholder involvement – reveals how this can work (Klerkx and Leeuwis 2008). Policymakers from the Dutch Ministry of Agriculture are involved at the program level to provide input on the broad themes of the program, farmers are involved at project level to check whether the research yields results that suit the needs of users. Hence, stakeholder involvement in the program's projects varies substantially due to local conditions, but the program has a certain model for challenge-driven research with stakeholders in complementary roles at different levels, for example setting a societal relevant research agenda (policy makers) and checking the relevance of research activities and output (farmers).

However, interactions between scientists and stakeholders can take a wide variety of forms and a more systematic insight into the diversity of roles that stakeholders can have in scientific knowledge production is needed. An overarching typology that does justice to the diversity of interactions between stakeholders and scientists is currently lacking, but the literature on stakeholder involvement provides many building blocks for such a typology. We take in this article the work of Carney and colleagues on stakeholder roles in British research centers as a starting point (Carney et al. 2009). To embed the roles identified by Carney et al. (2009) better in the existing literature we redefine them along the lines of three dimensions based on recurring themes in the literature. Before we discuss the roles, we introduce the three recurring themes that provide the building blocks: (1) the flow of information, (2) the phase of involvement, and (3) the type of contribution.

The first building block concerns the direction of the flow of information between scientists and stakeholders. The flow of information is a core concept in typologies that conceptualize science and society as two distinct domains. Examples are the concept of reconciling supply of scientific information with users' demands (RSD) (McNie 2007; Sarewitz and Pielke Jr 2007), the concept of usable science (Dilling and Lemos 2011; Lemos and Morehouse 2005) and the concept of end-to-end systems (Agrawala et al. 2001). Classification according to the direction of information flows is intuitively attractive and can be found – sometimes implicitly – in many different studies of stakeholder involvement (Edelenbos et al. 2011; Jolibert and Wesselink 2012; Rowe and Frewer 2005; Talwar et al. 2011). The literature that focuses on flows between science and society suggests a distinction between three types of information flow: (1) dissemination (one-way flow from scientists to stakeholders); (2) consultation (one-way flow from stakeholders to scientists); and (3) exchange (interactive flows between stakeholders and scientists).

The second building block concerns the phase in the research process in which stakeholders were involved. Various scholars stress the importance of interactions in all phases of the research process (Dilling and Lemos 2011; Edelenbos et al. 2011; Lemos and Morehouse 2005; McNie 2012; Wardenaar et al. 2012). However, it has been showed that the phase in which stakeholder involvement takes place has a large effect on the outcomes of a project (Mostert 2003). Stakeholder involvement consequently has a temporal dimension that is rarely made explicit in classifications of stakeholder involvement (for examples see (Jolibert and Wesselink 2012; Talwar et al. 2011). In our typology we use a broad distinction between three phases: (1) before the research, (2) during the research, and (3) after the research (Carney et al. 2009).

The third building block concerns the type of contribution made by stakeholders. In the literature, four types of contribution can be identified; (1) needs, (2) knowledge, (3) resources, and (4) audience. Needs are a focal point in concepts such as RSD and usable science. By expressing their needs or explaining their opinions and values, stakeholders enable scientists to work on scientific know-ledge that meets the needs of society (Lemos and Morehouse 2005; McNie 2007). Knowledge or information is the main interpretation of stakeholder contribution in concepts such as coproduction, joint knowledge production, and transdisciplinary research. The value of such a contribution is that stakeholder knowledge is grounded in local experiences and is strongly entwined with the day-to-day activities of people (Edelenbos et al. 2011). Stakeholders can also contribute to scientific knowledge production by providing resources, such as funding, facilities and personnel (Jolibert and Wesselink 2012). Finally, stake-holders can provide an audience for scientists and their work.

Figure 4.1 below provides a visual representation of how the seven roles are defined by the three dimensions. Before we specify the individual roles and illustrate them with examples from the literature, we briefly discuss the typology as a whole. The main differentiations between the roles are made by the flow of information (y-axis, three categories) and the phase of involvement (x-axis, three categories). That this doesn't result in nine stakeholder roles has to do with the linear character of the upper part of the typology (first two rows of the figure). "Consultation" can – by the used definitions – not occur after the research project, while "dissemination" cannot occur before or during the research project. Stakeholder interactions with a more interactive and non-linear character are covered by the roles in the bottom part of the typology (last two rows of the figure). While the roles of "shapers", "reviewer" and "reflectors" still have a linear character in a temporal sense, this only holds for the research project as such. For example, the contributions of "reflectors" are at the same time end and starting point of research activities and the contributions of "reviewers" can in an iterative sense rephrase research questions within a research project. In the case of "centrals" interactions between scientists and stakeholders become so frequent, that it is no longer possible to distinguish their contributions on either linear scale. Type of contribution is depicted per role in the cells of the figure. Some roles are associated with one specific type of contribution (e.g. "recipients"), while others are associated with various types of contribution (e.g. "reviewers).

1. *Sponsors* contribute to a research project by providing resources such as funding. Their contribution is one-way (from stakeholder to scientists) and before the research process starts. For example, charity funds in health-

care - representing patients, family members and donors - often organize their calls for research proposals as sponsors, i.e. in a similar way as research councils.

2. *Shapers* are involved before the research process but do exchange information. This exchange between scientists and stakeholders defines the eventual scope and focus of the research project. Shapers (can) provide various contributions. For example, they express their concerns about certain topics (needs) or suggest relevant case studies (knowledge). An example are the multi-stakeholder dialogues organized by the Dutch Ecogenomics Consortium on desirable directions for scientific developments in the context of the consortium (Roelofsen et al. 2011).
3. *Informants* are involved during the research process. They perform the conventional role of stakeholders in that they provide information that scientists need for their research. Informants can provide (1) information on needs (e.g. in interviews on attitudes on climate change) or (2) knowledge (e.g. in a survey on the adaptation strategies of local companies).
4. *Reviewers* exchange information with scientists during the research process. In this role they provide an audience for scientists but also reflect on the progress and results of the project. Their contribution can be either the expression of needs to better align the research to their own needs or the input of knowledge to strengthen the practicality of the research. The farmers from the abovementioned study of Klerkx and Leeuwis (2008) are an example of stakeholder in the role of reviewer in an agricultural research context.
5. *Recipients* are involved at the end of the research process as an audience for research outputs. Like the informant, the recipient is also 'traditional' stakeholder role in scientific knowledge production. Examples range from readers of (popularized) research findings to users of models, software, and other research output.
6. *Reflectors* are involved at the end of the research process. Reflectors exchange information with scientists on the results of the project. In this way, reflectors can be the starting point of a new research cycle. The English project on regional greenhouse gas emissions described by Carney et al. (2009) provides an example. Stakeholders were at the end of the project asked for their feedback on the research process, their feedback subsequently informed three follow-up projects on the same topic (Carney et al. 2009).
7. *Centrals* are involved throughout the research process. Their role in the process is comparable to that of scientists owing to their close connection to a project and the diversity of their contributions. So-called knowledge co-production projects provide ample examples of stakeholders in the role of central. For example, Boon and colleagues describe a project on flood risks in unembanked areas wherein stakeholder participants (from a local municipality) became full members of the research team (Boon et al. 2014).

Figure 4.1 Seven stakeholder roles based on three recurring themes in the literature on stakeholder involvement in environmental sciences

Flow of information		Phase of involvement: Before	Phase of involvement: During	Phase of involvement: After
	Consultation	**SPONSORS** Resources	**INFORMANTS** Needs Knowledge	
	Dissemination			**RECIPIENTS** Audience
	Exchange	**SHAPERS** Audience Needs Knowledge Resources	**REVIEWERS** Audience Needs Knowledge	**REFLECTORS** Audience Needs Knowledge Resources
		CENTRALS		

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4.3 Methodology

The typology will be empirically tested in order to verify that roles actually occur and can be identified as such. In this section we explain the methods used to collect and analyze the data.

4.3.1 Data gathering: case selection and interviews

We analyse stakeholder roles in three multi-actor research programs: NOAA RISA (USA), KLIMZUG (Germany), and Knowledge for Climate (the Netherlands). The programs were selected from an inventory of multi-actor research programs in climate (adaptation) research (Wardenaar 2013). The three programs have a transdisciplinary approach, aiming to involve stakeholders in all phases of the research process and – as table 4.1 shows – are large-scale, multi-annual, and multi-level programs.

Data were collected using interviews, document analysis, and site visits. For the interviews we selected program members from different subprograms (regions, themes) and in different positions (directors, managers, scientists, stakeholders) to adequately represent the diversity of each program. We selected subpro-grams with a different regional focus (e.g. one with an urban focus and another with a rural focus), and with a different thematic focus (e.g. one on drought and another on sea level rise). In the case of the RISA program, which is a program with a long history, we also selected subprograms with different starting dates (e.g. a well-established one and a newly started one). We selected three candidate subprograms and discussed our selection with program management to check (1) whether the selection gave a good representation of the program as a whole, and (2) whether subprogram members were available during our research period (in the case of the RISA program we changed one region for practical reasons).

Table 4.1 General characteristics of three cases[16]

	NOAA RISA	KLIMZUG	KfC
Country	**USA**	**Germany**	**the Netherlands**
Size (€ mln / year)	7	17	13
Period	1995 – present	2008 – 2014	2008 - 2014
Main funding source	NOAA	BMBF	FES
Focus	Regions	Regions	Regions & Themes
Number of regions	11 (& 2 finished)	7	8
Number of themes	0	1 (Begleitprozess)	8

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After the selection of subprograms, we approached interview candidates with different positions (management, scientists ranging from principal investigators to PhDs, and stakeholders). The availability of interviewees was an important criteria, owing to the limited duration of site visits (between 2 and 4 weeks per program). We conducted 63 interviews with program directors and with participants of different subprograms. Table 4.2 shows the number of interviewees by position and program.

Table 4.2 Overview of interviewees in different roles per strategic research consortium

	NOAA RISA	KLIMZUG	KfC
N Interviews	**20**	**22**	**21**
Directors	1	2	4
Management	7	3	5
Scientists	12	12	7
Stakeholders	0	5	6
N Regions/themes	5	3	6

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16 Sources: cpo.noaa.gov, www.klimzug.de, kennisvoorklimaat.klimaatonderzoeknederland.nl, Wardenaar (2013)

The interviews were open and semi-structured to allow for the rich diversity of stakeholder involvement in multi-actor research programs and the inclusion of cases from different countries. The interview protocol included four main themes that had to be addressed by the interviewees, but allowed interviewees to elaborate on topics they regarded most relevant. The four main themes of the interview were: (1) project and research activities in the context of the program, (2) involvement in interactions with stakeholders (or scientists in the case of interviews with stakeholders), (3) individual motivations and incentives for participation, and (4) the national science system. Interviews took around one hour, were recorded and transcribed.

4.3.2 Data analysis

Interview data were analysed using a standardized codebook. The codebook was created in an iterative process of theory-driven code development (DeCuir-Gunby et al. 2011). The initial codebook consisted of two main aspects, i.e. (1) organizational level and (2) stakeholder roles. The initial theory-driven version of the codebook was discussed among the research team, and was then tested and revised within the context of the data. Six interviews were randomly selected and coded with the first version of the codebook. The codes were found to be relevant and applicable. The coding of the six interviews helped to develop more precise codes and further clarify the meaning of codes.

The codes for organizational levels distinguish between four levels where stakeholders are involved: (1) program, (2) subprogram, (3) work package, and (4) project. The most general level concerns the aims and activities of the program as a whole. The other levels have an increasingly narrow focus on a specific part. This narrowing focus is accompanied by an increasing level of detail and specialization. The most specific level in this respect is the project where the actual research takes place. Stakeholder roles were defined as described in section 4.2.

After the codebook had been tested and adjusted, all interviews were coded using the standardized codebook. This resulted in a total of 360 coded quotes on stakeholder involvement, specifically 114 quotes for NOAA RISA, 115 for KLIMZUG and 131 for KfC. The verified quotes were grouped together to provide an overview of interactions within a subprogram. This resulted in 17 overviews (14 subprograms and 3 directors) that included all interactions per subprogram. Different interviewees discussed the exact same interactions between scientists and stakeholders. Double-counting was prevented by giving every interaction a unique name, thus bringing together quotes on the same interaction as recounted by different interviewees. This reduced the number of unique interactions to 150, specifically 55 for NOAA RISA, 47 for KLIMZUG and 48 for KfC. Finally, the codes assigned to these 150 interactions were checked for inconsistencies.

4.4 Empirical findings

In this section, we present the results of testing empirically the typology on three multi-actor climate adaptation research programs. We start with a description of the organizational structures of the three cases (section 4.4.1). The cases are then compared with respect to the roles of stakeholders in the programs (section 4.4.2). On the basis of this comparison, we discuss how stakeholder roles at different organisational levels influence research activities in the contexts of these programs (section 4.4.3).

4.4.1 Organizational structures

NOAA's RISA program was established in 1995 to build the USA's "capacity to prepare for and adapt to climate variability and change by providing cutting-edge scientific information to public and private user communities" (NOAA CPO, 2011a). Eleven RISA teams are currently operating throughout the USA. The teams have a large degree of freedom in organizing themselves, in defining their region, and in selecting research topics. As a consequence RISA teams can differ strongly among each other in organizational form and (research) approach (Feldman and Ingram 2009; McNie 2012), making it difficult to make generalizations about the eleven teams. The teams cover large geographical areas and between 3 and 11 research topics (per team). RISA teams are interinstitutional collaborations involving between 2 to 11 institutions. The majority of teams only consist of academic institutions.

The interviews reveal that the program has a strong bottom-up approach, which is driven by principal investigators:

> *"It is bottom-up, regional contextualized* […] *with respect to the research, we want to get money to people in places, to really understand the regional and local context"* (NOAA RISA, Program Manager)

As a result, the RISA program has a relative simple organizational form. NOAA funds the eleven RISA teams, which subsequently distribute the funding among their projects. Work packages are not formal parts of the structure but are loosely defined – i.e. bottom-up – themes that provide an umbrella for participants who share research interests.

The German KLIMZUG program was implemented in 2008 by the German Ministry of Education and Research (BMBF) to increase Germany's adaptive capacity. At present, seven KLIMZUG pilot regions are operational. In the regions, scientists are expected to collaborate with regional actors in an interdisciplinary way. The seven KLIMZUG region projects have organized their activities around 3 to 6 topics (per region). The main part of the work is done by project partners. Project partners have signed up at the beginning of the project and are individually responsible to the ministry for their part of the work. In addition to project partners, all projects have cooperating partners in the region with a less clearly defined role in the project. Project partners strive to include all relevant actors in their region into their network.

Like the RISAs, the KLIMZUG regions have a high degree of autonomy. However, during the proposal phase and the first evaluation BMBF exerted extensive pressure on the regions to incorporate the importance of building regional networks in their program. KLIMZUG regions consequently have projects that focus on conducting research and projects that focus on networking activities (to fulfil the objective to include all relevant actors in their region into their network). The organizational structure of the program is therefore more complex than that of the RISA program. There is a vertical difference because work packages around themes such as food, civil society or estuary river management are part of the formal structure. The distinction between network projects and research projects adds a horizontal difference: projects at the same level have another function within the organizational form.

Knowledge for Climate (KfC) was approved by the Dutch Cabinet in 2007 and funded from the Economic Structure Enhancing Fund (FES). Knowledge for Climate "aims to develop applied knowledge, through cooperation between the Dutch government, the business community and scientific research institutes, in order to ensure that long term decision making takes into account the impacts of climate change" (Knowledge for Climate 2012). In contrast to the RISA program and KLIMZUG there is an additional organizational level between the funder and the subprograms. The foundation Stichting Kennis voor Klimaat (Foundation Knowledge for Climate) has been established to coordinate the program and consists of a board of directors, a program office and a knowledge transfer office.

The program has two types of subprograms: (1) eight hotspots with a regional focus, and (2) eight themes. In the projects of hotspots, scientists and stakeholders are supposed to collaborate closely on urgent climate issues. The majority of hotspots is headed by a non-academic stakeholder like a municipality, a province, or a government agency. The thematic projects have a more long-term perspective and are dominated by scientists. The organizational structure of Knowledge for Climate is thus highly complex with an additional organizational level and different types of subprograms (i.e. hotspots and themes) and projects (i.e. hotspot projects and theme projects).

4.4.2 Stakeholder roles in NOAA RISA, KLIMZUG and Knowledge for Climate

The interviews resulted in data on 150 unique interactions between stakeholders and participating scientists. Figure 4.2 shows the percentage of stakeholder roles that occur within the programs. In this section we discuss how frequently the seven stakeholder roles occurred in the three programs and discuss differences between the programs.

Sponsors and *shapers* are the least frequent roles in the three programs. In most cases, sponsors are interested in a piece of research that does not fit neatly in the program logic. A typical example is the request for a report on regional climate change projections by the environmental office of the city of Bremen in Nordwest 2050 (KLIMZUG). The work on these projections had been done by a specialized consultant in the context of Nordwest 2050. The city of Bremen could have waited for the results of the project, but they needed the report for a specific working group and were especially interested in specific aspects and questions. They subsequently requested – and funded – a report on these topics from Nordwest 2050.

Shapers have a less ad hoc character than sponsors and mainly play a role in the Knowledge for Climate program.[17] The Dutch program has organized several fora and mechanisms for scientist-stakeholder exchanges before the research. An example is the involvement of hotspot members (stakeholders) in setting the research agenda of the thematic subprograms. In a first step, hotspot members were asked about their knowledge needs. The program directors included in the open call for thematic subprograms a document that contained these needs. In a second step, hotspot members were given tokens that represented research money. Scientists were given the opportunity to present their proposal and discuss it with hotspot members. After this exchange of information, hotspot members were asked to allocate their tokens to the proposals they found most relevant. This is how the research budgets of the thematic subprograms were determined.

Informants are stakeholders consulted during the research. In the three programs, about half of the informants perform their role in the conventional fashion, by providing scientists with the information scientists need for their research. KLIMZUG informants were most often consulted on information or data. For example, in a survey of the Nordwest 2050 project local companies were asked about climate awareness and strategies. In dynaklim – another KLIMZUG region – local authorities were interviewed about adaptation plans. In the case of the RISA program, informants are often consulted on their needs. RISA projects apply a broad range of methods ranging from anthropological approaches, like “sondeos” and listening sessions, to surveys.

Reviewers occur relatively frequently in the three programs, especially in Knowledge for Climate and NOAA RISA. Reviewers provide an audience during the research, but also give feedback. Typical organizational forms to involve reviewers are steering groups and sounding boards. For example, the RISA Western Water Assessment (WWA) has a stakeholder board with representatives of relevant sectors such as water and climate. According to WWA management, research progress is discussed to elicit insights on the relevance of the sub-

17 No shapers were identified in our analysis of the RISA program. A recent study on one of the RISA teams (GLISA) that was not included in our case selection does describe the involvement of stakeholders in a shaper role (Lemos et al. 2014).

program's activities and gather ideas for new research directions. Reviewers are also involved in less formal ways. CCRUN – a recently started RISA – actively approached city governments (who they consider as their key stakeholders) to provide presentations on their projects and gather feedback and suggestions.

Recipients – together with centrals – are the most frequent roles in the programs especially in the RISA program and KLIMZUG. The programs reach recipients by means of regular, standardized dissemination activities like climate forecast updates, websites, or newsletters; by giving presentations to specific audiences, such as for citizen or grass-root organizations, and chambers of commerce; by approaching or inviting the (local) press; and by setting up specialized websites that contain information, for example on tools for managing climate risk in agriculture or stream flow reconstructions from tree rings.

Reflectors do not occur very often in the three programs, perhaps because of the limited duration of the programs. Like recipients, reflectors are involved at the end of the research process. Scientists present or discuss the findings of a research project. Unlike in other roles, there is an exchange with stakeholders that leads to the start of a new research process. The public events organized by KLIMZUG NORD in areas where its researchers are active provide an example. The subprogram organizes such local events to generate new research projects with more involvement of local stakeholders. For example, one such an event in the small town of Buxtehude resulted in a new research project on the local river.

Centrals are involved throughout the research process. Among centrals, the line between scientists and stakeholders becomes blurred. In line with the mission statements of the programs, stakeholders participate frequently as centrals in the three programs. In some cases, centrals are stakeholders that are close to the research world, for example the involvement of Prognos AG in dynaklim (KLIMZUG). This consultant participates in two of the subprogram's research areas on an equal footing with participating academic scientists. Key regional stakeholders also participate as centrals. In the same KLIMZUG subprogram, the local water board EGLV participates as project partner, runs research projects, and facilitates dialogues with other stakeholders. The percentage of centrals is especially high in the Knowledge for Climate program. This can be explained by the program's matching requirement for stakeholders. This requirement is a strong incentive for participating scientists to talk to stakeholders:

> *"And the matching requirement works, because to get matching scientists have to go out and talk with stakeholders before the research"* (KfC, Program Director)

On their part, stakeholders who supplied matching funds have a strong incentive to stay involved throughout the research.

The description of stakeholder roles in the three programs reveals differences in their approach to challenge-driven research. Where it concerns the temporal dimension of stakeholder roles, Knowledge for Climate stands out. Compared to NOAA RISA and KLIMZUG, stakeholders of KfC are relatively more involved in roles before the research and throughout the whole process (sponsors, shapers, and centrals), namely 20% and 39% (KfC) versus 8% and 18% (NOAA RISA), and 6% and 22% (KLIMZUG). Knowledge for Climate is also different where it concerns the directional dimension of stakeholder roles. The Dutch program has a much lower frequency (18%) of one-way roles (sponsors, informants, recipients) than KLIMZUG (53%) and RISA (58%). An important reason is that the RISA program and KLIMZUG have a broader objective to reach the general public and/or to create a network for change.

Figure 4.2 Percentage of stakeholder roles (Total N = 160, and per case (N = 60 (RISA), 49 (KLIMZUG), 51 (KfC))

Flow of information	Phase of involvement: Before	Phase of involvement: During	Phase of involvement: After
Consultation	**SPONSORS 6%** NOAA RISA 8% KLMZUG 4% KFC 4%	**INFORMANTS 13%** NOAA RISA 15% KLMZUG 16% KFC 6%	
Dissemination			**RECIPIENTS 26%** NOAA RISA 35% KLMZUG 33% KFC 6%
Exchange	**SHAPERS** NOAA RISA 0% KLMZUG 2% KFC 16%	**REVIEWERS** NOAA RISA 17% KLMZUG 12% KFC 24%	**REFLECTORS** NOAA RISA 7% KLMZUG 10% KFC 4%
Exchange	**CENTRALS 26%** NOAA RISA 18% KLMZUG 22% KFC 39%		

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4.4.3 Linking stakeholder involvement to knowledge production

Like other multi-actor research programs, NOAA RISA, KLIMZUG and Knowledge for Climate have nested organizational structures. They are ambitious regarding the involvement of stakeholders in the various levels of their program. When we look at the roles that stakeholders play at these levels, we identify different ways of linking stakeholders to the research activities in the programs.

RISA program

Almost 60% of the interactions in the RISA program take place at the project level. This high percentage confirms the bottom-up, regional contextualized character of the program logic. At this project level, stakeholders are predominantly involved as recipients, centrals and reviewers, and to a lesser extent as sponsors and informants. The emphasis on stakeholder involvement is thus on the most detailed and specialized level during the research process. As has also been observed in other studies of the RISA program, research activities have been most closely aligned with either individual stakeholders or stakeholder groups (Feldman and Ingram 2009; McNie 2012). Looking at the type of contribution, stakeholders contribute mainly by expressing their values and needs.

The RISA teams are driven by projects with PIs who work – often for a long period of time – within the region. Their frequent interaction and familiarity with regional stakeholders provide them with new research directions and projects. During these projects values and visions of stakeholders are gathered as feedback on the relevance of the ongoing work. The focus of the projects is broad and strives to gather all relevant regional needs through the involvement of many different stakeholders:

> "[W]*hat we're looking for from a RISA is to interact with the diversity of stakeholders, so that we understand* [...] *how the agricultural community, the water community, the coastal community, the ecosystems community, managers and decision makers, from all those communities, understand and use climate information"* (NOAA RISA, Program Manager)

The knowledge that is produced in these projects is highly relevant for involved, individual stakeholders that range from water managers to ranchers to indigenous communities. To increase the reach of the program, produced knowledge is aggregated at the subprogram level. At this level, the only other frequent stakeholder role in the program occurs, i.e. recipients. These stakeholders are reached by channels like websites, newsletters, webinars.

