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Jong, S. de

Author: Jong, Stefan de
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3 Exploring the promises of transdisciplinary research: a quantitative study of two climate research programmes[14]

Stefan P.L. de Jong[1], Tjerk Wardenaar[2] and Edwin Horlings[1]

[1] Rathenau Institute, Department of Science System Assessment, The Hague, The Netherlands
[2] PNO Consultants, Schiphol, The Netherlands

Abstract
Scientists have long since become accustomed to explaining the future value of their work. Nowadays token statements are no longer sufficient. Societal impact must be embedded in the organisation of research. The call for societal impact is most explicitly expressed in and actively shaped by strategic research programmes that involve societal actors. We have examined two questions related to compliance in the principal-agent relation between a programme and its projects. The first question concerns the risk of moral hazard: is societal actor involvement a token activity or a substantial component of the research process? The second question relates to possible adverse selection: does societal actor involvement produce the expected benefits and, if so, under which conditions? We surveyed members and project leaders of 178 projects in two strategic research programmes in the Netherlands. There is no reason to suspect large-scale moral hazard. Projects formally labelled as transdisciplinary have characteristics typically associated with transdisciplinarity but academic projects share those characteristics. Neither is there reason to suspect adverse selection. The archetypical properties of transdisciplinary research are associated with the expected societal benefits. An important finding is that there are different types of benefit, each of which requires its own approach. Societal benefit is associated mainly with the characteristics of consulting transdisciplinarity rather than participatory transdisciplinarity. Benefit is achieved through informal involvement and a diversity of outputs, and much less by giving societal actors a prominent role or influence in the research process. Based on our conclusions we recommend customizing the design of research programmes and projects towards the needs of the specific societal benefits they aim to generate and reconsidering the emphasis on formal involvement of societal actors in funding procedures.

3.1 Introduction
Science is expected to produce benefits for society. This expectation is articulated in grant conditions of research funders, in research evaluation protocols, in government policy documents and public science budgets, and in various other government policies (Mowery, Nelson et al. 2001; Gulbrandsen et al. 2011; Lyall & Fletcher 2013). Scientists have long since become accustomed to explaining the future value of their work in grant applications, in reflections on

14 This chapter has been submitted for consideration for publication in Research Policy.

the possible implications of their results in the discussion section of papers, and in the dissemination sections of project funding proposals. Such token statements – sincere as they may be – are no longer considered sufficient. Societal impact must be embedded in the organisation of research.

Since Lewin first showed the potential of action research (Lewin 1946), a number of organisational modes has emerged that explicitly aim for science to produce societal change. They range from action research (Reason & Bradbury 2001) and participatory action research (Whyte 1991) to cooperative inquiry (Reason & Heron 1986), mode-2 research (Gibbons et al. 1994), transdisciplinary science (Rosenfield 1992; Pohl 2008), and knowledge co-production (Jasanoff 2006). These research modes have two significant commonalities: they aim to produce practical knowledge for a specific (social) context and they do so by engaging, involving, and empowering societal actors.

The call for societal impact is most explicitly expressed in and actively shaped by strategic research programmes. Societal actor involvement is a crucial part of the design of strategic research programmes (Hessels & Deuten 2013). By involving industry, local communities, regional governments, NGOs, and other societal actors in the research process, programmes aim to maximise societal impact, for example, by better adjusting knowledge to user needs, by creating commitment for contentious solutions, or by turning scientific inventions into new products and processes. Horizon 2020 is the most prominent recent example, allocating 31 billion euros to collaborative research into seven Grand Challenges. However, strategic research programmes have been growing in popularity as a public policy instrument for decades (Gray 2011; Kloet et al. 2013; Turpin et al. 2011). The rationale behind these programmes is that the urgency and complexity of the problems as well as their potential benefit for society warrant a "coordinated attack" (Bush 1945 p. 14). Strategic research programmes are expected to produce new knowledge and methods applicable in a specific socio-economic sector or problem area, share this knowledge with relevant actors to facilitate innovation, and bring about sustained improvement of the knowledge infrastructure (Van der Meulen and Rip 1998). Strategic research programmes with societal actor involvement as well as other inclusive research modes call for new evaluation criteria that reflect the interdisciplinary and transdisciplinary nature of research, the interests of the actors involved, and the variety of outputs and outcomes it produces (Carew & Wickson 2010; Wagner et al. 2009). There are two questions when it comes to identifying a particular mode and evaluating its impacts. The first question is if societal actor involvement is a token activity or a substantial component of the research process. The growing call to involve societal actors may tempt scientists to comply in name but not in fact. Weingart (1997) is concerned that although a research programme might have a transdisciplinary design, the research projects in the programme will still be organized along disciplinary lines. Weingart's concern may be warranted, as Pohl (2005) found that to many researchers transdisciplinarity is just another demand from the research programme.