KLIMZUG

In figure 4.2, KLIMZUG looks very similar to the RISA program. When we take the distribution of stakeholder roles across the various levels into account, this image changes. The emphasis of the BMBF on building a regional network of change has resulted in the two pillars; networking activities and scientific projects. In contrast to the RISA program, stakeholder interactions are much more evenly distributed across the various levels (subprograms 37%, clusters 19%, network projects 11%, and science projects 36%). In the science projects stakeholders predominantly play the role of informant (contributing by providing information) or recipient. The exchange of information takes place mainly at the levels of networking projects and especially in the clusters.

Stakeholders are identified in the networking activities and they are invited to attend a platform meeting or regional conference at cluster level. Here the two pillars of the KLIMZUG regions come together. Scientists present their research products, provide information about climate change and adaptation measures, and are open to suggestions. Stakeholders can provide feedback on ongoing research (by expressing opinions and needs) which consequently adjusts the direction of the research projects. Like in the RISA program, produced knowledge is aggregated at the subprogram level and recipients are reached through such channels as websites, newsletters, and presentations.

Knowledge for Climate

Section 4.4.2 revealed that Knowledge for Climate has a different approach to challenge-driven research than the RISA program and KLIMZUG. When we take the different levels into account, in some aspects the KfC model resembles the opposite of the American program. In the American model projects are the generators of challenge-driven research, whereas the Dutch program starts by involving stakeholders at the most general levels of the program, i.e. program, hotspot and theme level. At these levels, stakeholders are involved before the research as sponsors and especially as shapers. Their contribution of needs trickles down to the lower organizational levels.

At these levels, a second important difference with the RISA program emerges. Diversity of stakeholders is not a main objective in the projects, because the program focuses on a set of key stakeholders. These stakeholders are often governmental organizations who have provided matching funding for the research. These stakeholders are often involved during the research in the hotspot and theme projects, for example as centrals that provide practical knowledge. Unlike the RISA program and KLIMZUG, Knowledge for Climate does not primarily focus on the general public.

4.5 Conclusions

The increasing importance of grand societal challenges in the organization of scientific knowledge production results in a rising demand for stakeholder involvement. Multi-actor research programs are a popular organizational form for involving stakeholders in climate adaptation research. Stakeholder roles and activities in environmental multi-actor research programs have been shown to be highly diverse. Yet, there is no systematic insight into this diversity. Understanding multi-actor research programs as means to organize challenge-driven research requires such an insight.

In this study we have developed a typology of stakeholder roles that does justice to the diversity of the interactions between scientists and stakeholders. We took the work of Carney and colleagues on stakeholder roles in British research centers as a starting point (Carney et al. 2009). The roles identified by Carney et al (2009) were subsequently redefined along the lines of three recurring themes in the literature on stakeholder involvement: (1) the direction of the flow of information between scientists and stakeholders, (2) the phase of the research process in which stakeholders are involved, and (3) the nature of their contribution to the process. The combination produces seven distinct stakeholder roles, labelled sponsors, shapers, informants, reviewers, recipients, reflectors, and centrals.

The typology was tested empirically for two reasons. First, it should be possible to identify the typological roles in a real-world situation. Second, the typology has to be analytically useful. Application of the typology to climate adaptation programs in the US, Germany and the Netherlands verifies that the seven roles actually occur and can be identified as such. The empirical test also confirms that the typology is analytically useful. The results show that (1) stakeholders play different roles at different organizational levels, (2) involvement at one level affects (research) activities at other levels, according to a more or less explicit program logic, and (3) programs use different ways to link stakeholder involvement to scientific knowledge production. In the RISA program, the research is driven by involvement of stakeholders at the detailed project level. Their contribution of expressing needs generates the production of societal relevant knowledge that is subsequently disseminated at a more aggregated level. In KLIMZUG, stakeholder activities and research activities take place in two pillars (networking projects and research projects). At the cluster level, stakeholders can adjust the research process by providing feedback – needs and knowledge – on the ongoing research in the scientific projects. Knowledge for Climate starts with contributions of stakeholders at the most general level. Their input trickles down to lower, more detailed organizational levels where stakeholders provide additional contributions – especially practical knowledge – as centrals.
The comparative analysis of stakeholder roles in the three programs revealed differences within and between cases. The differences within cases revealed that interactive projects with stakeholders in the role of centrals were found alongside traditional (Mode 1) research projects with a linear conception on the possible contributions of stakeholder. Moreover, despite transdisciplinary objectives, traditional stakeholder roles like informants and recipients were still among the three most frequently occurring roles in the three programs. At a first glance, this finding is in line with critical studies of science and technology that have concluded that the "new" organizational forms of science merely reproduce traditional scientific ideals (see e.g. Turnhout et al. 2013). However, our analysis also suggest that in terms of research activities these more traditional roles are complementary to the roles of stakeholders in the more interactive projects. Additional research is therefore needed on the effects of programs' different organizational approaches to stakeholder involvement on the knowledge that is produced within these programs. An avenue of future research that would be very promising in this respect is linking the findings on organizational differences between programs

with the research on the usability and societal impact of the knowledge produced in these programs (De Jong et al. 2012; Feldman and Ingram 2009; Kirchhoff 2013; Kirchhoff et al. 2013; McNie 2012; Merkx et al. 2012).

The findings from this study are relevant for those policymakers who implement and oversee multi-actor research programs. At present, stakeholder involvement is often formulated as a general requirement, but its organization is essentially left to individual programmes. However every approach has its own strengths and weaknesses. The RISA program is able to gather a large diversity of stakeholder needs, but gives a high degree of autonomy to participating scientists and has the potential risk that regions are dominated by the hobbyhorses of some PIs instead of the region's needs. In addition, a recent study on the RISA program has argued that it is difficult for the program to increase its reach beyond the directly involved stakeholders (Kirchhoff et al. 2013). The two-pillar approach of KLIMZUG ensures that the scientific projects make progress even when stakeholder activities are difficult. Interviewees emphasize, however, the difficulty of bringing the two pillars together. Knowledge for Climate narrows down the number of stakeholders and, by including a funding requirement, it manages to keep stakeholders involved throughout the research process. A drawback of this model is that poorly organized stakeholders (or stakeholders without means) do not play a (direct) role in the program. Our typology is more than an analytical instrument. Policy makers can use it as an instrument in shaping stakeholder involvement, making for a more effective approach to the grand challenges.

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5 The role of knowledge users in public–private research programs: An evaluation challenge[18]

Abstract

Many contemporary science systems are witnessing the rise of public-private research programs that aim to build capacity for research and innovation in strategic areas. These programs create a significant policy challenge: how to select - based on ex ante evaluations - a consortium that will carry out public-private research activities that will contribute to the overall policy goal of capacity building in the science and innovation system? And how to make sure that knowledge users are involved in the research program in a meaningful way? The aim of this article is to explore the possibilities for ex ante evaluation of public-private research programs in a systematic comparison of 37 Dutch programs funded by the 'Investment Grants for Knowledge Infrastructure' (*Besluit Subsidies Investeringen Kennisinfrastructuur*) in 2004. Our research question is as follows: to what extent can involvement and commitment of knowledge users in the stage of drawing up the program proposal serve as a predictor of their later involvement and financial contribution? Using available archival data on the programs, we show that on average there is a close association between user involvement in the proposals of public-private research consortia and their eventual involvement during the implementation, but that there are substantial differences between plans and implementation in individual cases. Our analysis suggests that selecting consortia for funding based on their program proposals is possible and legitimate, but that strict rules are necessary to safeguard the financial contributions of knowledge users.

5.1 Introduction

A number of large-scale complex societal problems feature prominently in current science and innovation policy plans, as they are assumed to demand major research efforts. The European Commission has identified several 'Grand Challenges', such as climate change and healthy aging, which will guide agenda-setting in its upcoming research funding framework, Horizon 2020 (European Commission 2011). Dealing with grand societal challenges is a challenge in itself. Public authorities, companies, and the public at large expect science to make a big contribution, but the question is how research on these challenges should be organized in order to generate social and economic impacts. One common policy strategy is to launch large-scale public–private research programs.

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Public–private research programs bring together a diverse range of actors, both researchers and knowledge users, around a certain theme with the intention of concentrating research activities and fostering relationships among participants. Such programs, which are governed by various organizational structures, such as Leading Technological Institutes in the Netherlands (van der Veen et al. 2005), Cooperative Research Centres in the USA (Turpin et al. 2011), and Networks of Centres of Excellence in Canada (Fisher et al. 2001), share the fundamental principle that the government delegates responsibility for research programming to a consortium with a heterogeneous composition. The logic of delegating the research programming task to a varied network of researchers and knowledge users is that it saves transaction costs and provides a promising means of dealing with the lack of scientific expertise among policymakers (Braun 2003). However, consortia including both knowledge users and knowledge producers face the challenge of managing the involvement of the different participants, in terms of variety (range of actors) and depth (substantive and financial contributions). This creates a significant policy challenge: how to select, using ex ante evaluations, a consortium that will carry out public-private research activities that will contribute to the overall policy goal of capacity-building in the science and innovation system? In particular, how to make sure that knowledge users, as part of this heterogeneous consortium, can contribute to the research program in a meaningful way? Earlier studies have provided insights into the functioning of public-private research programs (Gray 2011; Kloet et al. 2013), and they have produced building blocks for monitoring and ex post evaluations (Klenk et al. 2010). The evaluation of public-private research programs is complicated owing to the multi-dimensional focus of these programs and the uncertain complex innovation processes involved (Salles-Filho et al. 2011), a lack of comparable data across countries (Lepori et al. 2007), and the limited possibility to measure long-term impacts (Rogers 2012). To date, little empirical analysis has been performed on the ex ante evaluation of such programs.

This article addresses the policy challenge of selecting public–private research programs, focusing specifically on assessing ex ante the role of knowledge users in the implementation and governance of these programs. The article studies 37 Dutch public-private research programs that were funded under a single government scheme, the 'Investment Grants for Knowledge Infrastructure' (Besluit Subsidies Investeringen Kennisinfrastructuur or BSIK) of 2004. All the programs funded were required to support collaborations between researchers and knowledge users, such as firms, governmental authorities, and nongovernmental organizations (NGOs). Second, they had to aim at large-scale economic and social challenges. Rather than delegating the selection and monitoring of the programs to a traditional research council, the government decided to set up a special high-level advisory committee to select and monitor the programs. The selection of programs for funding was based on general criteria such as scientific quality and societal relevance. The government or the Committee did not provide an organizational template for the programs and gave them ample room to develop their own governance structures. The ensuing variety, along with their user- and challenge-driven character, makes them an interesting object of study.

The aim of this article is to explore to what extent ex ante evaluation of public-private research programs enables policymakers to select consortia that will carry out programs in which knowledge users are involved. The precise degree to which users should be involved is a normative question, the answer to which will depend on the theme and mission of the program. In our analysis, we do not intend to judge whether users are adequately involved, but rather explore to what extent policymakers can select consortia based on the degree of user involvement from the assumption that they will always demand a certain degree of involvement. To this end, we make a systematic comparison of the 37 'BSIK' programs. Our research question is as follows: to what extent can involvement and commitment of knowledge users in the stage of the program proposal serve as a predictor of their later involvement and financial contribution? We will conclude our article with recommendations for science and innovation policy-makers concerning the selection and governance of public-private research consortia.

5.2 Theoretical framework

5.2.1 Rise of public-private research programs

Many contemporary science systems are witnessing the rise of public-private research programs that aim to build capacity for research and innovation in strategic areas (Fisher et al. 2001; Gray 2011). The rise of public-private research programs is related to the increased complexity of the scientific enterprise and to the recognition that societal problems require collective efforts by public research organizations, governments, and industry (Gibbons et al. 1994). Pooling research projects and coordinating the efforts of individual researchers in a public-private research program are expected to enhance their common effectiveness in terms of producing research of the required scientific quality and societal impact (Hessels 2013).

Public–private research programs can be seen as a manifestation of the rise of 'delegation to networks' (Braun 2003). Network delegation in the science system implies that policymakers do intervene by providing funding for thematic programs, but assign a large proportion of the responsibility for content and internal decision making to a consortium of scientists and knowledge users. The state acts as a facilitator that retains the right to control but makes use of the existing relations, expertise, and selfinterest of the research community, as well as creative and instrumental input of knowledge users (Braun 2003; Klerkx and Leeuwis 2008b).

As such, network delegation potentially has large benefits for the state: it decreases transaction costs related to control mechanisms, and it does not demand in-depth scientific expertise on the part of policymakers. However, the crucial step of selecting a consortium responsible for distributing funding and coordinating research projects based on ex ante evaluations is difficult. Given the inherent uncertainty of scientific research and the difficulties of ex ante evaluation of the broader societal impacts of science, this challenge is always present in the process of allocating research funding (Merkx and Van den Besselaar 2008; Bozeman and Sarewitz 2011; Rogers 2012). The challenge is even more considerable when it comes to public–private research programs, as a result of three characteristics:

1. The substantial scale, with funding generally in the order of several million euros,
2. the heterogeneous composition of the consortia, which include research organizations, commercial firms, and/or governmental organizations (Spielman and von Grebmer 2006), and
3. the multidimensional focus of these programs and the uncertain complex innovation processes involved, using novel models of collaboration and user involvement (Salles-Filho et al. 2011).

5.2.2 The role of knowledge users in public–private research programs

The main challenge of consortium selection concerns the role of knowledge users in public–private research programs. These programs aim both for scientific excellence and for societal relevance. They involve knowledge users, such as governments, firms, or NGOs, in the agendasetting and in the execution of the research, in order to include their knowledge needs in the research agenda and to stimulate cocreation of knowledge. For example, Canada's Networks of Centres of Excellence (Fisher et al. 2001) were inspired by the idea of Mode 2 knowledge production, which involves collaboration between various types of organizations, transgressing disciplinary boundaries, and introducing novel types of quality control (Gibbons et al. 1994; Hessels and van Lente 2008). In the same vein, the Cooperative Research Centres programs in Australia (Turpin et al. 2011) and the USA (Gray 2011) specifically aim to stimulate collaboration between universities and industry. The rationale behind user involvement is that academic research can have more impact on society or the economy if the activities of multiple organizations are combined, and if the responsibility for agenda-setting and knowledge transfer is shared by the research community and a set of societal stakeholders (Hessels 2013).

The science and innovation studies literature suggests that involving users in R&D can be beneficial. First, making use of the users' creative potential and experiential knowledge enhances the relevance and quality of scientific output (Caron-Flinterman et al. 2005; Von Hippel 2005). Second, users can facilitate the R&D process by making it more effective (Von Hippel 2005). Third, a more prominent role for knowledge users can lead to strong links between the activities of knowledge users and knowledge producers. Possible relationships include collaboration, complementarity, similarity, relevance, and synchronicity. Eventually, such relationships enhance the societal or economic impact of the program in terms of legitimization of its output, utilization of the results, and interest in follow-up research initiatives (Roelofsen et al. 2011).

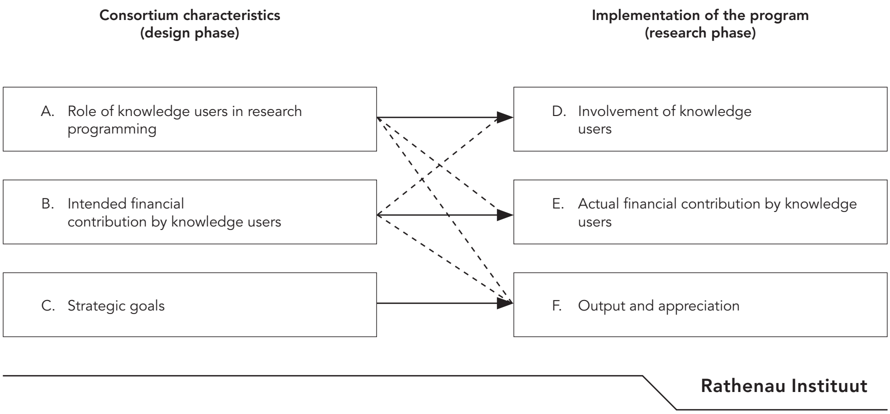
Involving knowledge users can be difficult, costly, and risky. In general, the more participating organizations there are, the higher the coordination costs (Cummings and Kiesler 2007). This is especially true of public– private research programs, in which different actors with their varying stakes and interests participate, and the agendas of academic researchers, commercial firms, and other knowledge users need to be aligned (Kloet et al. 2013).

Given their hybrid nature, public–private research programs by definition involve knowledge users in the funding, design, or implementation of the program. In some cases, users restrict their role to funding R&D. For example, charity funds in healthcare – representing patients, family members and donors – organize their calls for research proposals in a similar way as research councils. Knowledge users can also be prominent during the agenda-setting phase (Davenport et al. 2003). In this stage, they are often involved as one out of many experts and some cases even just as a token person. However, sometimes they take the lead in the agenda-setting phase in terms of organization and content (Elberse et al. 2012). Empirical evidence shows that programs may host users who are involved in all phases of the research cycle (Klerkx and Leeuwis 2008b). However, some studies have indicated that the prominent role of users in agendasetting is not carried through during the execution of the research (Bozeman and Sarewitz 2005; Kloet et al. 2013; Wardenaar 2013). There are various conceptualizations of the degree of user involvement, ranging from variations on Arnstein's participation ladder to combinations of dimensions and attributes (Neef and Neubert 2011). One attribute of user involvement is the extent to which programs choose to include knowledge users in formal bodies, such as the board, steering committee, or program council (Jolibert and Wesselink 2012). In these positions, users can give feedback on the progress of the program as a whole or the progress of individual projects, which enables them to influence the direction of the program and to shape it in relation to their own activities and knowledge needs. Such a role can lead to 'productive interactions', fruitful exchanges between researchers and stakeholders in which knowledge is produced that is valued as both scientifically robust and socially relevant (Spaapen and Van Drooge 2011). However, this type of participation does not imply an active contribution as operational partners in research projects. In many cases, firms participate in research projects to be up-to-date on current scientific directions and to scout for skilled and talented researchers, without aspiring to play a role as a coproducer of knowledge (Van Gils et al. 2009).

5.2.3 Research model

In this study, we will analyze the implementation of a set of public-private research programs in relation to a number of characteristics of these programs in the design phase (see fig. 5.1). Given the above considerations, we will pay particular attention to the role of knowledge users. The distinction between the design phase on the left of the research model and the research phase on the right directly reflects the relationship between program proposals and 'later involvement and financial contribution', which is the focus of our research question. The implementation of the program will be analyzed in terms of three variables: the involvement of knowledge users in decision making (D), their financial contribution (E), and the types of output and appreciation of the program (F). In order to investigate the correspondence between program design and program implementation, we shall explore the extent to which each variable is associated with a matching characteristic of the consortium in the program design phase (variables A, B, and C). In addition, a number of other relationships will be explored, based on more tentative hypotheses (indicated with dotted arrows in the model). In our analysis, the term 'program' refers to a collection of research activities with a certain degree of substantive coherence and organizational delineation. With 'consortium', we refer to a set of partners committed to a common research program.

Figure 5.1 Research model. The main arrows indicate the main relationships under study between a program variable in the research phase and a corresponding variable in the design phase. The dotted arrows indicate a number of other relationships which will be explored, based on more tentative hypotheses.



5.2.3.1 The involvement of knowledge users

First, we analyze the degree to which knowledge users are involved during the research phase (D) in relation to their role in the design phase (A). Interactions with knowledge users during actual research activities tend to increase researchers' awareness of the potential practical applications of their work (Hessels 2013). This type of contact can lead to adjustments in the project content, which enhances the project's relevance to industry or other users. Knowledge user- producer interactions in the implementation phase can be organized in various ways: by setting up user committees, by conducting part of the work in-house at a firm or other user organization, or through other in-kind contributions. In this article, we analyze the influence of knowledge users on the research agenda.

User involvement during the design phase (A) can create a common focus and relevance in the activities of both parties (Hemlin and Rasmussen 2006). It allows stakeholders to articulate their knowledge needs and to shape the content and organization of the research program. Knowledge users can make this contribution either by being directly involved in the writing process or by participating in brainstorm sessions or other forms of consultation.

5.2.3.2 Financial contribution from knowledge users

Second, we analyze the *actual* financial contribution provided by knowledge users (E) in relation to their intended contribution during the program design phase (B). Although knowledge is often regarded as a 'public good' (Arrow 1962; Stiglitz 1986), there are plenty of sectors where private parties have an interest in investing in collective research, as this is cheaper than conducting research in-house. In agriculture, farmer levy funding of R&D is an institutionalized way of end-user demand steering of R&D in which farmers form collectives that become clients of R&D providers (Klerkx and Leeuwis 2008a). Obviously, investment in R&D by users pertains more to applied research, but in many research areas, such as chemistry (de Wit et al. 2007), firms and other knowledge users also fund precompetitive strategic research.

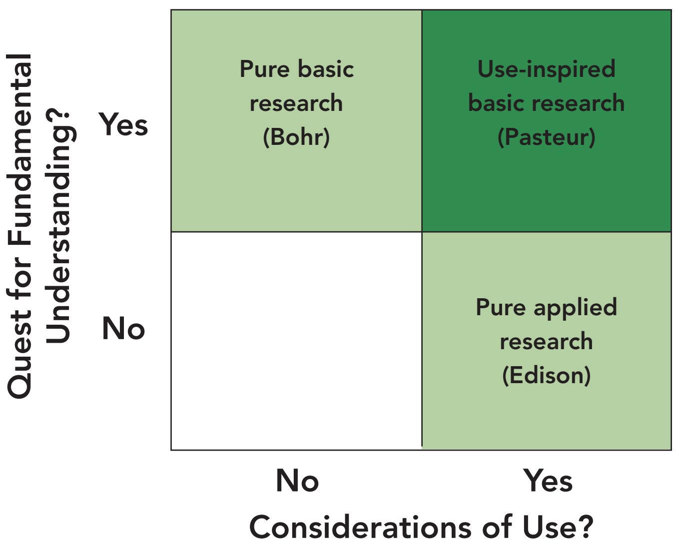
Some policy instruments provide users with the opportunity to influence the content of research programs without making a financial contribution, but public policies for research in strategic areas increasingly aim at inducing industry or other users to provide substantial contributions to the research budget. This obviously enhances the available research capacity and, furthermore, makes users more committed to the activities performed (Hegger et al. 2012). Adopting user funding as a determinant for R&D programming has the upside that users have a 'practical perspective on costs and benefits which scientists themselves may lack' (Stewart 1995). This might be an effective way of applying R&D funding in strategic research, at any rate (Johnson et al. 2003). The downside is that users may have difficulty valuing the benefits of basic research.

In order to make users interested in funding R&D, a large-scale public–private program must offer a perspective on significant revenues. In health research, for example, charity funds and pharmaceutical companies participate in precompetitive public-private programs because their research objectives require investments that a single company could not carry and their outcomes are difficult to appropriate (Reich 2000). In general, users face a tradeoff between benefiting from public subsidies by investing in collective research, and exclusive access to knowledge and intellectual property by outsourcing research individually.

5.2.3.3 Output and strategic goals

Third, we explore four types of output, reflecting the scientific achievements and the practical output of the programs (F). Although the output of a research program does not directly reflect the role of knowledge users, the balance across various types of output does indicate a relative orientation toward the development of products for scientific audiences versus products for nonacademic knowledge users and in this way can be regarded of a manifestation of user involvement. Straightforward and commonly accepted indicators for the analysis of scientific output are counts of scientific publications and PhD degrees awarded. The practical output of scientific research is difficult to measure, given the wide variety of practical products that can be generated (de Jong et al. 2011; Hessels et al. 2011). Owing to the limited data available, the analysis in this article will focus on practical output in terms of the numbers of patent applications and spin-off firms created. In addition, we analyze the qualitative assessment of a responsible evaluation committee as an indication of the overall quality.

Figure 5.2 Stokes' quadrant model (Stokes 1997).



Source: Stokes (1997)

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The output of the programs will be analyzed in relation to the strategic goals of the programs (C). A predominantly scientific program will demand different coordination processes than a predominantly practical program. To classify the programs in our data set, we chose to go beyond the traditional dichotomy of basic versus applied research, and use Stokes' Quadrant (Stokes 1997). The two dimensions constituting this quadrant model are the relative commitment to considerations of use and the relative commitment to the quest for fundamental understanding (see fig. 5.2). Stokes has named three quadrants after exemplary researchers: pure basic research (Niels Bohr), use-inspired basic research (Louis Pasteur), and pure applied research (Thomas Edison). In the original presentation, the fourth box remained unnamed, but Stokes did refer to ornithologist Roy Tory Peterson as an example, since research in this area is mainly oriented at description and classification (Stokes 1997: p. 75). In this article, we will therefore refer to it as the 'Peterson' quadrant.

5.3 Methods

5.3.1 General approach

We opted for a comparative approach in exploring the possibilities for ex ante evaluation of public–private research programs. The set of programs funded by the BSIK is an interesting area for our endeavor. The BSIK policy aimed to increase the societal relevance of the Dutch science system. To meet this objective, the government made 802 million euros available from the national gas reserve fund for a temporary subsidy for public–private research programs. Consortia of research organizations, firms, and/or governmental organizations were invited to submit program proposals, which might qualify for 50% BSIK funding; the other half had to be 'matched' by consortium partners. A special high-level advisory committee (the so-called 'Commissie van Wijzen') was installed to advise on the awarding of funding to individual programs and to report to the government on the progress of the BSIK funding program as a whole through annual reviews. The committee assessed the proposals on the quality of the proposed activities in terms of scientific excellence and potential for societal and economic results. A third main criterion for selection was the structural involvement of knowledge users, such as companies and NGOs, that would contribute to the creation of knowledge networks.

The Committee received advice from the Royal Netherlands Academy of Arts and Sciences (KNAW) and from the CPB Netherlands Bureau for Economic Policy Analysis. NL Agency, the agency of the ministry of Economic Affairs, was responsible for the administrative follow-up and helped the Committee monitor the programs. A total of 37 public–private research programs covering five different themes were awarded grants. All the programs operated within the same policy framework, but had no fixed organizational template. Given their relative autonomy, each program had to choose its own governance structure, which means that the set of programs can serve as a fruitful domain for comparative analysis.

A particularly interesting feature of the BSIK framework is its temporary nature. In the Dutch science system, the coordination of research activities has traditionally been the preserve of permanent organizations (Hessels and Deuten 2013), particularly the Netherlands Organization for Applied Scientific Research (TNO), KNAW, and the Research Council for Pure Scientific Research (ZWO). Since the 1980s, however, when new strategic research areas began to emerge that called for collaboration between public research organizations and industry, research has increasingly been organized in the form of public–private partnerships. These new intermediaries often had a temporary status, lasting only for the duration of a limited grant program. The 37 BSIK programs under study in this article are examples of such intermediary organizations.

This article is based on archival research at NL Agency, the agency of the ministry of Economic Affairs responsible for monitoring the BSIK programs. NL Agency gave us unrestricted access to the relevant archives of the BSIK programs, as well as assistance where necessary. Our main data sources are listed in table 5.1. The various sources span the entire lifetime of the programs, from the design phase to the implementation and wrap-up. Data collection was structured by a long list of 176 indicators, producing a database with systematic information on all 37 programs. The set of indicators was composed in order to capture as much available information as possible about the governance of the programs, their aims, budgets, and output.

Data collection was carried out by a team of three research assistants led by one of the authors. Eventually, a selection of relevant indicators was used for our analyses. Some of the indicators are straightforward counts, such as the number of PhD degrees awarded. Other indicators, such as the relative influence of a user committee, required interpretation and judgment by the data collector. After analyzing two programs as pilot cases, the data collectors discussed their coding approaches with each other and with the authors. Random crosschecks were also performed to monitor interpretations between data collectors. The authors conducted interviews with the unit director responsible for monitoring the programs at NL Agency and with three members of the high-level advisory committee to validate the data and help interpret the findings. Moreover, the authors were involved in in-depth qualitative studies on several specific programs, such as the Ecogenomics Consortium, Next-Generation Infrastructures, and Climate changes Spatial Planning (Kloet et al. 2013; Roelofsen et al. 2011; Wardenaar et al. 2014).

We operationalized the distinction between design and the research phase as the moment of program selection, based on the program proposal and related documents as listed in table 5.1. Given the lack of instructions from the government, the division of activities over these two phases differed across programs. For example, some programs had designed individual research programs in the design phase and specified them in their program proposals, while other proposals only sketched activities in general terms. Although the activities between the two phases may show a certain degree of overlap, we do believe that it is possible and necessary to make such a distinction in order to answer our research question.

Table 5.1 Main data sources

Phase of the program	Data sources (for each program)
Design phase	Program proposal
	Business plan/project plan
	Baseline assessment
Research phase	Mid-term review
	Annual reports
	Final report (by program management)
	Assessment by high-level advisory committee

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Three limitations of our data set deserve a mention. First, although both NL Agency and the high-level advisory committee checked all documentation, thus limiting the likelihood of factual errors, it should be underlined that most data were self-reported by the program consortia. This might result in higher output numbers, since researchers can typically attribute the same publication to multiple funding sources. Second, although the program evaluation reports are standardized thanks to NL Agency's monitoring approach, they vary significantly in terms of their content and structure. In principle, our database only covers information reported in the documents available, so some activities or achievements may have been missed. In general, however, program managers tended to report manifestations of user involvement relatively well, as they were appreciated by the high-level advisory committee. If activities were not reported, it is therefore safe to assume that they did not occur. Third, we were unable to fill in certain variables for some of the programs because of the quality of the available documentation. For example, three programs had only just been completed at the time of the study (TREND, KvR, and ESI) and one had not actually been completed (NGInfra), which meant that they could not supply complete data about finances and output. Overall, these limitations suggest that data about individual programs can deviate, which restricts the possibilities to assess the performance of individual programs. However, there is no reason to assume that there are systematic errors which constrain the possibility to analyze general trends across different programs.

5.3.2 Operationalization of the main variables

5.3.2.1 Role of knowledge users in research programming

The role of knowledge users in research programming was characterized on a numerical scale from 0 to 3, as presented in table 5.2. The scale is defined in terms of the contribution knowledge users made to the program proposal. In 16 cases, users acted as coauthors of the text. A somewhat weaker form was chosen by two programs that approached users with their draft proposals, inviting them to sign letters of support to indicate their interest. The minimal form of consultation was to inquire about knowledge users' interests, without asking for any commitment.

Table 5.2 Definition of the scores for the role of users in research programming

Role of knowledge users	N	Numerical score
No contribution to the program proposal	5	0
Limited consultation of users	10	1
Users signed letters of support indicating their interest in the program	2	2
Users were part of the writing committee	16	3
Other / unknown	4	-
Total	37	

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5.3.2.2 Intended financial contribution by knowledge users

The intended financial user contribution was calculated using figures from the program proposals or business plans. In our operationalization, we defined knowledge users as all organizations that did not qualify as knowledge producers, such as research institutions. Research institutions are all public and semipublic organizations whose primary mission is to produce knowledge: universities, basic research institutes,[19] and applied research institutes.[20] Knowledge users are all private organizations and all public and semipublic organizations whose primary mission is not the production of knowledge. These include firms, governmental organizations, and NGOs. To control for different program sizes in our analysis, we used the ratio between the intended financial contribution of knowledge users and the intended financial contribution of research institutions. Given the quality of the available documentation, this figure could only be calculated for 23 programs.

5.3.2.3 Strategic goals

The BSIK programs were designed to strengthen the Dutch knowledge system and stimulate both scientific excellence and societal impact. Although all BSIK programs were selected on the basis of high scores for scientific excellence as well as economic relevance, the relative emphasis on scientific and practical goals varied significantly between individual programs. To characterize the programs in terms of Stokes' quadrants, the relative emphasis on scientific goals and the relative emphasis on practical goals in the program proposal or baseline

19 Research institutes that are governed by NWO or the KNAW.
20 The Netherlands Organization for Applied Scientific Research (TNO) and the four 'major technological institutes' Marin, ECN, Deltares, and NLR.

assessment were rated by our research team on a five-point scale ranging from 'very weak' to 'very strong' for both scientific and practical (i.e. economic or societal) goals (see table 5.3). These two goals were scored independently, and our assessment was based on the different targets set by the consortium and the ambitions defined. Emphasis on scientific goals scored as 'high' when the proposal included multiple and specific references toward scientific goals, such as above average targets for scientific publications and PhD degree, the organization of and participation in scientific congresses, citation impact, and when the mission and/or strategy sections frequently mentioned terms such as 'scientific excellence' without a direct connection to application. Emphasis on practical goals scored as 'high' when the proposal made multiple and specific references to economic goals, such as ambitious targets for patents, spin-offs, technology user interaction working sessions or when the mission and strategy sections referred explicitly to valorization or practical applications.

Table 5.3 Classification of the programs in terms of Stokes' quadrants

		Emphasis on practical goals	
		Very weak, weak or neutral	Strong or very strong
Emphasis on scientific goals	Strong or very strong	Bohr (N=16)	Pasteur (N=12)
	Very weak, weak or neutral	Peterson (N=2)	Edison (N=7)

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Obviously, it is based on self-presentation in the different programs, which may include a strategic component, and this assessment should therefore be interpreted as an indicator of the strategic positioning of the programs, rather than an objective indicator of the orientation of the programs toward fundamental research or practical application. Any results flowing from this classification should therefore be interpreted with the caveat that this classification is only a rough proxy for actual strategic focus.

5.3.2.4 Involvement of knowledge users during the research phase

The influence of knowledge users during the research phase was analyzed on three levels:

- Influence on decisions regarding individual projects (project level)
- Influence on decisions regarding a larger set of projects organized into a theme or work package (subprogram level)
- Influence on decisions regarding the program as a whole (program level)

In addition, we calculated the average score at these various levels for each program. We measured the involvement of knowledge users in terms of their estimated *influence* on the actual research agenda. Based on the available documentation we scored the influence on a numerical scale, as explained in table 5.4.

Table 5.4 Definition of the scores for user influence

Description	Definition	Numerical score
No influence	Knowledge users have no influence at this particular level	0
Indirect influence	Influence by way of an advisory body that interacts with the program at this particular level	1
Direct influence	Influence by a right to vote in the decision-making body at the level in question. Knowledge users have a structural influence over a significant number of projects or activities.	2
Direct and indirect influence	Influence through both an advisory and a decision-making body	3

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5.3.2.5 Actual financial contribution from knowledge users

This value was calculated on the basis of figures reported in the final accounts of the programs. As with the *intended* financial contribution, we used a ratio between the contribution of knowledge users and knowledge producers.

5.3.2.6 Output and appreciation

We analyzed the scientific output of each program in terms of two indicators as measured in the final reports. First, the number of academic peer-reviewed papers (disregarding book chapters and conference contributions). Second, the number of PhD degrees awarded to researchers funded by the programs.
As indicators for the practical outputs of the programs we analyzed the number of patent applications and the number of new spin-off firms to have emerged from the research conducted as part of the program. These variables reflect only a limited share of all possible practical outputs, mainly emphasizing economic impact and disregarding media contributions and policy advice, for example. However, these variables are the only types of practical outputs that have been systematically documented by all programs under study.

Finally, we analyzed the evaluation of the high-level advisory committee in their final report to the government. In this report the committee graded each program as ‘highly successful’, ‘successful’, ‘satisfactory’, or ‘partly successful’, which we translated to a four-point ranking to enable statistical analysis.

5.4 Results

5.4.1 Descriptive overview of the programs

Table 5.5 provides an overview of the 37 programs that received BSIK funding, their budgets, the role of knowledge users, the ratio between the financial contributions of users and producers, and a characterization of their strategic goals.

Table 5.5 Overview of the programs and a number of key characteristics (if known)

Program name (abbreviated)	Topic	Actual budget (x million euros)	Role of knowledge users in research programming[21]	Strategic goals (quadrant)	Intended funding ratio users / producers	Realized funding ratio users / producers
BRICKS	Informatics	27	0	Bohr	0.00	0.00
Gigaport NG	Data networks	86	1	Edison	0.61	1.26
SRG	Spatial planning	66	-	Bohr	0.37	-
KSI	System innovations	22	0	Bohr	-	-
Nanoned	Nanotechnology	179	3	Bohr	0.08	0.07
MultiM	Multimedia	35	3	Pasteur	0.29	0.43
SCDD	Stem cells	20	1	Bohr	0.00	0.23
ICIS	Intelligent systems	30	1	Pasteur	0.94	0.99
TREND	Posttraumatic dystrophy	22	1	Bohr	0.06	0.10
Nbsik	Mouse phenomics	28	3	Edison	-	-
NPC	Proteomics	68	1	Bohr	-	-
NBIC	Bio-informatics	-	-	Bohr	-	-
Biomade	Molecular nanotechnology	15	0	Edison	0.12	0.11
LOFAR	Multiple sensor array	107	0	Edison	2.00	1.30
Cyttron	Bio-imaging	21	-	Bohr	0.21	0.16
Delft Cluster	Urban infrastructures	51	1	Pasteur	0.20	0.74
NG	Nutrigenomics	21	3	Bohr	-	-
ESI	Embedded systems	49	3	Pasteur	0.07	0.00
KvR	Climate and spatial planning	84	1	Bohr	-	-
Virgo Consortium	Respiratory virus infections	21	3	Pasteur	0.29	0.20
VL-e	e-science	43	3	Pasteur	0.48	0.11
CDC	Celiac disease	18	3	Bohr	0.01	0.00
LmW	Water management	56	1	Peterson	-	-
Microned	Microsystems	54	3	Pasteur	0.30	0.20
Molecular Imaging	Molecular imaging	24	3	Bohr	0.13	0.07
B-Basic	Bio-based materials	54	1	Bohr	0.00	1.14
DPTE	Tissue Engineering	55	1	Pasteur	-	-
CATO	Carbon capture and storage	27	3	Pasteur	0.25	0.30
Eco-genomics	Ecogenomics	22	0	Bohr	0.29	0.14
Smart Surroundings	Ambient systems	14	-	Pasteur	0.86	0.55
Freeband	Telecommunication	60	3	Pasteur	1.21	0.45
NGInfra	Infrastructural systems	19	3	Pasteur	-	-

21 0: no contribution; 1: limited consultation; 2: Letters of support; 3: part of writing committee; -: unknown / other

Program name (abbreviated)	Topic	Actual budget (x million euros)	Role of knowledge users in research program-ming3	Strategic goals (quadrant)	Intended funding ratio users / producers	Realized funding ratio users / producers
PSI Bouw	Construction	-	3	Edison	-	-
RGI	Geo-informatics	46	3	Bohr	-	-
Transumo	Mobility	60	1	Edison	-	-
Transforum	Sustainable agriculture	59	3	Edison	0.86	1.09
We@sea	Off-shore wind power	21	1	Peterson	-	-
Average (non-weighted)		45	N.A.	N.A.	0.40	0.42

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The budgets of the programs range from 14 to 179 million euros with an average of 45 million euros. As indicated above, the most popular models for user involvement in the design phase are 'limited consultation' (N=10) and 'participation in the writing committee' (N=16). The ratio between the financial contributions of knowledge users and knowledge producers varies from 0.00 (BRICKS, B-Basic) to 2.00 (LOFAR) in the intended budget, and 1.30 (also LOFAR) in the actual budget. The average ratio is about 0.4. One remarkable change from intended to realized input was the shift in the B-Basic program, from 0 to 1.14.

5.4.2 Involvement of knowledge users

The first relationship explored is that between the involvement (influence) of knowledge users at various program levels (A) and the role of knowledge users during the design phase (D). Table 5.6 shows that there is a significant weak to medium correlation at all program levels. The relationship is strongest at the subprogram level and fairly weak at the program level.

Table 5.6 Correlations in the influence of knowledge users at various levels and the role of users during the design phase

Influence of knowledge users on the research phase	Spearman correlation (with role of users during design phase)
Project level	0.406** (N=33)
Sub-program level	0.609*** (N=30)
Program level	0.337* (N=32)
Average influence (in cases the influence on all levels was known)	0.589*** (N=29)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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Given the ordinal character of the 'knowledge user influence' indicator and the small sample, we simplified our four-point scale indicator to a dichotomous measure indicating participation versus nonparticipation in the writing committee.

Table 5.7 gives the median scores of these groups for the role of knowledge users during the research phase. The scores are in line with our earlier results. A Mann–Whitney test roughly confirms these results because a significant effect on subprogram level influence and average influence was found. This result does not hold for the project and program level.

Table 5.7 Nonparametric comparison of influence of knowledge users when part of the writing committee versus not part of writing committee

Influence of knowledge users during the research phase:	Not in writing committee	Writing committee	Significant differences ('Writing committee' minus 'not in writing committee')a
Project level	2.0 (17)	2.0 (16)	
Sub-program level	0.0 (16)	1.5 (14)	+1.5**
Program level	1.0 (16)	2.0 (16)	
Average influence	.67 (15)	2.0 (14)	+1.3*

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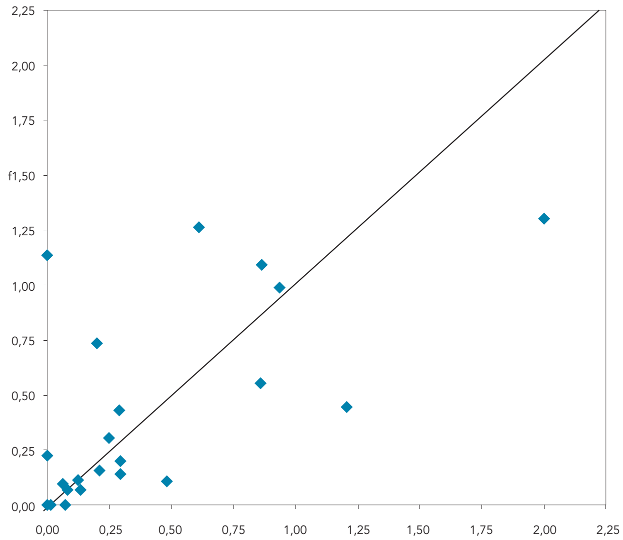
We also investigated an additional hypothesis that was tentatively shown in our formal research model: the relationship between financial contribution and user involvement. There are no significant correlations with the relative intended financial contribution of knowledge users (N=23). This indicates that the degree of involvement by knowledge users during the research is strongly associated with their involvement during the programming phase, but not with their intended financial contribution.

5.4.3 Actual financial contribution

In many programs, the actual financial contribution of knowledge users deviated substantially from the intended contribution (see fig. 5.3).

The ratio remained equal (that is, 0) in one case, increased in nine cases and decreased in 13 cases. On average, the ratio increased slightly from 0.40 to 0.42, but this effect was due to one case. Without B-Basic, the average ratio decreases from 0.42 to 0.39. Apart from these dynamics, the ratio between the intended contributions of knowledge users and knowledge producers correlates with the ratio between their actual contributions (N=23; Pearson correlation: 0.635; $P<0.001$). No significant correlation was found between the actual proportion of financial contribution and the influence of knowledge users at any of the three levels.

Figure 5.3 Actual financial contribution by knowledge users (x-axis) versus their intended contribution (y-axis) (N=23). Both are depicted as the ratio between the contributions of knowledge users and knowledge producers.



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5.4.4 Output and evaluation score

None of the relative output indicators correlates with the share of intended financial contributions from knowledge users or the role of users in the programming. A comparison of the four quadrants indicates that the relative emphasis on various goals at the outset relates to the output of the programs to some extent (see table 5.8). Programs that place strong emphasis on scientific goals do indeed produce relatively more publications and PhD degrees than those with a weaker emphasis on these goals. The highest number of patents and spin-off firms are created in Pasteur's quadrant programs, which emphasize both scientific and practical goals in their proposals. The six programs in Edison's quadrant (low emphasis on scientific goals and high emphasis on practical goals) produce relatively little on average in most output categories. This could be explained by the fact that our output indicators are restricted to scientific output and commercialization, whereas other practical outputs such as policy innovations or public debate were not documented sufficiently to be captured in this study.

The final evaluation of program performance by the high-level advisory committee is also highest for programs that have a strong emphasis on scientific goals. The programs in Edison's quadrant score slightly lower on average. There are insufficient programs in Peterson's quadrant to make a systematic comparison, but they also score relatively low.

Table 5.8 The average output (unweighted) and evaluation scores compared across the four quadrants

	N	Average number of publications per million euros	Average number of PhD degrees per million euros	Average number of patents per million euros	Average number of spinoff firms per million euros	Average evaluation score
Overall mean (std. dev.)	35	7.7 (7.4)	0.68 (0.44)	0.24 (0.55)	0.082 (0.11)	2.8 (N=36)
Peterson	2	2.0	0.38	0	0.05	1.5 (N=2)
Bohr	15	9.1	0.75	0.13	0.06	3.0 (N=16)
Pasteur	12	9.3	0.86	0.41	0.11	2.9 (N=11)
Edison	6	2.9	0.20	0.24	0.096	2.4 (N=7)

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5.5 Conclusions and discussion

National governments face a policy challenge in selecting consortia that will carry out adequate public–private research programs. Given the substantial size, heterogeneous composition, and complex tasks of the desired programs, it is difficult for governments to select consortia that contribute optimally to the overall policy goal of capacity-building in the science and innovation system. This article contributes to the understanding of coordination in science by a systematic comparison of 37 public–private research programs. We analyzed the involvement of knowledge users during the implementation of the programs in relation to a number of characteristics of the research consortia in the design phase.

The main finding of this article is that, in general, the plans of research consortia give a reasonable indication of the involvement of knowledge users during the implementation of the program and their financial contribution. In agreement with the case study by Kloet et al. (2013), we found that the implementation of many individual programs deviated significantly from the intentions expressed in program proposals. However, we found significant correlations between the degree of user involvement in the design phase and their involvement in decision making at various program levels while the research was being carried out. The eventual financial contribution of knowledge users also correlates with their intended contribution as promised in the consortium proposals. This suggests that user involvement in the early stages of program design tends to give an indication of the way in which knowledge users participate in coordinating programs, shaping the content and governance of large-scale research programs. Building on earlier in-depth studies (Klerkx and Leeuwis 2008b; Roelofsen et al. 2011), further research might provide a deeper understanding of this process through qualitative analyses of these kinds of programs, based on interviews with program managers, researchers, and knowledge users.

Second, it appears that within the set of programs studied, those consortia more oriented toward scientific goals performed better in several respects. As can be expected, they produced on average more scientific publications and more PhD degrees. But they also created more patents and received a higher score from evaluation committees. A possible explanation is that scientifically oriented programs benefit from existing networks of scientific researchers, whereas programs with lower scientific ambitions depend more strongly on new relationships between public researchers and knowledge users to achieve their goals (Bercovitz and Feldman 2011). Building such relationships may require more time than the 6–8 years that most programs lasted (Rogers 2012). Literature about inter- and transdisciplinary research generally agrees that it takes time to establish collaborations across disciplinary and organizational boundaries, owing to differences in norms and incentive structures (Hegger et al. 2012; McNie 2012). It seems that in the cases of programs with lower scientific ambitions, the involvement and commitment of knowledge users in the stage of drawing up the program proposal, e.g. in the form of including users in program agenda-setting, do not increase the output as measured in terms of publications, PhD degrees, patents, or spin-off firms. Note that such programs might well have generated other types of output, such as policy advice or public debate, which have not been systematically documented here. Besides 'tangible' outputs, programs might lead to 'intangible' outputs such as the creation of a context conducive to combining research results with non–research-related innovation activities, resulting in, for example, building product prototypes (Salles-Filho et al. 2011). This especially applies to programs that are rather more focused on innovation and cocreation of novel products than on knowledge production. A current challenge for research evaluation is to develop indicators that make these intangible outputs visible (Spaapen and Van Drooge 2011). More advanced indicators could help to qualify the relatively low output of Edison programs.