The second question is whether and under which conditions societal actor involvement produces the expected benefits (Jolibert & Wesselink, 2012; Phillipson et al. 2012). The involvement of societal actors in scientific research has been the subject of many empirical studies (e.g. Cohen 1997; Roelofsen et al. 2011; Talwar et al. 2011; Olmos-Peñuela et al. 2014). It is generally accepted that involving societal actors in research is conducive to generating societal impact. Yet, there remains a lack of systematic quantitative evidence on the effects of their involvement (Abreu et al. 2009).

In this paper, we use a principal-agent perspective to look for an answer to the two questions. Is societal actor involvement real or token? And does it fulfil its promises by producing the expected societal benefits?

A survey among participants and project leaders in two large-scale transdisciplinary research programmes on climate adaptation in the Netherlands, augmented with detailed information from the programmes' project databases, was used to compare projects designated as transdisciplinary ('hotspot projects') with projects designated as purely scientific ('thematic projects'). A comparison of the organisational properties of hotspot projects and thematic projects reveals no significant differences, which seems to suggest that transdisciplinarity is token. However, contrary to expectations societal actor involvement was also found in thematic projects, suggesting that societal actor involvement is most likely a substantial part of the research process, an effect that can be attributed to the design of the programme rather than that of the projects. We also find an association between specific ways of organising societal actor involvement and five types of societal impact, which shows that benefits were produced and reveals under which conditions that occurred.

The structure of this paper is as follows. In the next section we explain the context of our study. In the third section we present our theoretical framework. We discuss transdisciplinarity literature, conceptualize the relationship between government and science in terms of principal-agent theory and integrate these two strands of literature. In the fourth section we present our data and method. Our data consists of an administrative project database and a survey among project representatives. Data is analysed using non-parametric tests and regression models in section five. In section six we draw conclusions, discuss our findings and formulate policy recommendations.

3.2 Background

Until recently, strategic research programmes were an important component of the funding landscape of science and innovation in the Netherlands. Between 1995 and 2011 billions of euros of public revenues from natural gas extraction were invested in the Economic Structure Enhancing Fund (*Fonds Economische Structuurversterking*; FES) to strengthen the physical infrastructure and the knowledge infrastructure of the Dutch economy. The third of proposals aimed at strengthening the knowledge infrastructure (Decision Subsidies Investments Knowledge Infrastructuur; *Besluit subsidies investeringen kennisinfrastructuur*; *Bsik*) involved 37 programmes and investments of 802 million euros, supplemented with co-financing from European Structural Funds and the private and non-profit sectors. Programmes funded under *Bsik* were to represent collaborative networks of knowledge users and knowledge producers, do high-quality fundamental research, and translate the results into new products, processes, competences and services.[15]

15 Source: Erawatch (http://erawatch.jrc.ec.europa.eu/erawatch/opencms/index.html)

A number of Bsik programmes were eligible for additional funding in the FES 500 selective continuation (selectieve continuering) round, in which additional funding of 500 million euros was allocated (Ministry of Education, Culture and Science and Ministry of Economic Affairs 2009; Ministry of Economic Affairs 2010.)

There is a difference between proposals and actual projects. Hessels et al. (2014) have examined user involvement in the 37 programmes funded by Bsik. They conclude that there is a close association between how users were involved in proposals and how they were involved in the eventual programmes, although users may fall short when it comes to contributing financially. This indicates formal compliance with design requirements, but is not sufficient to assess the nature of the involvement of societal actors in the research process or the production of expected societal benefits.

In this paper, we make an in-depth analysis of two FES programmes that focus on climate adaptation. Climate research is a good example of problem-oriented research with close involvement of societal actors (Wardenaar 2013; Hegger 2012; Pohl et al. 2005; Funtowicz & Ravetz, 1993). Climate changes Spatial Planning (CcSP) is part of the Bsik round and ran from 2004 until 2011 and had a total budget of 80 million euros; it was succeeded in the FES 500 round by Knowledge for Climate (KfC), which ran from 2008 until 2014 and had a total budget of 100 million euros. The two programmes are transdisciplinary in design: they involve a substantial number of public and private societal actors and aim to produce practical solutions for a complex societal problem in a specific context, based in part on high-quality fundamental science.[16]

The projects in the two programmes are similar with respect to the research field, the type of funding source, and the societal actors that were involved. These similarities as well as the institutional integration of the programmes allow us to treat the projects as a single set. There is, however, a significant difference between the programmes in how they organise transdisciplinary research. CcSP organized research in scientific projects along research themes, the results of which were integrated and disseminated through so-called communication projects in the second phase of the programme. KfC organized its research from the outset in clusters of so-called hotspot projects –regional projects working on societal problems– and thematic projects that develop more fundamental knowledge to support the research in the hotspots (Merkx et al. 2011). The communication projects and hotspot projects are transdisciplinary in design, while the thematic projects have an academic focus and will serve as our control group.