Third, our analyses suggest that there is a substantial difference between the involvement of knowledge users in financial terms and their involvement in terms of influence on the content. The influence of knowledge users during the research is associated with their role in the design phase, but it does not correlate with their relative financial contribution. Their eventual financial contribution is associated with their intended financial contribution, but it shows no correlation with their role in the design phase. Apparently, in some programs, users prefer to delegate research tasks to the research community: they are willing to make significant financial contributions while leaving decision making to the research community. This finding is in line with an earlier finding that knowledge users often participate in public–private research programs for other reasons than knowledge acquisition, such as scouting for talented human resources or technology assessment (Van Gils et al. 2009). Another possible explanation might be a lack of cognitive resources. Although a few studies reveal programs supporting specific capacity building to develop the ability to articulate knowledge demand (Jacob 2005; Klerkx and Leeuwis 2008a), user organizations may not possess the absorptive capacity to assimilate and/or discuss the knowledge produced or the competence to articulate their knowledge demands

(Boon et al. 2011). Conversely, in some programs in this scheme, users were granted an influential position without providing a financial contribution. Overall, it seems that during the design of research programs negotiations about content and funding are two parallel tracks without strong linkages.

5.5.1 Policy implications

To conclude, let us reflect on the policy implications of our findings. Note that this article does not intend to express normative judgments about the relative success of the individual programs under study, as a robust evaluation would require additional analysis of both their scientific output and broader impacts. Rather, we intend to formulate recommendations for public policy based on the aggregated analysis of 37 public–private programs funded by a common scheme.

In general, our findings that the consortium proposals give a reasonable indication of the role of knowledge users, their financial contribution and the output of the programs suggest that it is possible and legitimate to make a selection of consortia for funding based on their proposals. Governments aiming to stimulate public–private research programs with intensive user involvement should select them based on the degree of user involvement in the program design and the intended financial contribution.

The many discrepancies between program proposals and implementation of individual programs confirm the general image of science as an unpredictable activity. Apparently, research activities are not only difficult to foresee in terms of their content, but also in terms of their governance and coordination structures. Since the scheme under study did not demand a predefined governance structure, the ensuing set of programs illustrates this unpredictability by being a remarkably heterogeneous set in terms of their goals, processes, and output. The role of knowledge users during the research varied strongly between programs, and in many cases, deviated from the role they played in the program design phase.

The programs also differed strongly in terms of their productivity, i.e. in their scientific and practical output. Although we did find significant correlations, the implementation of many individual programs deviated strongly from the design in the program proposal. These deviations may be due to strategic rhetoric in the consortium proposals intended to maximize funding chances, rather than providing an honest representation of plans and ambitions. However, the deviations may also simply reflect the inherently limited possibilities of planning complex research programs and predicting their outcomes. Anyhow, if substantial public investments (hundreds of million euros) are being made, more consistency between consortium proposals and program implementation seems desirable. This is, for example, expressed in the financial contributions by users. As has been indicated by the highlevel advisory committee, the total industrial contribution to the programs is disappointing from a societal perspective

(Commissie van Wijzen Kennis en Innovatie 2011). We recommend policymakers to use stricter rules than the regulations governing the Dutch BSIK framework to safeguard the financial contributions of industry and other user organizations.

Overall, our analysis confirms that the selection of public–private programs is a considerable challenge, especially in the case of a temporary funding instrument such as BSIK. Owing to its temporary nature, the BSIK policy did not provide a straightforward opportunity for a systematic learning process. Policy learning can strongly enhance innovation policies (Borras 2011). A permanent public policy for supporting public–private programs would facilitate a policy learning process of both the government as a program selector ['government learning' in the typology of (Bennett and Howlett 1992)] and of the consortia in producing their proposals and governing their activities ('social learning'). Owing to the temporary nature of BSIK, neither of these learning processes could reach their full potential. First, the temporary advisory committee responsible for the program selection could not systematically benefit from earlier experience. Second, some of the programs under study could benefit from personal experience of program directors or program officers in similar public–private research programs, but many needed to 'reinvent the wheel'. The wide variety of observed coordination approaches illustrates this. A systematic learning process would also require complete documentation, which was lacking in many cases. Given these considerations, we recommend governments to strongly strive for continuity in their policies for supporting public–private research, in order to facilitate policy learning.

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6 Skill development in collaborative research projects: A comparison between PhD students in multi-actor research programs and in traditional trajectories[22]

Abstract
The growing number of PhD students has spurred debates about the societal relevance of PhD training trajectories. The academic labour market does not provide enough jobs and many PhD graduates will have a career outside academia. It has been questioned whether current PhD training trajectories are still adequate and collaborative research projects are introduced as alternative trajectories. Such trajectories can support the development of a broader set of skills, but might have adverse effects on the development of academic skills. This article studies the effects of collaborative training trajectories on PhD skill development. We specifically focus on PhD students in multi-actor research programs (MARPs), an increasingly popular organizational form for facilitating transdisciplinary research activities. Using a survey among PhD students in MARPs and in traditional trajectories, we study the effects of a MARP on the development of four types of skills: (1) academic research skills, (2) academic communication skills, (3) translation and dissemination skills, and (4) transferable skills. Our findings suggest that collaborative training trajectories can indeed result in the development of a broader set of skills without negative effects on academic skill development. We conclude that collaborative research projects can be a viable alternative and identify three conditions for an optimal effect on PhD skill development.

6.1 Introduction
The number of PhD holders has been growing for decades, for example between 1998 and 2008 the worldwide number of yearly earned science doctorates grew by nearly 40% (Cyranoski et al. 2011). Of course, the academic labour market does not provide enough jobs for all those PhD graduates (Enders 2005; Mangematin 2000), and most will have a career outside academia (Borrell-Damian et al. 2010; LERU 2014). Although the share of PhD holders in a country's labour force is seen as an indicator for the development of a knowledge economy,

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it has been questioned whether current PhD training trajectories are still adequate (Campbell et al. 2005): Have PhD holders acquired the relevant skills during their training? The "new academic generation should be trained to become creative, critical and autonomous intellectual risk takers, pushing the boundaries of frontier research" (EuropeanCommission 2011), but the modern doctorate should also prepare students for careers beyond research and education (LERU 2014). Recent studies on skill development in PhD training trajectories are, in this respect, not uniformly positive (De Grande 2009; Manathunga et al. 2009).

The debate on the societal relevance of PhD trajectories has spurred interest in alternative PhD training trajectories. Many of these alternative trajectories are implemented with a belief that transdisciplinarity is essential for innovation and they induce collaborations with different disciplines and other sectors (Borrell-Damian et al. 2010; LERU 2014). Such collaborative trajectories can support the development of a broader set of skills (Harman 2002; Thune 2009, 2010). However, there is also evidence that a transdisciplinary approach in PhD projects poses difficulties for early career researchers (Felt et al. 2013), as non-research activities places additional burdens on PhD students (Borrell-Damian et al. 2010).

This article studies the effects of collaborative training trajectories on PhD skill development. We specifically focus on multi-actor research programs (MARPs), an increasingly popular organizational form for facilitating transdisciplinary research activities (Hessels et al. 2014; Lyall and Fletcher 2013). Using a survey among PhD students in MARPs and in traditional trajectories, we study the effects of a MARP on the development of four types of skills: (1) academic research skills, (2) academic communication skills, (3) translation and dissemination skills, and (4) transferable skills.

The rest of the paper is structured as follows. In section 6.2 we develop our theoretical framework. In section 6.3, we describe our survey and sample. The empirical results are presented in section 6.4. In section 6.5, we draw conclusions and discuss their implications.

6.2 Theoretical background

6.2.1 Skill development during the PhD trajectory

A PhD project is the training trajectory for an academic research career. PhD holders are best known for their analytical and technical skills and their ability to translate issues into research questions (Bogle et al. 2011). More recently, attention has shifted to the development of a broader set of skills, especially so-called transferable skills (Borrell-Damian et al. 2010). Transferable skills are defined as skills developed in one context (in this case the academic context) that are useful in other contexts, for example future employment whether that is in research, government or business (Scholz et al. 2009). Other concepts used in the literature are professional skills and soft skills, but we use the concept of transferable skills because of its emphasis on the fact that these skills are learned in one context but can be used in another context. This fits exactly to what is at stake in this discussion, i.e. do PhD students obtain skills that can be useful in a non-academic context. Consensus about transferable skills for PhD students is lacking but most descriptions include project management, teamwork, and communication (EuropeanCommission 2011; LERU 2014; Metcalfe and Gray 2005; Scholz et al. 2009). [23]

It has been argued that PhD students already develop a broad set of skills in traditional trajectories (Bogle et al. 2011). Unemployment among PhD holders is only around 2% (Auriol et al. 2013; Enders 2002), indicating that employers value PhD holders. Other studies, however, stress that transferable skills of PhD students are similar to those of master students (De Grande 2009); that employers are not aware of the broader skillset of PhD holders (Borrell-Damian et al. 2010); and that a large share of PhD holders with jobs outside academia believe that their training has little or no added value for his or her current job (Manathunga et al. 2009).

Although the relationship between training context and skill development remains unclear, new PhD training trajectories are being introduced to develop a broader set of skills (LERU 2014). These new trajectories emphasise transdisciplinary collaboration with other disciplines and sectors. The ultimate aim of these trajectories is to increase the attractiveness of PhD holders for (non-academic) employers and to educate a cadre of PhD holders with ties to other sectors and professions (Gemme and Gingras 2012; Harman 2002; Thune 2009).

Participation in such a collaborative project during the PhD training may, like other experiences during this career phase, have strong and lasting effects on skill development and on future work and research practices of PhD students (Slaughter et al. 2002; Verbree 2011), effects that might affect their career steps after the PhD (Manathunga et al. 2012).

6.2.2 Multi-actor research programs

MARPs are large-scale research programs that bring together a diverse range of actors around a grand societal challenge with the intention of concentrating research activities and fostering relationships among participants (Hessels et al. 2014). These programs offer a different structure for PhD students, by defining conditions and criteria for participation, formulating expectations in its mission and objectives, having a particular audience, and involving a variety of participants. MARPs differ from traditional trajectories on at least four characteristics. First,

23 Research skills can in this respect also be transferable. After all, PhD holders often work in non-academic contexts that are knowledge and research intensive. However, to distinct between skills that have traditionally been associated with the PhD (especially research skills) and this broader set of skills, we follow the existing definitions of transferable skills.

PhD students are likely to have limited freedom to develop their project. MARPs have nested organizational structures (Klerkx and Leeuwis 2008; Wardenaar et al. 2014). Programmes are divided in broad subprograms with more specific aims; the actual work is done in smaller work packages and in individual projects (de Jong et al. 2012; Merkx et al. 2012). Project aims and research questions are hence defined before a PhD student starts working in the project. It should be noted, however, that this may also occur in more traditional research environments.

Second, PhD students in MARPs are more likely to be involved in interactions with non-academic stakeholders. MARPs bring together a diversity of participants around a certain theme or challenge (Hessels et al. 2014), with stakeholders in a variety of roles (Kloet et al. 2013; Roelofsen et al. 2011). It is argued that such frequent interactions and on-going dialogues between researchers and stakeholders increases the usability of science (Lemos and Morehouse 2005; Wardenaar et al. 2012).

Third, MARPs typically focus on grand societal challenges which do not follow the borders of academic disciplines, and interdisciplinary research is increasingly seen as essential in addressing these challenges (Lyall and Fletcher 2013; Millar 2013). PhD students in MARPs will therefore more often work in projects characterised by involvement of researchers with different disciplinary backgrounds.

Finally, PhD students in MARPs are likely to have a more society-oriented outlook, as MARPs serve multiple goals: On the one hand scientific advancement and on the other hand the development of practical solutions for societal problems (Hegger et al. 2012; Pohl 2008). These programs subsequently have a large emphasis on and production of societal output (Koier and Horlings under review).

6.2.3 Skill development in multi-actor research programs

Given the characteristics of MARPs, we expect participating PhD students to obtain a different set of skills than PhD students in traditional trajectories. The literature suggests two possible mechanisms that we will discuss below: (1) (self-) selection, and (2) socialization.

(Self-)selection

MARPs may attract a different type of PhD student than traditional trajectories. People do not randomly choose their work environment, but select organizations with characteristics that match their own (Schneider et al. 1995). In addition, MARPs need PhD students that can adapt to their objectives and work practices. Several individual characteristics may affect the (self-)selection of PhD students.

Personality traits – PhD students who prefer the specific context of a MARP may have a stronger interest in research focusing on societal problems. And MARPs need PhD students who are able to adapt to the broader goals of the program and are open to different types of collaborations. This requires proactive and open-minded people, who are relatively unconstrained by situational forces (Briscoe et al. 2006; Seibert et al. 1999).

Experience – PhD students presumably select (and are selected by) a PhD program based on their personal characteristics as well as on an expected match with their skills and abilities. Hence, MARPs provide the context for developing certain skills, but also attract students that already own these skills and look for a place to apply them.

Socialization

After joining a MARP, the PhD student will be involved in different processes and activities. It is likely that such socialization affects skill development. In this part, we describe several characteristics of MARPs and formulate expectations about how these characteristics affect skill development.

Working with predefined research questions and within large teams can hinder PhD students to take full responsibility for their project. This would run against the belief that PhD students should take responsibility at an early stage for a project's scope, direction and progress (EuropeanCommission 2011). In the case that PhD students are indeed hindered to take responsibility, limited freedom to develop their own project is expected to have negative effects on the development of academic skills.

Involvement of heterogeneous partners enriches the knowledge base and brings together a diversity of values, incentives, and practices. Various studies have drawn attention to the obstacles such projects raise for individual researchers (Butcher and Jeffrey 2007; Felt et al. 2013). Other studies indicate, however, that PhD students are more open and able to adapt to this type of boundary-crossing research (Gardner et al. 2013). We expect that stakeholder involvement can have positive effects on non-research skills like communication but negative effects on the development of academic (research) skills.

The involvement of researchers from different disciplinary backgrounds are expected to have similar effects on the development of non-research skills as the effects of involvement of stakeholders. With respect to academic skills, interdisciplinary research was long considered harmful for an individual's academic career. However, recent studies show that this is changing (Millar 2013; Sobey et al. 2013). Interdisciplinary research is increasingly seen as a condition for early career researchers to develop independency (Bogle et al. 2011). We therefore expect that the involvement of researchers from different disciplinary backgrounds in MARPs help PhD students to develop both their academic and broader skills.

Finally, translating research findings into societally relevant output requires a concerted effort (Ford et al. 2013). Time and efforts spent on societal output may go at the expense of time and efforts spent on research, while it has been argued that a very research intensive period in the early career phase is essential if one wants to become an independent researcher (Laudel and Gläser 2008). We expect that translation and dissemination activities have positive effect on the development of (non-academic) communication skills but negative effects on academic skill development.

To summarize, MARPs provide PhD students a working environment that is different from traditional trajectories. We expect that participating PhD students obtain a different set of skills, either through (self-)selection or socialization. We raise the following three specific questions to test our expectations:

1. *Is the set of skills developed by PhD students in multi-actor research programs different from the set of skills developed by PhD students in traditional trajectories?*
2. *Are differences between training trajectories in skill development related to individual characteristics and to training context?*
3. *What is the relationship between individual characteristics and training context characteristics and the development of different types of skill?*

6.3 Methodology

6.3.1 Method and data

Our study focuses on training trajectories of PhD students in sustainability research. Studies of sustainability programs show a strong emphasis on inter- or transdisciplinarity (Hegger et al. 2012; Pohl 2008). Our analysis requires comparison of PhD students in a MARP with PhD students in a traditional trajectory. Given that no two MARPs are the same, that the context of a specific MARPs may affect skill development, and that countries rarely have more than one large-scale MARP in sustainability research, we compare MARP trajectories and traditional trajectories in two countries, the Netherlands and the UK. This also allows us to study international differences in skill development. Our sample consequently comprises four groups of PhD students.

We started the selection of respondents with participants of two MARPs: Knowledge for Climate (the Netherlands)[24] and the Tyndall Centre (UK)[25], which have ambitious transdisciplinary approaches and large numbers of PhD students (Wardenaar 2013). The programs provided us with background information and contact details of participants. PhD students in traditional environments were found by identifying non-MARP PhD students from the same home institutions and scientific specializations as the MARP PhD students. The total population consists of 415 PhD students: 152 from the Netherlands and 263 from the UK.

24 www.klimaatonderzoeknederland.nl
25 www.tyndall.ac.uk

Surveys were distributed and data were gathered by a specialized organization under the supervision of the researchers. The response rate in the Dutch group was 61% (n=93), the response rate in the British group was 33% (n=86). The British response rate is significantly lower, because the contact information of the UK sample turned out to be less up-to-date. Respondents were asked to indicate whether they were in a traditional or a MARP training trajectory. Their response was used to create four groups (table 6.1). Although we aimed for respondents in their second year or later, some first-year PhD students (n=12) did fill out the questionnaire. These respondents were excluded because they may have only just started and may not have had the opportunity to grasp the context of their project.

Table 6.1 Overview of respondents per group

	MARP	Traditional trajectory	Total
Netherlands	40	47	87
United Kingdom	37	43	80
Total	77	90	167

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6.3.2 Skill development

The dependent variable of this study is skill development. The literature does not provide a standard categorization of skill types. From available categorizations (Metcalfe and Gray 2005; Precision 2007; Scholz et al. 2009; Vitae 2010), we selected 21 skills, either because they were mentioned in (almost) every categorization or because they are especially relevant to collaborating with non-academic stakeholders. For every skill, respondents were asked to indicate on a scale from 1 (no experience) to 7 (excellent) their present level, and their level at the start of their PhD studies.[26] Using factor analysis the 21 skills were classified into four groups:

1. **Academic research skills**: seven skills needed to work as an independent researcher, namely the ability to (1) formulate a good research question, (2) apply properly research methods and techniques, (3) link own work to relevant theories within academic specialization, (4) develop and maintain relations with colleagues in the wider research community (5) work independently, (6) show leadership and (7) reason analytically. This group fits neatly with the set of skills that is traditionally associated with a PhD trajectory (LERU 2014). The reliability of the scale in the current study was $\alpha = .79$.

26 When respondents indicated that they presently had no experience with a certain skill, while they also indicated they had some level of that skill at the start of their PhD, we considered the values as missing.

2. **Academic communication skills**: four skills researchers need to make themselves visible within the academic community, namely to (1) get articles published, (2) review academic work, (3) write proposals for funding or grants, and (4) keep up-to-date on developments in your academic specialization. Becoming visible is essential for early career researchers to gain recognition and become a full member of the research community (Åkerlind 2008). The reliability of the scale in the current study was α = .74.

3. **Translation and dissemination skills**: six skills needed to explain and transfer knowledge to non-academic stakeholders, namely to (1) present findings to a non-academic audience, (2) contribute to public debates related to research topics, (3) support the education of professionals, (4) get findings implemented outside the academic world, (5) develop and maintain work relations with people from government, and (6) develop and maintain work relations with people from industry/business. These skills fit within the definition of transferable skills, but due to their explicit emphasis on non-academic communication we labeled them as translation & dissemination skills. The reliability of the scale in the current study was α = .74.

4. **Transferable skills:** four skills that are required to work at an advanced level in any organization namely to (1) manage a project, (2) take initiative, (3) work in a team with a division of tasks, and (4) work with targets defined by the management or senior staff. The reliability of the scale in the current study was α = .65.

6.3.3 Measuring characteristics of individual participants and training contexts

Personality
We assessed whether a PhD student has (1) a proactive personality and (2) a boundaryless mindset. The proactive personality scale (Seibert et al. 1999) includes four items such as: 'I am always looking for better ways to do things'. The reliability of the scale in the current study was α = .66. A boundaryless mindset (Briscoe et al. 2006) was assessed with four items such as: 'I am energized by new experiences and situations'. All items are measured on a 5-point Likert-scale ranging from (1) 'little or no extent' to (5) 'a great extent'. The reliability of the scale in the current study was α = .78.

Experience
PhD students presumably select a PhD program based on their personal characteristics but also on an expected match with their skills and abilities. We therefore specifically examine the starting level of the four skill types.

Freedom to develop own project:

The freedom to develop one's own project was measured based on contribution to the PhD research proposal, using two survey questions: (1) what was the status of the research proposal at the start of the project? and (2) who wrote the main part of the research proposal? Three categories were distinguished. Low influence: the project proposal was developed before the start of the project by somebody other than the PhD student; medium influence: the project proposal was developed during the project by somebody other than the PhD student as main author; and high influence: the PhD student developed the main part of the project proposal before or during the project.

Multidisciplinary context

MARPs have multi- or interdisciplinary compositions. We focus on multidisciplinarity because interdisciplinarity is difficult to measure by means of a questionnaire (Millar 2013). We developed a straightforward variable using two survey questions: (1) in which field(s) of research are you working and (2) in which field(s) of research are the academic researchers you work with working. Respondents were provided a list of research fields based on the Survey of Earned Doctorates (NORC 2011), consisting of those categories and subcategories relevant for the respondents' specializations. The variable multidisciplinary consists of three categories: (1) monodisciplinary: the PhD student and his or her colleagues work in one and the same research field, (2) multidisciplinary influences: the PhD student works in one research field and the colleagues in several research fields, and (3) multidisciplinary approach: the PhD student and his or her colleagues all work in more than one research field.

Stakeholder involvement

Non-academic stakeholders do not have a self-evident role in academic research and may be involved in different research phases (de Jong et al. 2011). To assess stakeholder involvement in a PhD student's project we asked about stakeholder influence in five research phases: formulating research questions, setting up research design, doing the actual research, discussing and interpreting outcomes, and communicating outcomes. The answer categories were 5-point scales ranging from 'little or no influence' to 'a great influence'. The average of these scores was taken as the indicator for stakeholder involvement.

Society-oriented outlook

To assess the extent to which a PhD student has a society-oriented outlook, we asked respondents about their activities and outputs. Subsequently we constructed three variables: (1) society-oriented activities, (2) society-oriented output, and (3) academic outlook. Society-oriented activities counts the number of times a PhD was involved in activities like attending policy, industry or business meetings. Society-oriented output counts the number of non-academic publications and presentations that resulted from a respondent's project.

Academic outlook is a control variable and combines both the number of times a PhD was involved in academic activities (e.g. attending a scientific conference) and the number of academic output that resulted from a respondent's project (e.g. a written publication for a scientific audience).

Supervision and teaching
Existing literature on MARPs do not discuss supervision of PhD students or teaching activities performed by PhD students. Previous studies on skill and career development of early career researchers show that these are crucial aspects (Butcher and Jeffrey 2007; Mainhard et al. 2009; Scaffidi and Berman 2011), which is why we include them in our analysis.

Supervision was assessed by asking the respondents to what extent they agree with 11 statements about their supervisor(s) using a 5-point Likert-scale ranging from (1) 'little or no extent' to (5) 'a great extent'. An example of a statement is 'My academic supervisor provides direct assessments of my progress'. Factor analysis identified three different dimensions of supervision: narrow (focused on research) (6 items, $\alpha = .86$), broad (focused on careers) (3 items, $\alpha = .76$) and network (focused on collaboration and networking outside academia) (2 items, $\alpha = .53$).

To make an assessment of the importance of teaching, we asked respondent to indicate in percentages the amount of working time they spend on teaching during the PhD project.

6.3.4 Comparing groups

The results with respect to skill levels, individual characteristics and training contexts are compared using independent samples tests (ANOVA). Kolmogorov-Smirnov tests show that in most cases data are normally distributed. The ANOVA tests for academic research skills, society-oriented activities and output, and supervision network does not meet the criterion of homogeneity of variance (Levene's test). Separate analyses using non-parametric Kruskal-Wallis tests for all comparisons between the groups produce the same results as the ANOVA tests. In order to make the results comparable, in the next section we present only the results of the ANOVA tests. Post hoc tests are used to find differences between specific pairs of groups, using the Ryan-Einot-Gabriel-Welsch Q procedure.

6.4 Empirical findings

In this section, we first analyze skill development in the four distinguished groups. Second, we compare individual characteristics and training context between the groups. Finally, we analyze how skill development is related to both characteristics of individual participants and the training context.

6.4.1 Differences in skill development

We expect the set of skills developed by PhD students in MARPs to be different from the skills developed by PhD students in traditional trajectories. Table 6.2 summarizes our findings with respect to current skill levels.

Table 6.2 Current skill levels

			Current skill level			
			Academic research	Academic communication	Translation & Dissemination	Transferable
Netherlands	MARP	Mean	4.93	4.00	3.65	4.63
	N = 40	Sd.	.81	1.24	1.33	.99
	Traditional	Mean	4.92	4.00	3.23	4.32
	N = 47	Sd.	1.14	1.26	1.38	1.25
UK	MARP	Mean	5.54	4.01	3.76	5.41
	N = 37	Sd.	.78	1.31	1.36	1.26
	Traditional	Mean	5.28	4.00	3.07	4.99
	N = 43	Sd.	.77	1.22	1.42	1.27
ANOVA		df Between	3	3	3	3
		df Within	163	163	163	163
		F	4.517	.001	2.330	6.317
		Sig.	.005	1.000	.076	.000

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The results show that PhD students in MARPs do not report lower academic research skills or academic communication skills. Post hoc tests show that the British MARP group reports significant higher academic research skills than the two Dutch groups. The MARP groups report, as expected, higher non-academic skills than their national counterpart. However, the groups are only significantly different in the level of transferable skills. Post hoc tests show that UK MARP PhD students report significant higher transferable skills than the groups from the Netherlands and that the traditional group from the UK report significant higher skills than the traditional group from the Netherlands.

The comparison of PhD groups reveals some differences in skill levels of PhD students in MARP and traditional training trajectories. Results with respect to translation and dissemination skills and transferable skills confirm our expecta-tions, while results for academic skills are contrary to what we expected. Differences between groups are small and not always significant however. These results mean that either our assumptions about MARPs were wrong or that other variables should be taken into account which have different effects on skill development. We subsequently take a closer look at the differences between groups in terms of characteristics of participants and training contexts.

6.4.2 A comparison of participants and their training contexts

Differences between PhD students in MARP and traditional training trajectories may have their origins in (self-)selection (the characteristics of participants) and in socialization (the training context). Do MARPs attract a different type of PhD student?

Table 6.3 Individual characteristics

			Personality type		Skill level at start of PhD			
			Bound.less	Pro-active	Aca-demic research	Academic. Com-munic.	Trans-lation & dissemi-nation	Trans-ferable
Nether-lands	MARP	Mean	3.98	3.90	3.88	2.28	2.77	4.00
	N = 40	St. dev.	.66	.60	1.01	1.06	1.32	1.18
	Traditional	Mean	3.86	3.90	3.89	2.59	2.44	3.70
	N = 47	St. dev.	.70	.60	1.15	1.12	1.16	1.28
UK	MARP	Mean	4.32	4.14	4.30	2.36	2.95	4.87
	N = 37	St. dev.	.52	.64	1.07	.93	1.51	1.37
	Traditional	Mean	3.92	4.05	4.08	2.30	2.37	4.25
	N = 43	St. dev.	.76	.62	.98	.86	1.24	1.41
ANOVA		df Between	3	3	3	3	3	3
		df Within	163	163	163	163	163	163
		F	3.643	1.457	1.398	.890	1.807	5.780
		Sig.	.014	.228	.245	.448	.148	.001

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The results in table 6.3 indicate that some form of (self-)selection does occur. PhD students in MARP groups score higher than their national counterpart on boundaryless mindset, which is associated with working across boundaries and neatly fits the objectives of MARPs. PhD students in the MARP groups have higher initial levels of translation and dissemination skills and transferable skills than the traditional groups. Post hoc tests show that the UK MARP group has a significant stronger boundaryless mindset and higher initial transferable skills than the British and Dutch traditional groups.

The results in table 6.4 show that there are some differences between the four groups of PhD students on the freedom to develop their own project. Other than expected, differences between the two Dutch trajectories are small, while PhD students in the British MARP group have more freedom to develop their own project than their colleagues working in traditional arrangements. As expected, PhD students in MARPs work significantly more often in multidisciplinary research contexts (Chi-square = 17,78, p = .007).

Table 6.4 Training context characteristics (part 1)

		Netherlands		UK	
		MARP	**Traditional**	**MARP**	**Traditional**
N		40	47	40	43
Freedom	Low	10%	13%	8%	14%
	Medium	25%	19%	25%	35%
	High	65%	68%	67%	51%
Multidisciplinary	Monodisciplinary	32%	52%	9%	40%
	Multidisciplinary influences	19%	19%	31%	23%
	Multidisciplinary approach	49%	29%	60%	37%

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The results in table 6.5 confirm our expectations that in both countries PhD students in MARP groups have more stakeholder involvement, are more involved in society-oriented activities, and – in the Dutch case – produce more society-oriented output.

Table 6.5 Training context characteristics (part 2)

			Stakeholder involvement	Society-oriented Activities	Society-oriented Output	Academic outlook
Netherlands	MARP	Mean	1.78	11.35	10.25	21.55
	N = 40	St. dev.	1.10	5.87	4.99	5.93
	Traditional	Mean	.98	6.85	6.83	20.36
	N = 47	St. dev.	1.21	4.10	3.03	6.20
UK	MARP	Mean	.95	7.19	5.84	18.95
	N = 37	St. dev.	1.10	4.04	2.30	5.65
	Traditional	Mean	.88	6.93	6.58	18.56
	N = 43	St. dev.	1.20	4.29	3.19	5.06
ANOVA		df Between	3	3	3	3
		df Within	163	163	163	163
		F	5.369	9.136	12.400	2.330
		Sig.	.002	.000	.000	.076

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It should be noted, however, that the Dutch MARP group stands out, while differences between British groups are small. This is confirmed by the post hoc test. Differences in academic outlook are small, and do reveal that the strong society-oriented outlook of MARP PhD students is an addition to, rather than a substitution, for an academic outlook.

A comparison of supervision and the amount of time spent on teaching (table 6.6) shows that in both countries PhD students in traditional trajectories are more positive on supervision, but that supervisors in MARPs have better networks and collaboration experience. PhD students in the UK groups are more positive about supervision than PhD students in the Dutch groups. Post hoc tests confirm that traditional trajectories in the UK report more positive on narrow supervision than MARP trajectories in either country. Differences in teaching activities are minor and not significant.

Table 6.6 Training context characteristics (part 3)

			Supervision			Teaching
			Narrow	Broad	Network	
Netherlands	MARP	Mean	3.08	2.76	3.84	2.18
	N = 40	St. dev.	.83	.93	.91	1.08
	Traditional	Mean	3.37	2.94	3.78	2.23
	N = 47	St. dev.	.80	.93	.99	1.11
UK	MARP	Mean	3.17	2.93	4.19	2.05
	N = 37	St. dev.	.85	1.04	.87	1.05
	Traditional	Mean	3.63	2.98	4.02	2.05
	N = 43	St. dev.	.82	1.13	.66	.98
ANOVA		df Between	3	3	3	3
		df Within	163	163	163	163
		F	3.647	.373	1.880	.329
		Sig.	.014	.773	.135	.804

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To summarize, there are differences among the four groups in individual and training context characteristics. Post hoc tests do not reveal a sharp delineation between trajectories – only on interdisciplinarity – but do reveal differences between specific groups. The PhD students in the British MARP group stand out with a significant stronger boundaryless mindset and higher initial transferable skills. The Dutch MARP group PhD students are significant more active in transdisciplinary activities: they have stronger stakeholder involvement, undertake more society-oriented activities, and produce more society-oriented output. Important to note with respect to individual and training context characteristics is that the reported standard deviations show that differences within groups can be rather large. The variance within and between MARP groups indicate that these programs are less uniform than we initially presumed.

6.4.3 Explaining the development of different types of skill

Skills, personal characteristics, and training context are interrelated: Training context provides opportunities to develop skills; individual characteristics enable some persons to exploit such opportunities better than others; and the different characteristics can have contrary effects. In this section, we explore these interrelationships in a multivariate model. Table 6.7 presents the results of backward linear regressions using the development of the four skill types as the dependent variable and the various personal characteristics and aspects of the training context as independent variables.

Table 6.7 Backward linear regression models for skill development (standardized coefficients; *=p<.10, **=p<.05, ***=p<.01)

	Variables	Academic research	Academic communication	Translation & dissemination	Transferable
Personal	Start level specific skill	.582*** (10,810)	.405*** (6,976)	.584*** (11,955)	.713*** (14,814)
	Boundaryless mindset	.218*** (3,981)		.157*** (3,405)	
	Proactive attitude		.147** (2,512)		.147*** (3,120)
Context	British science system	.142*** (2,706)			
	Multidisciplinary			.090** (2,044)	.136*** (3,058)
	Stakeholder involvement		.095* (1,685)	.174*** (3,527)	
	Society-oriented outlook[27]			.194*** (3,914)	
	Academic outlook	.154*** (2,832)	.426*** (7,216)		
	Teaching		.107* (1,877)		
	Supervision	.094* (1,868)		.093** (2,099)	.156*** (3,505)
Model	R2	.629	.535	.720	.708
	R2 adjusted	.616	.519	.708	.700
	F	51,106	34,690	64,169	92,014
	(p)	(.000)	(.000)	(.000)	(.000)
	Valid N	167	167	167	167

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The models in table 6.7 are strong (high R2) and generalizable (adjusted R2 is close to unadjusted R2). Initial skill levels explain most of the variance. Supervision makes a modest contribution but not to academic communication skills. A multidisciplinary context is only conducive to non-academic skills, while academic outlook is only conducive to academic skills. Stakeholder involvement and society-oriented outlook support the development of translation and dissemination skills, but have – contrary to expectations – no negative associations with academic research skills. Conducting your PhD project in the British science system makes a significant contribution to academic research skills.

27 Society-oriented outlook consists of both society-oriented activities and society-oriented output.

Academic research skills

Table 6.7 reveals that supervision – lower in MARP groups – contributes positively to academic research skills. That we didn't find in section 6.4.1 the expected negative effect on academic research skills for the MARP PhD groups, is due to the positive effects of the other relevant variables: Boundaryless mindset (more often found in the MARP groups), current skill level and academic outlook (no significant differences between MARP and traditional groups). Finally, the positive effect of conducting a PhD in the British science system confirms the differences between the groups from the Netherlands and the U.K. found in section 6.4.1.

Academic communication

The backward linear regression also provides an explanation for the lack of difference between the groups on academic communication skills. Skill level at the start, proactive attitude, and academic outlook make the main contributions to development of academic communication skills. As discussed in section 6.4.2 traditional and MARP groups do not differ significantly on these characteristics. Stakeholder involvement and teaching make minor contributions.

Dissemination & translation skills

The MARP groups developed more translation and dissemination skills. Table 6.7 reveals that skill level at the start, boundaryless mindset, multidisciplinary approach, stakeholder involvement, society-oriented outlook, and supervision all contribute significantly to the development of these skills. The MARP groups score better on all these characteristics expect for supervision and in the British MARP group society-oriented outlook.

Transferable skills

Development of transferable skills in a PhD trajectory is to a large extent explained by the level of transferable skills at the start. This possibly explains best the differences between PhD students in MARP and traditional trajectories. Other variables that contribute are proactive attitude (no differences between MARP and traditional groups), multidisciplinary approach (higher in MARP groups), and supervision (lower in MARP groups).

6.5 Conclusions and discussion

This study contributes to the understanding of the effects of collaborative training trajectories on PhD skill development. A comparison of skill development in MARPs and traditional trajectories in the UK and the Netherlands reveals no differences in academic skills but slightly higher dissemination and translation skills and transferable skills in MARP groups (section 6.4.1). A closer look into individual and context characteristics of PhD students in the two trajectories (section 6.4.2) shows that MARPs attract PhD students that have a more boundaryless mindset, and a broader set of skills at the start of their project, and that they work in a more multi- and transdisciplinary research context. Differences within and between MARP groups on context characteristics indicate, however, that these collaborative training trajectories are not uniform trajectories. Multivariate analysis (section 6.4.3) shows that the individual and context characteristics of training trajectories are a good explanation for the differences and similarities between the four groups in skill development (section 6.4.3). Especially the skill level before the start of the PhD trajectory is important, suggesting that activities before the PhD are essential in shaping the skill profile of PhD holders.

Our study has several limitations that provide directions for future research. First, time and resource constraints forced us to limit the scope of our study to one scientific field (sustainability research) and two countries (UK and the Netherlands). Sustainability research has a rich history of transdisciplinarity, also in traditional research modes. This may imply that the differences between the MARP and traditional trajectory groups are underestimated. By comparing the Netherlands and the UK we can better distinguish the effects of a MARP from the specifics of the science system. However, both countries have well-developed science systems that are relatively open to change. A general understanding of the effects of different training trajectories would need the study of scientific fields with less transdisciplinary experience as well as of training trajectories in more traditional science systems (e.g. Germany) and in emerging science systems (e.g. China, Brazil, India). Second, variance within and between research teams within MARPs is large. A better understanding of how MARPs translate their challenge-driven approach into training trajectories will strengthen our understanding of skill development in the context of collaborative projects. More in-depth analysis of functioning of MARPs is consequently required.

Our study reveals that collaborative PhD training trajectories have different effects on skill development than traditional trajectories. As we didn't find the expected negative effect on academic skill development, we believe that participation in a collaborative research project can result in a broader set of skills. However, an optimal effect of collaborative training trajectories on skill development depends on three conditions:

One, organizers of collaborative research programs (MARPs, universities, etc.) should be aware that participation in a collaborative training trajectory does not automatically result in the development of a broader set of skills. PhD students should be exposed to and participate in actual multi- and transdisciplinary processes. The variance within studied MARP groups in training context characteristics reveals that at present this is not the case. Program managers must make a concerted effort to create a context that is conducive to the skill development of individual PhD students.

Two, academic activities and output remain central in every PhD training trajectory. The development of a broader set of skills depends on involvement in both academic and society-oriented activities and processes. PhD students in the studied MARP groups develop a broader set of skills because their challenge-driven approach is an addition to, rather than a substitution for, an academic outlook. PhD students and their supervisors should be aware of and guard the balance between these different activities. Our findings suggest that in the cases studied they are – as the academic performance does not suffer from the societal activities.

Three, personal characteristics should get a more prominent role in the hiring procedures of PhD students. Most of the variance in skill development is explained by initial skill levels, boundaryless mindset and proactive attitude. If focus in hiring PhD students would be mainly on cognitive capacity and academic research skills, this may hinder the development of transferable skills. A broad focus in hiring procedures – especially for collaborative training trajectories – will identify not only the students that are best for the job, but also signal early-on aspects of individual students that require additional attention and support.

To conclude, our findings suggest that collaborative training trajectories can indeed result in the development of a broader set of skills. These trajectories can be seen as a viable alternative to traditional trajectories. Collaborative training trajectories that meet the mentioned conditions are a reasonable response to the criticism on the lack of societal relevance for educating ever increasing numbers of PhD holders.

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7 The dynamics and long-term effects of multi-actor research programs

7.1 Brief summary

This dissertation started with the observation that multi-actor research programs are an increasingly popular form in which to organize scientific research. Multi-actor research programs link their research agendas to the grand challenges that contemporary societies face. Participants from different disciplinary, organizational and sectoral backgrounds are encouraged to collaborate on topics such as climate change, ageing society and food security. The resulting collaborative research practices should be sustained beyond the programs' lifespan in order to make science systems more responsive to these grand societal challenges.

Although multi-actor research programs are increasingly popular, there is not a lot of clarity on their organization and effects. For example, a systematic understanding of how these programs provide non-academic stakeholders with a role in scientific knowledge production is lacking. In addition, it is difficult to assess the long-term effects of these programs due to attributional and temporal issues. To fill these knowledge gaps and to strengthen the use of these programs as policy instruments, this dissertation raised two central questions:

- *How do multi-actor research programs organize collaborative research practices?*
- *Do multi-actor research programs have long-term effects on scientific knowledge production?*

To answer these questions we focused first on the organization of collaborative research practices and subsequently on the programs' long-term effects. Nine sub-questions were identified at the start of the dissertation. The answers and conclusions to these sub-questions are summarized below.

7.2 Collaborative research practices

Multi-actor research programs are expected to organize collaborations across disciplinary, organizational and sectoral boundaries. In this dissertation, the focus was on collaborations between participants from different organizational and sectoral backgrounds. In other words, collaborations between researchers from different disciplines were not studied in the context of this dissertation. For interesting studies on this aspect of multi-actor research programs see, for example, the work of Lyall and colleagues (Lyall and Fletcher 2013; Lyall et al. 2013). Our main findings and conclusions on collaborative research practices are summarized below.

7.2.1 Cross-organizational collaboration

The consortium approach of multi-actor research programs is seen as a means to organize collaborative research practices between organizations. In the literature, it is often assumed that the involvement of a consortium of organizations will result in what is known as 'network coordination'. Multi-actor research programs have readily been understood as a manifestation of a process of 'delegation to networks'. However, empirical studies of the actual coordination approaches of network organizations have been limited. Chapter 2 raised the following two sub-questions:

1. *What actual coordination approaches do multi-actor research programs develop?*
2. *How can we explain the development of a certain coordination approach?*

A systematic comparison of the actual coordination approaches of two Dutch research consortia showed that multi-actor research programs do not necessarily develop a network coordination approach. The two programs studied in Chapter 2 – Climate changes Spatial Planning and Next Generation Infrastructures – did apply network coordination attributes, but only to a limited extent and mainly in combination with other coordination attributes. Moreover, the coordination approaches of the two programs differed substantially. The case studies indicate that 'delegation to networks' as applied by multi-actor research programs is not an undifferentiated form of research coordination. The development of a certain coordination approach seems unrelated to the challenge-driven focus of a program. Internal consortium characteristics (such as the number of consortium partners and the relationships between them) appear to have the greatest influence on the development of a coordination approach by the consortia.

7.2.2 Cross-sectoral collaboration

Collaborations across sectors are expected to be stimulated by giving non-academic stakeholders a role in the knowledge production process. At the start of this dissertation, we identified two main gaps in the understanding of stakeholder involvement in multi-actor research programs. First, previous studies had already shown a wide variety of stakeholder activities in different parts of these programs, but a more systematic understanding of stakeholder involvement at different organizational levels and the links with research activities was lacking. Second, the diversity of possible stakeholder roles meant it was unclear which consortia policymakers should select in order to achieve the desired collaborative research practices. We subsequently raised the following four sub-questions:

3. *What roles do stakeholders play at the different levels of multi-actor research programs?*
4. *How are these different roles linked to the research activities in multi-actor research programs?*

5. *How are stakeholders involved in the design phase of a multi-actor research program?*
6. *To what extent is such involvement a predictor of their later involvement and financial contribution?*

Chapter 4 addressed the first two sub-questions. A typology was introduced based on a combination of three dimensions: (1) the direction of the flow of information between scientists and stakeholders, (2) the phase of the research process in which stakeholders are involved and (3) the nature of their contribution to the process. Application of the typology on climate adaptation programs in the US, Germany and the Netherlands confirmed that stakeholders play diverse roles in multi-actor research programs. By comparing programs in terms of the involvement of stakeholders at the various organizational levels, we identified different ways of linking stakeholders to the processes of scientific knowledge production: in the RISA program (US), research activities are driven by the involvement of individual stakeholders who express their needs at the detailed project level; in the KLIMZUG program (Germany), the cluster level serves as an interface for two separate pillars of projects (networking projects and research projects); and in Knowledge for Climate (the Netherlands), research starts with contributions of stakeholders at the most aggregate level which then trickles down to lower, more detailed organizational levels. Every approach to the organizing of stakeholder involvement has its strengths and weaknesses. Our typology provides policy-makers with an instrument to shape involvement in alignment with the overall policy aims. Further research is needed, however, into the effects of different approaches on program output (scientific and societal) (see the discussion in 7.4.3).

Chapter 5 focused on sub-questions 5 and 6 about selecting a consortium that will actually carry out collaborative research activities beyond sectoral boundaries. The study of 37 Dutch multi-actor research programs revealed that involvement in the design phase ranges from full involvement as part of the writing committee to no contribution to the program proposal at all. We subsequently found significant correlations between the degree of user involvement in the design phase and their involvement in decision-making at various program levels while the research was being carried out. The actual financial contribution of knowledge users correlates quite strongly with their intended contribution, as promised in the consortium proposal. In general, our findings suggest that ex-ante evaluation based on stakeholder involvement in the design phase is a possible and legitimate means to select consortia for multi-actor research programs. Governments aiming to stimulate cross-sectoral collaborations should select them on the basis of the degree of user involvement in the program design and the intended financial contribution.

7.2.3 Facilitators of collaborative research practices

The comparative case studies in Chapters 2, 4 and 5 revealed that there are large differences between multi-actor research programs in terms of the way they organize collaborative research practices (see e.g. the quite different coordination approaches of the two Dutch multi-actor research programs described in Chapter 2). At first glance, these findings suggest that there is no single typical multi-actor research program approach to organizing collaborations beyond organizational and sectoral boundaries. It is important to note, in this respect, that differences between programs are not necessarily due to different ideas about addressing societal challenges. The main differences between the multi-actor research programs studied appear to be related to either internal consortium characteristics (Chapters 2 and 5), such as the network composition of a consortium at the outset, or context characteristics related to national culture or the science system (Chapter 4, and see also Chapter 6), such as the level of controversy in a country about the issue of climate change.

However, in addition to differences *between* cases, this dissertation also revealed large differences *within* cases. For example, innovative and ambitious ways to involve stakeholders were found alongside traditional (Mode 1) research projects. Despite transdisciplinary objectives, traditional stakeholder roles, such as being informants and recipients, were still among the three most frequently occurring roles in the RISA, KLIMZUG and Knowledge for Climate programs (Chapter 4). Interviews with participants of the programs confirm previous studies on collaborative research practices that have found that participants often observe obstacles created by home institutions and other formal and informal institutions (such as evaluation schemes for scientific researchers) (Boon et al. 2014; Feldman and Ingram 2009; Jacobs 2002; McNie 2007; Turnhout et al. 2013).

This variety *within* multi-actor research programs and the dynamics observed in the interviews led to the conclusion that these programs share an organizational approach that stimulates collaborative research practices. Multi-actor research programs should be seen as 'facilitators' of collaborative research. Most of the effect of the programs studied on research practices is achieved by providing participants with opportunities to work in new ways, rather than by imposing and enforcing requirements. Most of the innovative examples of collaborative research practices in these programs come from participants who are intrinsically motivated and believe in this approach to grand societal challenges. By providing resources, network opportunities and a structure, multi-actor research programs do not make the above-mentioned obstacles disappear, but at least make them seem surmountable to such participants. A quote from a senior researcher from the NOAA RISA program is illustrative:

> [I]*n my regular research as a university professor I would do some of the work I do for* [the RISA project] *anyway, but the time to go out and meet and the travel funding and so on, to leave the university and go out and work with people and go to their meetings and so on.* […] *I can go and see them and go to meetings* […]*, which I otherwise probably would not be able to go'* (NOAA RISA, Senior researcher).

Hence, the findings in the chapters on collaborative research practices suggest that despite differences in organizational form a shared approach to organizing collaborative research does exist. Multi-actor research programs organize collaborative research by facilitating and providing motivated participants with opportunities to engage in activities that can be labelled as knowledge co-production, transdisciplinary research or post-normal science.

7.3 Long-term effects of multi-actor research programs

Multi-actor research programs are implemented with the ambitious objective of having long-term effects on the science system. The assessment of the long-term effects of research and innovation programs is a difficult endeavor. In this dissertation, we selected one important issue: the actual effects of these programs on the skills of participating PhD students, which were studied as an indicator of such long-term effects.