3.3 Theoretical framework

The literature provides a range of concepts and labels to describe modes of research that involve societal actors and aim to produce practical knowledge for societal problems. We position our paper in the context of transdisciplinary research. However, the results are equally relevant for mode-2 research, knowledge co-production, or any of the other modes.

16 For a more detailed description of the programmes we refer to Wardenaar et al. (2014) and Wardenaar et al. (under review).

3.3.1 Involving societal actors in transdisciplinary research

The origin of the notion of transdisciplinarity can be traced back to Jantsch (1972) who envisioned a new way of problem solving, moving beyond the disciplinary organisation of academic knowledge development. His vision encompasses the integral coordination of science, education and innovation, aimed at contributing to a certain societal issue.
The understanding of Jantsch's notion has evolved. Numerous definitions of transdisciplinarity have been proposed – in addition the various alternative labels and theories on inclusive and collaborative modes of research – but there is as yet no consensus definition (Pohl 2011). Many authors do use Rosenfield's description (1992) that emphasises the integration of knowledge by researchers from different disciplines and societal actors from different fields, working on a common problem over an extended period of time, and developing shared conceptual frameworks, skills, and goals (see also Choi & Pak 2006). Recurring elements of what is considered transdisciplinarity are 'collaboration between academics and societal actors', 'integrating knowledge' and 'real world problem oriented' (Carew & Wickson 2010; Walter et al. 2007; Wagner et al. 2009; Wickson, Carew & Russel 2006).

Scientists operating in a transdisciplinary research setting are expected to engage actively in collaborating with societal actors (Lawrence & Després 2004). Societal actors can be included as official project partners, but their contributions can also be organized more loosely. Olmos-Peñuela et al. (2014) emphasize that relations with societal actors regularly remain non-formalized, involving no legal or other traceable documents. The involvement of societal actors changes the focus of the research process. Societal actors tend to focus on practice and on products that can be applied in specific contexts and not on the future rewards from the scientific community (Podestá 2013). In many studies societal actor involvement has been positively associated with the development of societally relevant knowledge (e.g. Walter et al. 2007; Raftery 2009; Meagher 2008; Rogers 1995; Clark & Holmes 2010; Jolibert & Wesselink, 2012) and with the social robustness of that knowledge (Gibbons et al. 1994; Lawrence & Després 2004)

Societal actors can be involved in different roles. Mobjörk (2010) distinguishes two types of transdisciplinary research: consulting and participatory. In consulting transdisciplinary research, societal actors provide input and feedback but they do not do research. In participatory transdisciplinary research scientists and societal actors are equal partners, making it easier for societal actors to contribute to the research process. Ideally, societal actors should have a role in each phase of the process, as impact has been shown to increase with the number of phases in which they have a role (Pohl & Hirsh Hadorn 2008; Voinov & Brown Gaddis 2008; Peer & Stoeglehner 2013). In setting goals and defining questions, societal actors have a preference for research questions that are more relevant to their own context (Rietchel et al. 2009, Brousselle et al. 2009; Molas-Gallart & Tang 2007; Philipson et al. 2012) and for practice-oriented research (Jolibert & Wesselink, 2012). In research design, they can make valuable contributions to the selection of cases and data sources, based on their practical and local knowledge (Siegel et al. 2003). In executing the research, they contribute data that would otherwise be difficult to obtain (Voinov & Brown Gaddis 2013) and provide access to facilities and study sites (Molas-Gallart & Tang 2007; Phillipson et al. 2012). In communicating research results, their involvement helps to take into account local contexts and to communicate research results in understandable terms (O'Fallon & Deary, 2002; Weichselgartner & Kasperson 2010).

3.3.2 Research programmes as intermediaries between government and science

The relationship between government and science can be conceptualized as a principal-agent relationship. Central to the relationship is the exchange of resources. Guston (2000) described this relationship using the notion of a contract in which science supplies new knowledge in exchange for financial support by government. Government is uncertain about two aspects of the compliance of science, both resulting from information asymmetries, specifically the government's lack of specific knowledge. The first uncertainty concerns the possibility of adverse selection: are the most capable scientists funded? The second uncertainty involves the risk of moral hazard: are scientists performing as agreed upon? (Guston 1996).