7.3.1 A new generation of PhD holders?

Multi-actor research programs create an environment for the professional and social development of large numbers of PhD students. These programs offer a different structure for PhD students, by defining different conditions and criteria for participation, formulating expectations in their missions and objectives, having a particular audience and involving a variety of participants. To assess whether this has an effect on the skills of participating PhD students, Chapter 6 raised the following three sub-questions:

7. *Is the set of skills developed by PhD students in multi-actor research programs different from the set of skills developed by PhD students in traditional trajectories?*
8. *Are differences between training trajectories in skill development related to individual characteristics and to training context?*
9. *What is the relationship between individual characteristics and training context characteristics and the development of different types of skill?*

To answer these sub-questions, a survey among 415 sustainability PhDs in both multi-actor research programs and traditional trajectories in the UK and the Netherlands was conducted. The survey covered questions on research practices and the development of four types of skill: (1) academic research skills, (2) academic communication skills, (3) translation and dissemination skills, and (4) transferable skills.

The comparison of skill development in multi-actor research programs and traditional trajectories in the UK and the Netherlands revealed no differences in academic skills but slightly higher dissemination, translation and transferable skills in multi-actor research program groups. A closer look at the individual and context characteristics of PhD students in the two trajectories showed that multi-actor research programs attract PhD students who have a more boundaryless mindset and a broader set of skills at the start of their project, and that they work in a more multi- and transdisciplinary research context. However, differences between multi-actor research groups on context characteristics indicate that these collaborative training trajectories are not uniform. This is in line with the observation that multi-actor research programs are facilitators rather than organizers of collaborative research practices, in other words, these programs provide opportunities for collaborative research practices instead of imposing them.

7.3.2 PhD skill development and future research practices

Socialization during the PhD phase of a research career can have long-term effects on a researcher's future working practices and future career path. Chapter 6 revealed that differences between groups of PhD students in multi-actor research programs and traditional trajectories in the UK and the Netherlands are small and not always significant. Does that mean that – via this mechanism – multi-actor research programs do not have long-term effects on future research practices? The answer to this question is twofold.

On the one hand, it has to be concluded that the effects of multi-actor research programs are smaller than what such programs aim for in their objectives and mission statements. Variety between and within multi-actor research programs on PhD training trajectories confirm the findings of the case studies in Chapters 2, 4 and 5. The empirical results of Chapter 6 indicate that large numbers of PhD students in multi-actor research programs experience socialization that is no different from the experiences of PhD students in a traditional training trajectory.

On the other hand, the analysis of skill development by PhD students also revealed that there are PhD students who are involved in collaborative research practices across organizational and sectoral boundaries. Once more, this is in line with the findings of the case studies on the organization of multi-actor research programs. By providing opportunities to work in collaborative ways, the programs facilitate PhD students who are intrinsically motivated, by providing them with a training trajectory that includes interaction with participants from other disciplines, organizations and sectors. Multivariate analysis revealed that such interactions do – apart from individual characteristics – contribute to the development of translation and dissemination skills, as well as transferable skills. By facilitating such trajectories for individual PhD students, multi-actor research programs do have effects beyond their own lifespan.

7.4 Limitations and future research

The approach of and studies in this dissertation have several limitations that provide directions for future research. Before drawing recommendations on the basis of the main findings of this dissertation, this section discusses three limitations and suggestions for future research.

7.4.1 From explorative research to theory building and testing

As mentioned in the introduction to this dissertation, multi-actor research programs are an increasingly popular organizational form for scientific research, but there is relatively little systematic understanding of their organization, dynamics and effects. This starting point resulted in two central research questions with an exploratory character: (1) How do multi-actor research programs organize collaborative research practices? and (2) Do multi-actor research programs have long-term effects on scientific knowledge production?

Because of the exploratory character of these questions, a case study approach was selected to answer most of the sub-questions of this dissertation. In addition, the studies build on theoretical insights of various sub-disciplines rather than on one overarching organizational theory of multi-actor research programs. This dissertation has taken some steps towards theory building, but many steps remain in relation to integrating theoretical components (e.g. on the relationship between organizational and sectoral collaborations) and ultimately testing these theoretical assumptions. In this respect, two strands of research appear to be most promising.

The analysis of the coordination of collaborative research practices revealed that network coordination of research programs is not an undifferentiated form of research coordination (Chapter 2). The comparison of two Dutch multi-actor research programs resulted in the conclusion that internal consortium characteristics determine – via the governance form – a consortium's actual coordination approach. Firstly, this conclusion should be empirically tested in comparable studies to determine the external validity of this finding. Secondly, in order to increase the explanatory reach of this conclusion, additional in-depth studies are needed into the relationships between: (1) the internal characteristics of consortia and the chosen governance form and (2) the governance form and a consortium's coordination approach. Together, these two research steps can result in a substantive, explanatory theory about the coordination approaches of multi-actor research programs.

The comparative studies of stakeholder involvement in multi-actor research programs revealed that the three programs studied use different approaches to stimulate cross-sectoral collaborations (Chapter 4). It is rather unlikely that the approaches to stakeholder involvement of all multi-actor research programs fit within these three models. Additional research is needed to take stock of other possible models of multi-actor research programs that link stakeholders to the processes of scientific knowledge production. Such research should result in a taxonomy of models that enables policymakers and program managers to select program proposals and research consortia with approaches to cross-sectoral collaborations that fit the overarching policy objectives.

7.4.2 Generalizability

The strong focus on climate (adaptation) programs in developed national science systems is a clear limitation of this study. The rationale for focusing on climate programs is that the environmental sciences have a rich history of collaborative research. This history provides a research setting that is to a certain extent mature (it did not start experimenting with this type of research only recently) and provides a rich population of programs from which to draw cases. The focus on national programs from developed science systems was chosen to reduce complexity. Multi-actor research programs are complex organizations with many dimensions and factors that potentially affect internal dynamics. An additional focus on international collaboration, for example, would have added additional – and at present unnecessary – complexity to the main research object; complexity that would have made the explorative research tasks even more difficult. However, to test the generalizability of the findings of this dissertation, future research is needed beyond the boundaries of focus chosen here. This requires studies of multi-actor research programs: (1) from scientific research fields with less collaborative research experiences, (2) from emerging science systems (e.g. China, Brazil, India) and less developed science systems (e.g. African countries) and (3) with participants from different countries (e.g. EU Framework Program projects).

7.4.3 Linking organizational forms to output indicators

One of the main findings of this dissertation is that multi-actor research programs differ in terms of organizational form. This triggers the questions: (1) What are the effects of organizational differences on the output of programs? and (2) What are the best organizational forms to achieve certain types of outcomes? These questions are beyond the scope of this dissertation, but deserve future research attention.

At present, interesting work is being conducted on the output side of multi-actor research programs. At least three strands of research can be identified in this respect: (1) research on the scientific output of these programs (Ingwersen and Larsen 2007; Koier and Horlings *under review*; Van den Besselaar and Sandstrom 2013), (2) research on the usability and societal impact of the knowledge produced in these programs (De Jong et al. 2012; De Jong et al. *under review*; Feldman and Ingram 2009; Kirchhoff 2013; Kirchhoff et al. 2013; McNie 2012; Merkx et al. 2012) and (3) research on the effects on participating organizations (e.g. organizational learning) (Boon et al. 2014; Crona and Parker 2012). The focus of these studies is either on specific parts of multi-actor research programs (e.g. Boon et al. 2014; Kirchhoff 2013) or on the program as a whole, without taking organizational differences between programs into account (e.g. Van den Besselaar and Sandstrom 2013, but see also Chapter 6 of this dissertation). Future research that links the findings on organizational differences with the work on the output of multi-actor research programs is therefore needed.

7.5 Recommendations

The current popularity of multi-actor research programs is an indication that these programs are likely to be an important part of the science system in the near future. The final part of this dissertation provides two distinct recommendations for the organization of future multi-actor research programs. The first recommendation concerns the selection and guidance of multi-actor research programs and is directly derived from the findings presented in the previous chapters. The second recommendation concerns the organization of collaborative research in the context of these programs. These are based on the studies presented in this dissertation, but also on additional observations, conversations and interviews conducted in the context of this research project (see e.g. Wardenaar 2013).

7.5.1 Selecting, guiding and learning from multi-actor research programs

Policymakers rely on multi-actor research programs because they can save on transaction costs and provide promising means to deal with the lack of scientific expertise among policymakers (Braun 2003; Lepori 2011). However, this dissertation shows that the selection, guidance and learning of these programs require more effort on the part of policymakers than is currently the case (Chapters 2, 4 and 5).

More time and effort spent on ex-ante evaluation of consortia compositions – and especially the role stakeholders have within a composition – will increase the likelihood that the consortium selected will contribute to the overall policy goal of addressing grand societal challenges. Three central questions have to be addressed during the selection procedure for a research consortium: (1) Does the consortium's composition reflect the diversity of the community involved? (2) Is there sufficient stakeholder involvement in the design phase of a multi-actor research program? (3) Is there sufficient proof of the intention of stakeholders to contribute (financially) to the multi-actor research program?

The guidance of and learning about multi-actor research programs are interrelated. Experience with and knowledge of multi-actor research programs will enable program management to address the grand organizational challenge of coordinating these programs. However, due to the temporary character of these programs, learning within the context of one multi-actor research program is limited. In many multi-actor research programs, the wheel is subsequently re-invented by new directors and program managers (e.g. this is what happened in many of the Bsik programs described in Chapters 2 and 5). As policymakers oversee multiple programs, they can – and should – organize more systematic learning processes that subsequently provide lessons and good practices for new programs.

7.5.2 Challenge-driven research should start with local problems

Multi-actor research programs are implemented to address grand societal challenges such as climate change, ageing society or food security. Collaborative research practices to address such challenges are most effectively stimulated by providing motivated participants with opportunities to work in collaborative ways (Section 7.2.3). However, interviews and conversations with participants revealed that a great deal of misunderstanding, confusion and frustration can occur within these programs. This may be due to the fact that many multi-actor research programs translate the overall challenge-driven objective into general requirements – that are inspiring for some participants but very burdensome to others. At the start of individual projects, project members often have very different expectations. In line with the conclusion that multi-actor research programs are 'facilitators' of collaborative research practices, I propose an adage that can serve as an organizing principle for multi-actor research programs:

> *Start from a local problem, select the right people, provide proper organization, and subsequently contribute to solving grand societal challenges.*

Different local problems require different approaches. A one-size-fits-all approach is not appropriate. Most crucial in this step is that the people who will work on the problem actually match with the characteristics and issues of the problem. Non-academic stakeholders should only participate when they have an actual stake in and concern about an issue. Academic participants should be motivated or believe in a challenge-driven approach to scientific knowledge production. In contrast to current practices in multi-actor research programs, it is important to spend more time and resources on selecting the right people, who want to and can do this work.

After the problem and the people are identified, programs should provide them with appropriate project organization. For example, in the case that no willing stakeholders are identified, do not force a knowledge coproduction process upon participants. An initial explorative study by academic participants could generate the necessary interest of stakeholders. A follow-up project can then be more interactive or transdisciplinary. In the case that stakeholder interest is not generated, it should be assumed that the topic is not yet ready to be studied in a transdisciplinary way. In addition, by providing the appropriate organization, programs can give much needed training and support. Many studies have revealed that the collaborative research approach is not a walk in the park, but an intensive and difficult process (Feldman and Ingram 2009; Jacobs 2002; Wardenaar 2013). Participants – academic and non-academic – can benefit enormously from such guidance and support. Relying on this adage as an organizing principle will enable multi-actor research programs to be more successful in facilitating participants and subsequently in organizing collaborative research practices.

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Nederlandse samenvatting

Het organiseren van gezamenlijk onderzoek: De dynamiek en langetermijneffecten van multi-actor onderzoeksprogramma's

Samenwerken aan de aanpak van de grote maatschappelijke uitdagingen

Relevantie, valorisatie en maatschappelijke impact zijn centrale thema's in de organisatie van het hedendaagse wetenschapssysteem. Beleidsmakers en onderzoeksfinanciers zetten een scala aan beleids- en financieringsinstrumenten in om wetenschappelijk onderzoekers aan te sporen het maatschappelijk nut van hun onderzoek te vergroten. Een in het oog springend beleidsinstrument zijn multi-actor onderzoeksprogramma's. Deze grootschalige onderzoeksprogramma's koppelen onderzoeksagenda's aan de grote maatschappelijke uitdagingen van deze tijd. Uitdagingen zoals klimaatverandering en vergrijzing zijn vertrekpunt en leidraad van het uit te voeren onderzoek.

Multi-actor onderzoeksprogramma's hebben een aantal onderscheidende kenmerken. Het vertrekpunt is, zoals reeds opgemerkt, een (maatschappelijk) thema – en dus niet de academische discipline. In onderling samenhangende werkpakketen en projecten wordt vervolgens gewerkt aan het onderzoek. Dit onderzoek wordt uitgevoerd door deelnemers van verschillende academische disciplines, organisaties en professies. Deelname aan multi-actor onderzoeksprogramma's is dus niet voorbehouden aan wetenschappelijk onderzoekers. De programma's trachten juist de belanghebbenden bij het thema (stakeholders) te betrekken bij de onderzoeksactiviteiten. De uitkomsten van het onderzoek moeten wetenschappelijk excellent, maar vooral ook direct in de praktijk toepasbaar te zijn.

Multi-actor onderzoeksprogramma's zijn populair. Een inventarisatie uitgevoerd bij aanvang van dit onderzoek laat zien dat in veertien van zestien onderzochte landen een multi-actor onderzoeksprogramma – op het gebied van klimaatonderzoek – is geïntroduceerd. Ondanks de groeiende populariteit is er veel onduidelijkheid over deze onderzoeksprogramma's. Hoe coördineren ze al die samenwerking? En wat zijn precies de bijdragen van die betrokken stakeholders? Om deze leemte op te vullen – en de effectiviteit van multi-actor onderzoeksprogramma's te vergroten – stelt dit proefschrift twee centrale onderzoeksvragen:

- *Hoe organiseren multi-actor onderzoeksprogramma's gezamenlijk onderzoek?*
- *Hebben multi-actor onderzoeksprogramma's langetermijneffecten op de productie van wetenschappelijke kennis?*

Het onderzoek in dit proefschrift richt zich specifiek op vier aspecten van multi-actor onderzoeksprogramma's:

1. het coördineren van onderzoeksactiviteiten;
2. de rol van stakeholders en hun invloed op het onderzoeksproces;
3. de ex-ante evaluatie en selectie van onderzoeksprogramma's;
4. de vaardigheden die deelnemende promovendi opdoen in de context van deze programma's.

De empirische focus ligt in het onderzoek op multi-actor onderzoeksprogramma's gericht op de aanpak van (de gevolgen van) klimaatsverandering. Klimaatonderzoek heeft een rijke traditie op het gebied van gezamenlijk onderzoek. De lessen die van klimaatprogramma's geleerd kunnen worden, hebben dus veel relevantie voor onderzoeksgebieden met minder ervaring op het gebied van gezamenlijk onderzoek.

Het organiseren van gezamenlijk onderzoek

Onderzoek in multi-actor onderzoeksprogramma's wordt uitgevoerd door deelnemers van verschillende (academische) disciplines, organisaties en professies. Dit vereist organisatie en coördinatie. Om inzicht te krijgen in de manier waarop deze onderzoeksprogramma's hier invulling aan geven, is eerst gekeken naar het coördineren van inter-organisatorische samenwerking, of te wel *cross-organizational collaboration* (hoofdstuk 2). Daarna is gekeken naar het organiseren van betrokkenheid en deelname van stakeholders, of te wel *cross-sectoral collaboration* (hoofdstuk 3 t/m 5).

Het coördineren van samenwerking tussen organisaties

Multi-actor onderzoeksprogramma's zijn consortia van organisaties. In de literatuur wordt er daarom vanuit gegaan dat deze programma's zogenoemde "netwerk organisaties" zijn en op overeenkomstige wijze samenwerking tussen organisaties coördineren. Netwerkcoördinatie betekent in dit opzicht een grote mate van zelforganisatie gebaseerd op gedeelde belangen en onderling vertrouwen. Een systematische vergelijking van de coördinatieaanpak van twee Nederlandse onderzoeksprogramma's – Klimaat voor Ruimte en Next Generation Infrastructures – laat zien dat dit onjuist is. Netwerkcoördinatie is onderdeel van de coördinatieaanpak van deze twee onderzoeksprogramma's, maar wel in combinatie met andere coördinatiemechanismen. De programma's verschillen bovendien sterk in hun coördinatieaanpak. Een belangrijke observatie in dit opzicht is dat er geen samenhang blijkt te zijn tussen coördinatieaanpak en het thematische uitgangspunt van een programma. De coördinatieaanpak lijkt vooral bepaald te worden door interne toevalligheden van het consortium.

De rol van stakeholders

Deelname van stakeholders is één van de meest in het oog springende eigenschappen van multi-actor onderzoeksprogramma's. Beleidsmakers en onderzoeksfinanciers hopen met de introductie van deze programma's de deelname van stakeholders aan wetenschappelijk onderzoek te vergroten. Deelname kan echter geïnterpreteerd worden als intensieve samenwerking maar ook als eenmalig contact. In dit proefschrift is daarom gekeken naar: (1) de rollen die stakeholders spelen in (de verschillende niveau's van) multi-actor onderzoeksprogramma's; en (2) de mogelijkheid om aan de hand van ex-ante evaluatie een programma te selecteren dat de gewenste betrokkenheid zal organiseren.

Om inzicht te verschaffen in de rollen die stakeholders spelen in multi-actor onderzoeksprogramma's introduceert dit proefschrift een typologie gebaseerd op drie dimensies: (1) de richting waarin informatie tussen wetenschappelijk onderzoeker en stakeholder stroomt; (2) de onderzoeksfase waarin een stakeholder betrokken is; en (3) het soort bijdrage dat door een stakeholder geleverd wordt. De typologie wordt in het proefschrift toegepast op drie multi-actor onderzoeksprogramma's, d.w.z. NOAA's RISA programma (Vereningde Staten), KLIMZUG (Duitsland), en Kennis voor Klimaat (Nederland). Het toepassen van de typologie op deze programma's laat zien dat multi-actor onderzoeksprogramma's verschillende modellen hebben om stakeholders een rol te geven in de productie van wetenschappelijke kennis: in het RISA programma leveren individuele stakeholders een bijdrage aan individuele projecten waarin ze hun kennisbehoeften en -vragen formuleren; in het KLIMZUG programma voltrekken kennisontwikkeling en stakeholderbetrokkenheid zich in parallelle programma-lijnen die samengebracht worden in zogenoemde clusters of platformen; in het Kennis voor Klimaat programma zijn stakeholders betrokken op het hoogste aggregatieniveau (het formuleren van programmadoelstellingen) waarbij hun inbreng doorsijpelt naar alle onderdelen van het programma.

Is van te voren te bepalen of een consortium inderdaad stakeholders betrekt bij de onderzoeksactiviteiten in het programma? Om die vraag te beantwoorden zijn in dit proefschrift de voorstellen en eindevaluaties van 37 Nederlandse multi-actor onderzoeksprogramma's vergeleken. De programma's werden allemaal gefinancierd vanuit de Bsik-regeling (*Besluit Subsidies Investeringen Kennisinfrastructuur*). Deelname van stakeholders aan het opstellen van het voorstel en financiële toezeggingen van niet-academische organisaties blijken indicatoren voor stakeholderbetrokkenheid tijdens het programma: stakeholders zijn meer betrokken in programma's waar stakeholders ook een rol speelden bij het opstellen van het voorstel; financiële toezeggingen hangen samen met de uiteindelijke financiële bijdragen van stakeholderorganisaties.

Faciliteren van gezamenlijk onderzoek

De studies in hoofdstukken 2 t/m 5 laten veel verscheidenheid zien in de organisatie van gezamenlijk onderzoek, zowel tussen als binnen multi-actor onderzoeksprogramma's. Deze verscheidenheid wordt deels bepaald door een gedeelde eigenschap van de programma's. Succesvolle en innovatieve voorbeelden van gezamenlijk onderzoek worden niet afgedwongen, maar komen vooral tot stand omdat gemotiveerde deelnemers kansen krijgen om op een andere manier te gaan werken. Multi-actor onderzoeksprogramma's bieden middelen, netwerkmogelijkheden en een structuur die gemotiveerde deelnemers gebruiken om samen aan de aanpak van de grote maatschappelijke uitdagingen te werken. Deze programma's organiseren gezamenlijk onderzoek door te faciliteren, hetgeen verklaard waarom de verscheidenheid tussen en binnen programma's zo groot is.

Langetermijneffecten van multi-actor onderzoeksprogramma's

Multi-actor onderzoeksprogramma's worden geïmplementeerd met de ambitie het wetenschapssysteem te veranderen, d.w.z. ze moeten op de lange termijn resulteren in meer interactie met en een beter aansluiting op de praktijk. Studie naar de langetermijneffecten van deze generatie innovatieprogramma's is lastig. We zijn afhankelijk van indicatoren omdat deze effecten in de toekomst liggen. In dit proefschrift is daarom onderzoek gedaan naar de vaardigheden die deelnemende promovendi opdoen in de context van deze programma's.

Een nieuwe generatie doctors?

In veel multi-actor onderzoeksprogramma's participeren promovendi. De programma's bieden promovendi een specifieke structuur voor hun professionele en sociale ontwikkeling: afwijkende condities en criteria voor deelname; onderzoeksvragen gericht op maatschappelijke uitdagingen; een breder publiek; betrokkenheid van stakeholders en onderzoekers uit andere vakgebieden. Heeft deze structuur effect op de vaardigheden die deelnemende promovendi ontwikkelen? En vooral, zijn de vaardigheden die deelnemende promovendi ontwikkelen anders dan de vaardigheden die promovendi in traditionele opleidingstrajecten ontwikkelen? Om deze vragen te beantwoorden is een vragenlijstonderzoek uitgevoerd onder 415 promovendi in Nederland en Groot-Brittannië (hoofdstuk 6). De promovendi richten zich allen op duurzaamheidsonderzoek. Ongeveer de helft participeert in een multi-actor onderzoeksprogramma, de andere helft in een traditioneel opleidingstraject.

De vergelijkende studie naar de ontwikkeling van vaardigheden van promovendi in multi-actor onderzoeksprogramma's en promovendi in traditionele opleidingstrajecten laat zien dat de verschillen op het gebied van academische vaardigheden klein zijn. Promovendi in multi-actor onderzoeksprogramma's ontwikkelen wel meer communicatie, disseminatie en professionele (bijv. project management) vaardigheden. Promovendi in multi-actor onderzoeksprogramma laten zich overigens minder begrenzen door organisatorische afbakeningen (*boundaryless mindset*) en zijn pro-actiever. Deze individuele eigenschappen dragen sterk bij de ontwikkeling van vaardigheden. Het dient opgemerkt te worden dat ook op dit punt verschillen tussen en binnen multi-actor onderzoeksprogramma's groot zijn. De observaties in hoofdstuk 6 sluiten dan ook goed aan bij de hierboven getrokken conclusie dat multi-actor onderzoeksprogramma's gemotiveerde deelnemers faciliteert om gezamenlijk onderzoek uit te voeren.

Vaardigheden en de langetermijneffecten van multi-actor onderzoeks-programma's

Promotieonderzoek is – meestal – de eerste stap in een (wetenschappelijke) carrière. Socialisatie tijdens deze carrièrestap heeft effect op het verdere verloop van de loopbaan en de manier waarop iemand werkt (*working practices*). Hoofdstuk 6 laat op dit punt zien dat de verschillen tussen promovendi in multi-actor onderzoeksprogramma's en in traditionele opleidingstrajecten niet groot zijn. Hieruit volgt de conclusie dat het lange termijn effect van multi-actor onderzoeksprogramma op de manier waarop onderzoek gedaan wordt in de toekomst kleiner is dan verwacht. Het is op basis van dit onderzoek niet aannemelijk dat verandering zoals geformuleerd in de doelstellingen van veel multi-onderzoeksprogramma's bereikt zal worden door deze generatie programma's alleen.

Het is belangrijk om hierbij gelijk de kanttekening te maken dat een aanzienlijk deel van de promovendi in multi-actor onderzoeksprogramma wel degelijk een ander socialisatieproces doormaakt. Promovendi die gemotiveerd zijn om hun promotieonderzoek in lijn met de doelstellingen van een multi-actor onderzoeks-programma te verrichten, hebben meer interacties met deelnemers van ander (academische) disciplines, organisaties en professies. Multivariate analyses laten zien dat deze aspecten bijdragen aan de ontwikkeling van communicatie, disseminatie en professionele vaardigheden. Door zulke promotietrajecten te faciliteren hebben de programma's dus wel degelijk langetermijneffecten op de manier waarop onderzoek uitgevoerd wordt.

Aanbevelingen

Multi-actor onderzoeksprogramma's zijn populair en zullen in de nabije toekomst onderdeel blijven van het wetenschapssysteem. Dit onderzoek biedt inzicht in de organisatie van deze grootschalige onderzoeksprogramma's. Naar aanleiding van dit inzicht en bovenstaande conclusies, sluit dit proefschrift af met twee typen aanbevelingen voor de organisatie van toekomstige multi-actor onderzoeksprogramma's.

Selecteren, begeleiden en leren van multi-actor onderzoeksprogramma's

Beleidsmakers en onderzoeksfinanciers zetten multi-actor onderzoeksprogramma's in om wetenschappelijk onderzoekers aan te sporen het maatschappelijk nut van hun onderzoek te vergroten. Multi-actor onderzoeksprogramma maken daarbij gebruik van de expertise in het veld en zouden in theorie resulteren in lagere transactiekosten. Dit proefschrift laat echter zien dat het selecteren, begeleiden en leren van deze programma's meer aandacht en inspanningen van beleidsmakers behoeft (hoofdstukken 2, 4 en 5).

In de eerste plaats geldt dit voor de ex-ante evaluatie van consortia. Meer aandacht voor de rol van stakeholders in het consortium vergroot de waarschijnlijkheid dat een programma bijdraagt aan de aanpak van maatschappelijke uitdagingen. Bij de selectie van een consortium zouden drie vragen centraal moeten staan: (1) komt de samenstelling van het consortium overeen met de diversiteit van de belanghebbenden?; (2) is er voldoende stakeholder betrokkenheid in de voorstelfase van een multi-actor onderzoeksprogramma?; (3) hebben betrokken stakeholders de intentie om financieel bij te dragen aan een multi-actor onderzoeksprogramma?

Meer begeleiding van multi-actor onderzoeksprogramma's en het leren van lessen hangt samen. Ervaring en kennis van multi-actor onderzoeksprogramma's stellen programmamanagement in staat een programma succesvol te coördineren. Veel programmadirecteuren en –managers ontberen dit aan het begin van een programma, omdat veel programma's een tijdelijk karakter hebben. Het wiel wordt op dit moment steeds opnieuw uitgevonden bij de start van een nieuw programma. Beleidsmakers dienen te zorgen voor organisatorisch leervermogen: lessen uit afgeronde programma's moeten worden meegenomen bij nieuwe programma's (bijv. door actievere begeleiding).

Multi-actor onderzoeksprogramma's dienen te starten met lokale problemen
Multi-actor onderzoekprogramma's worden geïntroduceerd om onderzoeksagenda's te koppelen aan de grote maatschappelijke problemen, zoals klimaatverandering en vergrijzing. De meest succesvolle en innovatieve voorbeelden van gezamenlijk onderzoek in multi-actor onderzoeksprogramma's komen tot stand omdat gemotiveerde deelnemers worden gefaciliteerd. De ambitieuze doelstellingen van de programma's worden door sommige deelnemers opgepakt, maar door andere deelnemers dus ook niet. Verwachtingen binnen programma's lopen uiteen waardoor er binnen deze programma's ook veel onbegrip, verwarring en frustratie voorkomt.

Multi-actor onderzoeksprogramma's zouden gebaat zijn bij een organisatieaanpak die aansluit bij hun sterkte, d.w.z. het faciliteren van gemotiveerde deelnemers. Het onderstaande adagium zou hierbij leiden dienen te zijn:

> *Start met een lokaal probleem, selecteer de juiste (gemotiveerde) deelnemers, voorzie de deelnemers van een organisatie en goede begeleiding, en draag met geleerde lessen bij aan de aanpak van maatschappelijke vraagstukken.*

Verschillende lokale problemen vragen verschillende benaderingen. Gezamenlijk onderzoek past niet direct bij ieder lokaal probleem. Een cruciale organisatiestap is het selecteren van deelnemers die aansluiten bij het probleem dat zich aandient. Op dit moment wordt er echter weinig aandacht besteed aan het selecteren van de juiste mensen bij individuele projecten. Niet-academische deelnemers zouden alleen moeten participeren als ze een werkelijk belang en belangstelling hebben in het probleem. Academische deelnemers dienen gemotiveerd te zijn om deel te nemen aan gezamenlijke onderzoek.

Nadat probleem en deelnemers zijn geïdentificeerd, kunnen programma's ze ondersteunen met een goede projectorganisatie en begeleiding. In het geval dat er geen (juiste) stakeholders zijn geïdentificeerd, zou gezamenlijk onderzoek niet afgedwongen moeten worden. Een eerste exploratieve studie door de deelnemende academische onderzoekers kan de interesse van stakeholders opwekken. Een vervolgstudie kan dan een meer interactief karakter krijgen. Indien interesse van stakeholders uitblijft, dan is het onderwerp klaarblijkelijk (nog) niet geschikt voor gezamenlijk onderzoek. Ten slotte: tijdens het proces van gezamenlijk onderzoek, zouden multi-actor onderzoeksprogramma's meer ondersteuning en advies moeten leveren.

Appendix A

Interview protocols "Varieties of research coordination: A comparative analysis of two multi-actor research programs"

Climate changes Spatial Planning

Inleiding
- Wat is je achtergrond en hoe ben je betrokken geraakt bij KvR?
- Wat is je functie in het programma? En welke manier vul je dit in? Hoe kijk je er tegenaan?

Organisatie KvR
- Wat is de doelstelling van het thema? En welke rol heeft het thema in het programma?
- Op welke manier is de onderzoeksagenda van jouw thema tot stand gekomen?
- Op welke manier zijn de projecten/onderzoekers geselecteerd?
- Wordt het onderzoek in jouw thema gemonitord/geevalueerd? Op welke punten en door wie?
- Is er veel contact tussen de projecten in het thema? Heb jezelf veel informeel contact met de projecten?
- Je hebt ook zitting in de programmaraad; wat is het doel van deze raad? Vindt hier afstemming tussen de thema's plaats? Beslissingen en conflicten?

Maatschappelijke actoren
- Zijn er bij het thema maatschappelijke actoren (i.e. niet-wetenschappelijke organisaties) betrokken?
- Op welke manier zijn deze organisaties betrokken geraakt?
- Merk je in de samenwerking dat deze maatschappelijke organisaties een andere manier hebben waarop beslissingen worden genomen?
- Merk je in de samenwerking dat individuele werknemers in deze maatschappelijke organisaties meer/minder handelingsvrijheid hebben?
- Wat zijn de motivaties en verwachtingen van deze organisaties over de samenwerking? Wat vinden deze organisaties belangrijk in het onderzoek/in de resultaten?

Wetenschappers en samenwerking
- Hoe ervaren wetenschappers de samenwerking met maatschappelijke actoren?
- Is de nadruk op maatschappelijke relevantie (en op samenwerking) een extra druk/belasting voor betrokken wetenschappers?
- Wat is de rol van de themaleider in dit samenwerkingsproces?

- Welke groep (wetenschappers of maatschappelijke actoren) is het moeilijkst om “bij de les te houden”?

Next Generation Infrastructures

Inleiding

- Wat is je achtergrond en hoe ben je betrokken geraakt bij NG Infra?
- Wat is je functie in het programma? En welke manier vul je dit in? Hoe kijk je er tegenaan?

Organisatie NG Infra

- Wat is de doelstelling van het thema/project? En welke rol heeft het thema/project in het programma?
- Op welke manier is de onderzoeksagenda van jouw thema/project tot stand gekomen?
- Op welke manier zijn de projecten/onderzoekers geselecteerd?
- Wordt het onderzoek in jouw thema/project gemonitord/geëvalueerd? Op welke punten en door wie?
- Is er veel contact tussen de projecten in het thema? Heb je veel informeel contact met de projecten?
- Is er overleg tussen themacoördinatoren en programmamanagement (bijv. via een programmaraad)? Zorgt het programma voor afstemming tussen projecten? Beslissingen en conflicten?

Maatschappelijke actoren

- Zijn er bij jouw thema/project maatschappelijke actoren (i.e. niet-wetenschappelijke organisaties) betrokken?
- Op welke manier zijn deze organisaties betrokken geraakt?
- Merk je in de samenwerking dat deze maatschappelijke organisaties een andere manier hebben waarop beslissingen worden genomen?
- Merk je in de samenwerking dat individuele werknemers in deze maatschappelijke organisaties meer/minder handelingsvrijheid hebben?
- Wat zijn de motivaties en verwachtingen van deze organisaties? Wat vinden deze organisaties belangrijk in het onderzoek/in de resultaten?

Wetenschappers en samenwerking

- Hoe ervaren wetenschappers de samenwerking met maatschappelijke actoren?
- Is de nadruk op maatschappelijke relevantie (en op samenwerking) een extra druk/belasting voor betrokken wetenschappers?
- Wat is jouw rol in dit samenwerkingsproces?
- Welke groep (wetenschappers of maatschappelijke actoren) is het moeilijkst om “bij de les te houden”?

Appendix B

Interview protocols "Developing a typology of stakeholder roles in challenge-driven research programs and its application to climate adaptation programs in the US, Germany and the Netherlands"

Participating stakeholders

Introduction
- What is your background and current position? Can you briefly describe the organisation where you are working?

Motivations and expectations:
- How did your organisation get involved in [NAME PROJECT]?
- What was the reason for your organisation to get involved in the project?
- What were your expectations of your involvement in the project?

Collaborations
- In what phases of [NAME PROJECT] are you involved (e.g. research ques-tions, research tasks, performing research, conclusions, and implementation)? In what way (what is your role?)?
- How often do you have contact with the scientists from this project?
- On what output is this project focused? What are the main publics/target groups of this project?
- What output is already produced by the project? Does your organisation make use of the knowledge produced in the project? Has your organization implemented results of the project?

Outcomes
- Are you satisfied with the collaboration with scientists in [NAME PROJECT]?
- Do you perceive a cultural difference between scientists and stakeholders in the project?
- Were the scientists open for your input (e.g. for your questions, suggestions, practical knowledge)?
- Did you have influence on the research processes in the project (e.g. research agenda, research focus)?
- Did you perceive an area of tension between scientific ambitions of the scientists and project's emphasis on science-society collaboration? Does this influence the work in [NAME PROGRAM]?
- Are the results of the project usable for your organisation?
- Does the project so far match your expectations?

Participating scientists

Introduction
- What is your background and current position?

Description of project and research practice
- Could you describe the project(s) within [NAME PROGRAM] that you are working in? What is your role in this project?
- Why was [NAME PROJECT] initiated? How does it relate to [NAME PROGRAM]? What are [NAME PROGRAM] requirements?
- Who do you see as the main stakeholders? Are these stakeholders involved?
- How did these stakeholders got involved in the project? What was their motivation to participate? What expectations?
- What does stakeholder involvement consist of in your project? At what phases of the research process did you have contact with stakeholders (articulation of research questions, define research tasks, perform research, interpret conclusions and results, etc.)?
- Can you make an estimate of the frequency you meet with these stakeholders (e.g. average per month)?
- Did your work in the project already lead to output/results? What kind of output/results?
- Is it part of the project to make outcomes usable for the involved stakeholders? How do you do this?
- What do you see as the most valuable output of your work within [NAME PROGRAM]?

Motivations and incentives
- When you look at the work and processes in [NAME PROJECT]; are these different from your other research activities?
- What was your motivation to get stakeholders involved in the project? Personal or organisational? Who do you consider as the most important public of your work?
- Is your work monitored/evaluated by [NAME PROGRAM]? On what?
- What is the value of [NAME PROGRAM] for you as a researcher?

National science system
- Is collaboration between scientists and non-academic stakeholders common in climate programs in [NAME COUNTRY]?
- What is the position of [NAME PROGRAMS] in the organization of climate science in your country? (e.g. exception or typical climate science program)?
- Are "societal relevant" or "usable" scientific outcomes considered in the evaluation systems of scientific research in [NAME COUNTRY]?
- Or, are these evaluations mainly based on bibliometric indicators

(publications, citations, etc.)?
- Do you perceive an area of tension between scientific excellence and social relevance? Does this influence your work in [NAME PROGRAM]?

Program management

Introduction
- What is your background and current position?

Description of [NAME PROJECT]
- What is the objective / aim of [NAME PROJECT]?
- Why was it initiated? By whom?
- How did you come up with this structure (specificeren per project)?
- Why these themes/sectors/etc.
- How is the research agenda of this project being defined and developed?
- Are there special requirements by [NAME PROGRAM]? (On what? Stakeholder? Societal relevance?)
- Is [NAME PROGRAM] the sole funding source of the project?

Collaborations between scientists and stakeholders
- What does stakeholder driven research (or stakeholder collaboration) mean in [NAME PROJECT]?
- How did these stakeholders got involved in the project?
- What was their motivation to participate? What expectations?
- What is the input / value of stakeholders in this project? Examples?
- Can you make an estimate of the average frequency of contact with stakeholders?
- To what extent are the projects different from other projects you are familiar with? In what way? Examples?
- What are the motivations of scientists to participate in the project?
- Did the project already lead to output/results?
- What kind of output/results?
- Is it part of the project to make outcomes usable for the involved stakeholders?
- How is this done? By whom?

National science system
- Is collaboration between scientists and non-academic stakeholders common in climate programs in [NAME COUNTRY]?
- What is the position of [NAME PROGRAMS] in the organization of climate science in your country? (e.g. exception or typical climate science program)?
- Are “societal relevant” or “usable” scientific outcomes considered in the evaluation systems of scientific research in [NAME COUNTRY]?

- Or, are these evaluations mainly based on bibliometric indicators (publications, citations, etc.)?
- Do you perceive an area of tension between scientific excellence and social relevance? Does this influence your work in [NAME PROGRAM]?

Appendix C

Surveys "Skill development in collaborative research projects: A comparison between PhD candidates in multi-actor research programs and in traditional trajectories"

The Netherlands

Question V001
To start with, we would like to learn about the setting in which you work on your PhD project. In case that you have already finished your PhD, please answer according to your experiences and circumstances during the PhD trajectory.

What is the name of the university to which you are affiliated?

1 : Delft University of Technology
2 : Eindhoven University of Technology
3 : Erasmus University Rotterdam
4 : Leiden University
5 : Maastricht University
6 : Open University in the Netherlands
7 : Radboud University Nijmegen
8 : Tilburg University
9 : University of Amsterdam
10 : University of Groningen
11 : University of Twente
12 : Utrecht University
13 : VU University Amsterdam
14 : Wageningen University

Question V002
What is your daily work location? (Multiple answers possible)

1 : The university selected above
2 : A different university
3 : A public research organisation
4 : A governmental organisation
5 : A business or industrial organisation
6 : An NGO
7 : Home
8 : Other, please specify:

Question V003
Which of the statements below best describes your position as a PhD candidate?

1 : I am employed as a PhD candidate (i.e. by a university or a public research organisation)
2 : I am an external PhD candidate (buitenpromovendus)
3 : I am a student (with stipend, bursary or grant)
4 : I am a student (my own funding)
5 : Other, please give details:

Question V004
How is your position financed? (Multiple answers possible)

1 : By a BSIK programme (e.g. Climate changes Spatial Planning (KvR))
2 : By a FES programme (e.g. Knowledge for Climate)
3 : By a university
4 : By a public research organisation
5 : By a research council (NWO)
6 : By European research funding (e.g. FP, ERC)
7 : By a charitable fund
8 : By a governmental organisation (national, regional, local, European)
9 : By business or industry
10 : By an NGO
11 : Other, please give details:
12 : I don't know

Question V005
The following two questions relate to the research proposal of your PhD project. By research proposal, we mean a document that provides a detailed description of the proposed PhD project (i.e. research questions, work planning, research methods, theoretical framework, etc.).

Which of these statements best describes the situation at the start of your PhD project?

1 : There was from the beginning a full research proposal (with research questions, work planning, research methods, theoretical framework, etc.)
2 : There was a brief research proposal that was to be developed further
3 : There was no research proposal, but a research idea/ direction/ topic in place
4 : I did not have a research topic and had yet to work out the direction of my PhD project

Question V006
Who wrote the main part of your research proposal?

1 : I did
2 : My supervisor(s) did
3 : Someone else did
4 : I don't have a research proposal
5 : Don't know

Question V007
Do you conduct research on your PhD project in the context of a research team?

1 : Yes, I am part of a large research team (10 or more people including supervisors, senior researchers and post docs)
2 : Yes, I am part of a small research team (fewer than 10 people including supervisors, senior researchers and post docs)
3 : No, but I work in close collaboration with my supervisors
4 : No, I work individually, with some input from my supervisors

Question V008A
In which field(s) of research are you working?
(Multiple answers are possible)

1 : Agricultural sciences / Natural resources
2 : Astronomy
3 : Atmospheric science & meteorology
4 : Biological / Biomedical sciences
5 : Business management / administration
6 : Chemistry
7 : Communication
8 : Computer & Information sciences
9 : Education, Teaching & STS / Science Studies
10 : Engineering
11 : Geological & Earth Sciences
12 : Health sciences
13 : Humanities
14 : Mathematics
15 : Ocean / Marine Sciences
16 : Physics
17 : Psychology
18 : Social Sciences
19 : Other, please specify:

Question V008B
In which field(s) of research are the academic researchers you work with working (e.g. supervisors, co-authors, project members)?
(Multiple answers are possible)

1 : Agricultural sciences / Natural resources
2 : Astronomy
3 : Atmospheric science & meteorology
4 : Biological / Biomedical sciences
5 : Business management / administration
6 : Chemistry
7 : Communication
8 : Computer & Information sciences
9 : Education, Teaching & STS / Science Studies
10 : Engineering
11 : Geological & Earth Sciences
12 : Health sciences
13 : Humanities
14 : Mathematics
15 : Ocean / Marine Sciences
16 : Physics
17 : Psychology
18 : Social Sciences
19 : Other, please specify:

Question V009
The following set of questions is about stakeholder involvement. Stakeholders are increasingly involved in academic research. By stakeholders we mean non-academic actors that are directly or indirectly affected by your research and who could affect the implementation of the findings of your research (e.g. governmental organisations, NGOs, industry, consultants, public research organisations, etc.).

What statement best describes the involvement of stakeholders in your PhD project?

1 : Only academic researchers work in the project; stakeholders are not involved
2 : Only academic researchers work in the project, but stakeholders are involved in specific, relevant activities
3 : Academic researchers lead the project, but stakeholders are also part of the project
4 : Academic researchers and stakeholders work jointly in the project in an equal relationship

5 : Stakeholders lead the project, but academic researchers are also involved

Question V010
Please specify the types of stakeholders that are involved in your PhD project. (Please select all options that apply)

1 : Public research organisation(s)
2 : Governmental organisation(s)
3 : NGO(s)
4 : Business, industry, private sector, consultants
5 : Other(s), please specify:

Question V011
What kind of direct influence do stakeholders have on the following research activities in your project?

"Formulating research questions"
"Setting up the research design"
"Doing the actual research"
"Discussing and interpreting outcomes"
"Communicating research outcomes"

1 : little or no influence
2 : a limited influence
3 : some influence
4 : a considerable influence
5 : a great influence

Question V012
During you PhD project, how many times have you been involved in the following activities:

"Attending academic conferences"
"Helping organise academic conferences or workshops"
"Interacting with visiting scholars"
"Reviewing academic articles"
"Attending policy, industry or business meetings"
"Helping organise events for policy, industry or business"
"Giving workshops or training to professionals from policy, industry or business"
"Advising to policy, industry or business"

1 : 0
2 : 1
3 : 2
4 : 3
5 : 4
6 : >= 5

Question V013
Which of the following outputs have resulted from your PhD project so far? (Please quantify)

"Written publication for an academic audience (e.g. journal article, book (or chapter), etc.)"
"Written publication for a professional audience (e.g. advisory report, a piece in a professional journal, decision tool, protocol, etc.)"
"Written publication for the general public (e.g. newspaper, news-magazine)"
"Oral presentation for an academic audience"
"Oral presentation for a professional audience"
"Oral presentation for a broad audience (e.g. popularising lecture)"

1 : 0
2 : 1
3 : 2
4 : 3
5 : 4
6 : >= 5

Question V014
Have you participated in a course on any of the following topics during your PhD project?

"Theories for my subject"
"Research methods for my subject"
"Academic communication (e.g. presenting, writing)"
"Teaching"
"Project management"
"Personal efficiency / time management"
"Career development"
"Networking"

1 : No
2 : Yes

Question V015
Please indicate (in percentages) the amount of working time you spend or spent on teaching during your PhD project.

1 : None (no teaching)
2 : Less than 10%
3 : 10% to 20%
4 : 20% to 30%
5 : 30% to 40%
6 : 40% to 50%
7 : 50% or more

Question V016A
PhD candidates develop different skills during their PhD projects. The following questions relate to the set of skills you have acquired and your assessment of them.

Please rate your level for the following skills at the start of your PhD.

"Reviewing academic work"
"Keeping up to date on developments in your academic specialisation"
"Taking initiative"
"Working in a team with a division of tasks"
"Getting articles published"
"Developing and maintaining work relations with people from government"
"Contributing to public debates related to your research topics (e.g. blogs, radio, social media, op-eds)"

1 : No experience
2 : Poor
3 : Sufficient
4 : Satisfactory
5 : Good
6 : good
7 : Excellent

Question V016B
Please rate your level for the following skills now.

"Reviewing academic work"
"Keeping up to date on developments in your academic specialisation"
"Taking initiative"
"Working in a team with a division of tasks"

"Getting articles published"
"Developing and maintaining work relations with people from government"
"Contributing to public debates related to your research topics (e.g. blogs, radio, social media, op-eds)"

1 : No experience
2 : Poor
3 : Sufficient
4 : Satisfactory
5 : Good
6 : Very good
7 : Excellent

Question V017A
Please rate your level for the following skills at the start of your PhD.

"Working with targets defined by management / senior staff"
"Getting your findings implemented outside the academic world"
"Ability to formulate a good research question"
"Supporting the education of professionals (e.g. through workshops, other activities)"
"Writing proposals for research funding / grants"
"Developing and maintaining work relations with people from industry / business"
"Project management"

1 : No experience
2 : Poor
3 : Sufficient
4 : Satisfactory
5 : Good
6 : Very good
7 : Excellent

Question V017B
Please rate your level for the following skills now.

"Working with targets defined by management / senior staff"
"Getting your findings implemented outside the academic world"
"Ability to formulate a good research question"
"Supporting the education of professionals (e.g. through workshops, other activities)"

"Writing proposals for research funding / grants"
"Developing and maintaining work relations with people from industry / business"
"Project management"

1 : No experience
2 : Poor
3 : Sufficient
4 : Satisfactory
5 : Good
6 : Very good
7 : Excellent

Question V018A
Please rate your level for the following skills at the start of your PhD.

"Working independently"
"Linking your work to relevant theories within your academic specialisation"
"Presenting your findings to a non-academic audience"
"Showing leadership"
"Application of proper research methods and techniques"
"Developing and maintaining relations with colleagues and peers in the wider research community."
"Analytical reasoning"

1 : No experience
2 : Poor
3 : Sufficient
4 : Satisfactory
5 : Good
6 : Very good
7 : Excellent

Question V018B
Please rate your level for the following skills now.

"Working independently"
"Linking your work to relevant theories within your academic specialisation"
"Presenting your findings to a non-academic audience"
"Showing leadership"
"Application of proper research methods and techniques"

"Developing and maintaining relations with colleagues and peers in the wider research community."
"Analytical reasoning"

1 : No experience
2 : Poor
3 : Sufficient
4 : Satisfactory
5 : Good
6 : Very good
7 : Excellent

Question V019
The following section relates to your future career choices. There is a wide range of career options after completing a PhD degree.

Please indicate to what extent you have an interest or desire for each of the following positions:

"Research position in a college or university"
"Research position in business, industry or the private sector"
"Research position in a non-profit organisation or government agency"
"Teaching position in a college or university setting"
"Teaching position, but not in a college or university setting"
"Non-research / non-teaching position in a college or university"
"Non-research / non-teaching position in business, industry or the private sector"
"Non-research / non-teaching position in a non-profit organisation or government agency"

1 : little or no extent
2 : a limited extent
3 : some extent
4 : a considerable extent
5 : a great extent

Question V020
Based on your current level of skill, expertise and knowledge - to what extent would it be realistic for you to pursue the following positions:

"Research position in a college or university"
"Research position in business, industry or the private sector"
"Research position in a non-profit organisation or government agency"

"Teaching position in a college or university setting"
"Teaching position, but not in a college or university setting"
"Non-research / non-teaching position in a college or university"
"Non-research / non-teaching position in business, industry or the private sector"
"Non-research / non-teaching position in a non-profit organisation or government agency"

1 : little or no extent
2 : a limited extent
3 : some extent
4 : a considerable extent
5 : a great extent

Question V021
PhD career interests can often be driven by personal preferences.

Could you please indicate the extent to which you agree with the following statements?

"I am constantly on the lookout for new ways to improve my life"
"I enjoy jobs that require me to interact with people outside my organisation"
"I am always looking for better ways to do things"
"I seek job assignments that allow me to learn something new"
"I am energised by new experiences and situations"
"Nothing is more exciting than turning my ideas into reality"
"I like tasks at work that require me to work outside my own department"
"If I believe in something I will make it happen"

1 : little or no extent
2 : a limited extent
3 : some extent
4 : a considerable extent
5 : a great extent

Question V022
These next questions are about your academic supervisor.

In this context academic supervisor means an actor in a senior academic position who aids and guides you in your PhD project.

How often do you speak about your PhD project with your academic supervisor (in the case of multiple academic supervisors, take the one you have the most contact with):

1 : At least once per week
2 : At least once every two or three weeks
3 : Every month or two
4 : Infrequently

Question V023
Supervisors take very different approaches. For each of these statements, please indicate the extent to which it describes the behaviour of your academic supervisor (in the case of multiple academic supervisors, take the one you have the most contact with):

My academic supervisor:

"Is available to me when I need help with my research"
"Gives me regular and constructive feedback on my research"
"Provides direct assessments of my progress"
"Gives me the freedom to design my own research"
"Teaches me the details of good research practice"
"Provides me with information about ongoing research relevant to my work"
"Assists me in writing presentations or publications"
"Helps me develop professional relationships with others in the field"
"Provides information about career paths open to me"
"Supports any career path I might choose"
"Has experience with collaborative research"
"Has a network outside academia"

1 : little or no extent
2 : a limited extent
3 : some extent
4 : a considerable extent
5 : a great extent

Question V024
Do you also have a supervisor that works in a non-academic organisation? (Multiple options possible)

1 : No, I only have (an) academic supervisor(s)
2 : Yes, a supervisor in a public research organisation
3 : Yes, a supervisor in a governmental organisation

4 : Yes, a supervisor in an NGO
5 : Yes, a supervisor in a business/industry/private sector organisation
6 : Yes, other (please specify):

Question V025
In this section we would like to ask you some questions about your personal and research background.
They are important for the comparison of the data.

What is your gender?

1 : Female
2 : Male

Question V026
What is your age?

1 : Younger than 25
2 : 25 to 30
3 : 30 to 35
4 : 35 to 40
5 : 40 or older

Question V027
Is the Netherlands your country of origin?

1 : Yes, I am from the Netherlands
2 : No, I am from another EU country (EU-28)
3 : No, I am from another European country (but not EU-28)
4 : No, I am from a country in Africa
5 : No, I am from a country in Asia
6 : No, I am from a country in Australia / Oceania
7 : No, I am from a country in North America
8 : No, I am from a country in South America

Question V028
Are you part of an interdisciplinary programme or initiative?

1 : No
2 : Yes, Knowledge for Climate (KvK)
3 : Yes, Climate Changes Spatial Planning (KvR)
4 : Yes, Living with Water (LmW)
5 : Another interdisciplinary programme, please specify:
6 : I don't know

Question V029
Do you consider yourself a: (Select all possible options)

1 : Climate researcher
2 : Sustainability researcher
3 : Environmental researcher
4 : Water researcher
5 : Energy researcher
6 : Other, please specify:

Question V030
How many jobs did you have before you started your PhD project? Please quantify the number of primary jobs (i.e. not summer jobs, student jobs etc.)

1 : 0
2 : 1
3 : 2
4 : 3
5 : 4
6 : >= 5

Question V031
In what type of organisation did you have your last primary job before starting your PhD project?

1 : A university
2 : A public research organisation
3 : A governmental organisation
4 : An NGO
5 : Business, industry, private sector
6 : Other, please give details:

Question V032
For how many years is your PhD contract / appointment?

Question V033
What year of your PhD project are you currently in?

1 : 1
2 : 2
3 : 3
4 : 4
5 : >= 5
6 : I have already finished my PhD project

Question V034
On average, how many working hours per week do you spend on your PhD project?

Question V035
The completion of a PhD project can be delayed when compared to the original planning.

Do you expect your PhD to be delayed?

1 : No
2 : Yes, please specify by how many months:
3 : I don't think I will complete my PhD project

Question V036
What is or are the main reason(s) for the delay? / What is or are the main reason(s) why you think you will not finish your PhD project?
(Multiple answers possible)

1 : Lack of a clear research proposal at the start of my PhD project
2 : Involvement of academic researchers from (too) many different fields of research
3 : Involvement of stakeholder(s)
4 : Too much time spent on non-academic output (e.g. advisory reports, resentations for general public, etc.)
5 : Problems during data collection
6 : I underestimated the amount of work
7 : I have too many activities in addition to my research
8 : Personal circumstances (e.g. family obligations, illness, etc.)
9 : Other, please give details:

End
Many thanks for your cooperation.

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The Tyndall Centre (United Kingdom) brings together scientists, economists, engineers and social scientists who are working to develop sustainable responses to climate change. Tyndall Centre has hosted an early career research network since 2000 and convenes annual PhD researcher conferences (www.tyndall.ac.uk/Climate-Change-Research-in-Practice-PhD-Conference).

United Kingdom

Question V001

To start with, we would like to learn about the setting in which you work on your PhD project. In case that you have already finished your PhD, please answer according to your experiences and circumstances during the PhD trajectory.

What is the name of the university to which you are affiliated?

1 : Cardiff University
2 : University of Cambridge
3 : University of East Anglia
4 : University of Manchester
5 : University of Newcastle
6 : University of Southampton
7 : University of Sussex
8 : Another university in the UK, please specify:
9 : A university outside the UK, please specify:

Question V002

What is your daily work location? (Multiple answers possible)

1 : The university selected above
2 : A different university
3 : A public research organisation
4 : A governmental organisation
5 : A business or industrial organisation
6 : An NGO

7 : Home
8 : Other, please specify:

Question V003
Which of the statements below best describes your position as a PhD candidate?

1 : I am employed as a PhD candidate (i.e. by a university or a public research organisation)
2 : I am a student (with stipend, bursary or grant)
3 : I am a student (my own funding)
4 : Other, please give details:

Question V004
How is your position financed? (Multiple answers possible)

1 : By a university
2 : By a public research organisation
3 : By a Research Council
4 : By European research funding (e.g. FP, ERC)
5 : By a charitable fund
6 : By a governmental organisation (national, regional, local, European)
7 : By business or industry
8 : By an NGO
9 : Other, please give details:
10 : I don't know

Question V005
The following two questions relate to the research proposal of your PhD project. By research proposal, we mean a document that provides a detailed description of the proposed PhD project (i.e. research questions, work planning, research methods, theoretical framework, etc.).

Which of these statements best describes the situation at the start of your PhD project?

1 : There was from the beginning a full research proposal (with research questions, work planning, research methods, theoretical framework, etc.)
2 : There was a brief research proposal that was to be developed further
3 : There was no research proposal, but a research idea/ direction/ topic in place
4 : I did not have a research topic and had yet to work out the direction of my PhD project

Question V006
Who wrote the main part of your research proposal?

1 : I did
2 : My supervisor(s) did
3 : Someone else did
4 : I don't have a research proposal
5 : I don't know

Question V007
Do you conduct research on your PhD project in the context of a research team?

1 : Yes, I am part of a large research team (10 or more people including supervisors, senior researchers and post docs)
2 : Yes, I am part of a small research team (fewer than 10 people including supervisors, senior researchers and post docs)
3 : No, but I work in close collaboration with my supervisors
4 : No, I work individually, with some input from my supervisors

Question V008A
In which field(s) of research are you working?
(Multiple answers are possible)

1 : Agricultural sciences / Natural resources
2 : Astronomy
3 : Atmospheric science & meteorology
4 : Biological / Biomedical sciences
5 : Business management / administration
6 : Chemistry
7 : Communication
8 : Computer & Information sciences
9 : Education, Teaching & STS / Science Studies
10 : Engineering
11 : Geological & Earth Sciences
12 : Health sciences
13 : Humanities
14 : Mathematics
15 : Ocean / Marine Sciences
16 : Physics
17 : Psychology
18 : Social Sciences
19 : Other, please specify:

Question V008B
In which field(s) of research are the academic researchers you work with working (e.g. supervisors, co-authors, project members)?
(Multiple answers are possible)

1 : Agricultural sciences / Natural resources
2 : Astronomy
3 : Atmospheric science & meteorology
4 : Biological / Biomedical sciences
5 : Business management / administration
6 : Chemistry
7 : Communication
8 : Computer & Information sciences
9 : Education, Teaching & STS / Science Studies
10 : Engineering
11 : Geological & Earth Sciences
12 : Health sciences
13 : Humanities
14 : Mathematics
15 : Ocean / Marine Sciences
16 : Physics
17 : Psychology
18 : Social Sciences
19 : Other, please specify:

Question V009
The following set of questions is about stakeholder involvement. Stakeholders are increasingly involved in academic research. By stakeholders we mean non-academic actors that are directly or indirectly affected by your research and who could affect the implementation of the findings of your research (e.g. governmental organisations, NGOs, industry, consultants, public research organisations, etc.).

What statement best describes the involvement of stakeholders in your PhD project?

1 : Only academic researchers work in the project; stakeholders are not involved
2 : Only academic researchers work in the project, but stakeholders are involved in specific, relevant activities
3 : Academic researchers lead the project, but stakeholders are also part of the project
4 : Academic researchers and stakeholders work jointly in the project in an equal relationship

5 : Stakeholders lead the project, but academic researchers are also involved

Question V010
Please specify the types of stakeholders that are involved in your PhD project. (Please select all options that apply)

1 : Public research organisation(s)
2 : Governmental organisation(s)
3 : NGO(s)
4 : Business, industry, private sector, consultants
5 : Other(s), please specify:

Question V011
What kind of direct influence do stakeholders have on the following research activities in your project?

"Formulating research questions"
"Setting up the research design"
"Doing the actual research"
"Discussing and interpreting outcomes"
"Communicating research outcomes"

1 : little or no influence
2 : a limited influence
3 : some influence
4 : a considerable influence
5 : a great influence

Question V012
During you PhD project, how many times have you been involved in the following activities:

"Attending academic conferences"
"Helping organise academic conferences or workshops"
"Interacting with visiting scholars"
"Reviewing academic articles"
"Attending policy, industry or business meetings"
"Helping organise events for policy, industry or business"
"Giving workshops or training to professionals from policy, industry or business"
"Advising to policy, industry or business"

1 : 0
2 : 1
3 : 2
4 : 3
5 : 4
6 : >= 5

Question V013
Which of the following outputs have resulted from your PhD project so far? (Please quantify)

"Written publication for an academic audience (e.g. journal article, book (or chapter), etc.)"
"Written publication for a professional audience (e.g. advisory report, a piece in a professional journal, decision tool, protocol, etc.)"
"Written publication for the general public (e.g. newspaper, newsmagazine)"
"Oral presentation for an academic audience"
"Oral presentation for a professional audience"
"Oral presentation for a broad audience (e.g. popularising lecture)"

1 : 0
2 : 1
3 : 2
4 : 3
5 : 4
6 : >= 5

Question V014
Have you participated in a course on any of the following topics during your PhD project?

"Theories for my subject"
"Research methods for my subject"
"Academic communication (e.g. presenting, writing)"
"Teaching"
"Project management"
"Personal efficiency / time management"
"Career development"
"Networking"

1 : No
2 : Yes

Question V015
Please indicate (in percentages) the amount of working time you spend or spent on teaching during your PhD project.

1 : None (no teaching)
2 : Less than 10%
3 : 10% to 20%
4 : 20% to 30%
5 : 30% to 40%
6 : 40% to 50%
7 : 50% or more

Question V016A
PhD candidates develop different skills during their PhD projects. The following questions relate to the set of skills you have acquired and your assessment of them.

Please rate your level for the following skills at the start of your PhD.

"Reviewing academic work"
"Keeping up to date on developments in your academic specialisation"
"Taking initiative"
"Working in a team with a division of tasks"
"Getting articles published"
"Developing and maintaining work relations with people from government"
"Contributing to public debates related to your research topics (e.g. blogs, radio, social media, op-eds)"

1 : No experience
2 : Poor
3 : Sufficient
4 : Satisfactory
5 : Good
6 : Very good
7 : Excellent

Question V016B
Please rate your level for the following skills now.

"Reviewing academic work"
"Keeping up to date on developments in your academic specialisation"
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1 : No experience
2 : Poor
3 : Sufficient
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6 : Very good
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Question V017A
Please rate your level for the following skills at the start of your PhD.

"Working with targets defined by management / senior staff"
"Getting your findings implemented outside the academic world"
"Ability to formulate a good research question"
"Supporting the education of professionals (e.g. through workshops, other activities)"
"Writing proposals for research funding / grants"
"Developing and maintaining work relations with people from industry / business"
"Project management"

1 : No experience
2 : Poor
3 : Sufficient
4 : Satisfactory
5 : Good
6 : Very good
7 : Excellent

Question V017B
Please rate your level for the following skills now.

"Working with targets defined by management / senior staff"
"Getting your findings implemented outside the academic world"
"Ability to formulate a good research question"
"Supporting the education of professionals (e.g. through workshops, other activities)"
"Writing proposals for research funding / grants"

"Developing and maintaining work relations with people from industry / business"
"Project management"

1 : No experience
2 : Poor
3 : Sufficient
4 : Satisfactory
5 : Good
6 : Very good
7 : Excellent

Question V018A
Please rate your level for the following skills at the start of your PhD.

"Working independently"
"Linking your work to relevant theories within your academic specialisation"
"Presenting your findings to a non-academic audience"
"Showing leadership"
"Application of proper research methods and techniques"
"Developing and maintaining relations with colleagues and peers in the wider research community."
"Analytical reasoning"

1 : No experience
2 : Poor
3 : Sufficient
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Question V018B
Please rate your level for the following skills now.

"Working independently"
"Linking your work to relevant theories within your academic specialisation"
"Presenting your findings to a non-academic audience"
"Showing leadership"
"Application of proper research methods and techniques"
"Developing and maintaining relations with colleagues and peers in the wider research community."
"Analytical reasoning"

1 : No experience
2 : Poor
3 : Sufficient
4 : Satisfactory
5 : Good
6 : Very good
7 : Excellent

Question V019
The following section relates to your future career choices. There is a wide range of career options after completing a PhD degree.

Please indicate to what extent you have an interest or desire for each of the following positions:

"Research position in a college or university"
"Research position in business, industry or the private sector"
"Research position in a non-profit organisation or government agency"
"Teaching position in a college or university setting"
"Teaching position, but not in a college or university setting"
"Non-research / non-teaching position in a college or university"
"Non-research / non-teaching position in business, industry or the private sector"
"Non-research / non-teaching position in a non-profit organisation or government agency"

1 : little or no extent
2 : a limited extent
3 : some extent
4 : a considerable extent
5 : a great extent

Question V020
Based on your current level of skill, expertise and knowledge - to what extent would it be realistic for you to pursue the following positions:

"Research position in a college or university"
"Research position in business, industry or the private sector"
"Research position in a non-profit organisation or government agency"
"Teaching position in a college or university setting"
"Teaching position, but not in a college or university setting"
"Non-research / non-teaching position in a college or university"
"Non-research / non-teaching position in business, industry or the private sector"

"Non-research / non-teaching position in a non-profit organisation or government agency"

1 : little or no extent
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4 : a considerable extent
5 : a great extent

Question V021
PhD career interests can often be driven by personal preferences.

Could you please indicate the extent to which you agree with the following statements?

"I am constantly on the lookout for new ways to improve my life"
"I enjoy jobs that require me to interact with people outside my organisation"
"I am always looking for better ways to do things"
"I seek job assignments that allow me to learn something new"
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Question V022
These next questions are about your academic supervisor.

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How often do you speak about your PhD project with your academic supervisor (in the case of multiple academic supervisors, take the one you have the most contact with):
1 : At least once per week
2 : At least once every two or three weeks
3 : Every month or two
4 : Infrequently

Question V023
Supervisors take very different approaches. For each of these statements, please indicate the extent to which it describes the behaviour of your academic supervisor (in the case of multiple academic supervisors, take the one you have the most contact with):

My academic supervisor:

"Is available to me when I need help with my research"
"Gives me regular and constructive feedback on my research"
"Provides direct assessments of my progress"
"Gives me the freedom to design my own research"
"Teaches me the details of good research practice"
"Provides me with information about ongoing research relevant to my work"
"Assists me in writing presentations or publications"
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"Provides information about career paths open to me"
"Supports any career path I might choose"
"Has experience with collaborative research"
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1 : little or no extent
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Do you also have a supervisor that works in a non-academic organisation? (Multiple options possible)

1 : No, I only have (an) academic supervisor(s)
2 : Yes, a supervisor in a public research organisation
3 : Yes, a supervisor in a governmental organisation
4 : Yes, a supervisor in an NGO
5 : Yes, a supervisor in a business/industry/private sector organisation
6 : Yes, other (please specify):

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In this section we would like to ask you some questions about your personal and research background.

They are important for the comparison of the data.

What is your gender?

1 : Female
2 : Male

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What is your age?

1 : Younger than 25
2 : 25 to 30
3 : 30 to 35
4 : 35 to 40
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Question V027
Is your country of origin within the United Kingdom?

1 : Yes, I am from the United Kingdom
2 : No, I am from another EU country (EU-28)
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4 : No, I am from a country in Africa
5 : No, I am from a country in Asia
6 : No, I am from a country in Australia / Oceania
7 : No, I am from a country in North America
8 : No, I am from a country in South America

Question V028
Are you part of an interdisciplinary programme or initiative?

1 : No
2 : Yes, Tyndall Centre for Climate Change Research
3 : Yes, UK Climate Impact Program (UKCIP)
4 : Another interdisciplinary programme, please specify:
5 : I don't know

Question V029
Do you consider yourself a: (Select all possible options)

1 : Climate researcher
2 : Sustainability researcher
3 : Environmental researcher
4 : Water researcher
5 : Energy researcher
6 : Other, please specify:

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How many jobs did you have before you started your PhD project? Please quantify the number of primary jobs (i.e. not summer jobs, student jobs etc.)

1 : 0
2 : 1
3 : 2
4 : 3
5 : 4
6 : >= 5

Question V031
In what type of organisation did you have your last primary job before starting your PhD project?

1 : A university
2 : A public research organisation
3 : A governmental organisation
4 : An NGO
5 : Business, industry, private sector
6 : Other, please give details:

Question V032
For how many years is your PhD contract / appointment?

Question V033
What year of your PhD project are you currently in?

1 : 1
2 : 2
3 : 3
4 : 4
5 : >= 5
6 : I have already finished my PhD project

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On average, how many working hours per week do you spend on your PhD project?

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The completion of a PhD project can be delayed when compared to the original planning.

Do you expect your PhD to be delayed?

1 : No
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What is or are the main reason(s) for the delay?/ What is or are the main reason(s) why you think you will not finish your PhD project?
(Multiple answers possible)

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Dankwoord

Dit proefschrift gaat over samenwerken, maar is ook het resultaat van samenwerken. Ik mag veel mensen danken die hun informatie en kennis met mij wilden delen. Ik mag mensen danken die met mij meedachten, zodat we gezamenlijk op betere ideeën kwamen. Samenwerken is echter niet altijd makkelijk. Waardevolle inzichten en lessen zijn ook ontstaan op momenten dat samenwerken even niet werkte. Samenwerken heeft mijn proefschrift sterker gemaakt.

Ik ga jullie danken:

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24 + 11 = ∞

Curriculum Vitae

Tjerk Wardenaar

Tjerk worked as a researcher at the Science System Assessment department of the Rathenau Instituut between January 2010 and June 2014. His research focused on the organization of multi-actor research programs, coordination of scientific research, and (the assessment of) societal impact of research. In addition, Tjerk organized (expert) meetings (e.g. on knowledge coproduction) and provided workshops (e.g. for policy makers on collaborating with scientists). From 2013 onwards, he was an editorial member of the Rathenau Magazine Flux.

Before joining the Rathenau Instituut, Tjerk worked at the Centre for Environmental Sciences at Leiden University where he was involved in the development and coordination of a new Sustainable Development curriculum. Tjerk has a background in political sciences (BA, Leiden University), philosophy (BA and MA, University of Amsterdam) and industrial ecology (MSc, Delft University of Technology & Leiden University).

Since July 2014, Tjerk works as a consultant Energy and Environment at PNO Consultants.

Overview of main publications

Scientific publications

Wardenaar, T., S.P.L. de Jong & L.K. Hessels (2014), 'Varieties of Research Coordination: A Comparative Analysis of Two Strategic Research Consortia', *Science & Public Policy*, Advance Access (March 21st, 2014), pp. 1 – 13.

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Reports, factsheets and policy briefs (selection)

Deuten, J., A. Reitsma, T. Wardenaar, L.K. Hessels (2014). *Case study TKI Maritime: A strategic public/private partnership for the Dutch maritime sector.* The Hague: Rathenau Instituut.

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Wardenaar, T. & S.P.L. de Jong (2012), 'Promovendi - Kijk verder dan je proefschrift!' (www.rathenaunl.wordpress.com).

Who was Rathenau?

The Rathenau Instituut is named after Professor G.W. Rathenau (1911-1989), who was successively professor of experimental physics at the University of Amsterdam, director of the Philips Physics Laboratory in Eindhoven, and a member of the Scientific Advisory Council on Government Policy. He achieved national fame as chairman of the commission formed in 1978 to investigate the societal implications of micro-electronics. One of the commission's recommendations was that there should be ongoing and systematic monitoring of the societal significance of all technological advances. Rathenau's activities led to the foundation of the Netherlands Organization for Technology Assessment (NOTA) in 1986. On 2 June 1994, this organization was renamed 'the Rathenau Instituut'.

Societal relevance, valorization and the usability of scientific research are central concepts in contemporary science systems. The requirement of relevance is especially salient in multi-actor research programs. These popular organizational forms link their research agendas to the challenges that society faces. To address these challenges, multi-actor research programs aim for collaborative research activities across organizational and sectoral boundaries. Despite their popularity and far-reaching ambitions, there is little clarity about the organization and effects of these policy instruments. Little or no attention has been paid to the programs' actual approaches to agenda-setting and coordination. In the context of these programs, stakeholder involvement refers to a broad range of activities. This thesis addresses two main questions about these programs: (1) How do multi-actor research programs organize collaborative research activities? (2) Do multi-actor research programs have long-term, sustainable effects on scientific knowledge production?

The key results of this study address the coordination of research activities in the context of these programs; the roles of stakeholders and their influence on the research process; the ex-ante evaluation of multi-actor research programs; and the skills that participating PhD students develop. The empirical studies in this dissertation show a large diversity between and within multi-actor research programs. They reveal that multi-actor research programs are above all facilitators – not organizers – of collaborative research.

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