Government can manage these uncertainties by delegating control to intermediary organisations (Guston 2000) that use the expertise of other scientists to select those scientists (most) capable of performing the required tasks and to assess whether they actually did what was required (Fernandez-Carro 2007). Morris (2002) studied the mediating role of university departments that function as brokers between scientists and governmental policy and form a buffer between governmental research priorities, research councils and national research assessments. Research programmes are also a type of intermediary organisation between government and science (Rip & Van der Meulen 1996). They combine the roles of funding councils, by allocating research funds, and university departments, by brokering between the goals of government and science. Research programmes develop coordination measures to secure compliance (Wardenaar et al. 2014). For example, they organize the evaluation of research proposals by scientific and societal peers and monitor project progress.

A number of studies examines compliance in science. For example, in an analysis of the use of contracts in the relation between research councils and scientists, Caswill (2003) found that, although compliance with contracts is seldom verified, shirking is rare. Van der Meulen (1998) models the behaviour of scientists in reaction to policy as a game of developing strategies to maximize outcomes. Scientists can follow three strategies: (1) compliance, which involves adapting to policy demands, (2) symbolic compliance, which involves pretending to adapt to policy demands, and (3) negotiating in an effort to alter policy demands (Leisyte 2007).
Principal-agent theory can help in understanding the organisation of transdisciplinary research. Research programmes are a means to direct the research efforts of a collection of agents (Wardenaar et al. 2014). For example, Stemerding & Nahuis (2014) describe how the impact definition used by a research programme directs the efforts of scientists within the programme.

Programmes that provide funding for research that meets specific transdisciplinary requirements, will also attract projects that involve societal actors as window dressing, assigning them a role while not necessarily giving them influence. Mobjörk's (2010) distinction between consulting and participatory transdisciplinary research is comparable to the distinction between symbolic compliance and actual compliance in principal-agent theory. Elzinga's (2008) observation that societal actors can be involved in more symbolic roles, also suggests that scientists can comply symbolically with demands for societal actor involvement.
Compliance with transdisciplinary requirements has two dimensions, each of which comprises from two characteristics. The first dimension relates to roles and functions. Are societal actors included as official project partners as well as informally? Have societal actors been given a role

in taking decisions concerning the research? The second dimension concerns their influence and information on the results. Do societal actors actually have influence on the research? Are efforts being made to communicate (preliminary) results to societal actors? When a project only performs on the first dimension, this may indicate symbolic compliance with transdisciplinary requirements. Societal actors are included in the project's design but inclusion may not involve influence. When a project also performs on the second dimension, this may indicate actual compliance. Such a project takes into account the contexts of application from the outset and gives societal actors influence throughout the research.

We explore the relation between the two dimensions of compliance with transdisciplinary requirements and the main goals of the programme, that is, producing societal impact and contributing to the knowledge infrastructure. Societal impacts are defined as changes in thinking or behaviour of societal actors (Spaapen & Van Drooge 2011; De Jong et al. 2014). Examples of societal impacts of climate research are influence on the debate about climate change in local communities; raising awareness among regional watershed councils regarding climate change effects; or contributions to the implementation of climate adaptation measures, such as water storage below greenhouses (Ford et al. 2013; Verhoeven et al. 2011). Is transdisciplinary research the right approach to achieve these goals?

3.4 Methods and data

This section describes the methods and data that were used to find an answer to our questions. Our results are based on two complementary data sources. The first source is the combined project database that was created after the two programmes CcSP and KfC were integrated. The project database was maintained by the programme management office, which gave full access to our team. The second source is a survey among researchers who participated in the various projects of CcSP and KfC. A paper based on these data sources has been presented at the 2013 Atlanta Conference on Science and Innovation Policy (De Jong et al 2013).

3.4.1 Project database

The project database contains information on all projects funded by CcSP and KfC. There are two types of projects. Thematic projects have an academic focus and develop new academic knowledge on climate adaptation. Hotspot projects and communication projects have an explicit transdisciplinary focus, working on practical problems in collaboration with societal actors in a local context. Thematic projects are the traditional academic research projects that serve as the control group that is necessary for this type of study (Walter et al. 2007).

The database contains information on team size and composition. Participants were classified as scientists or societal actors based on their organisational affiliation. Universities and public research institutes are considered scientific, while governments, firms, knowledge platforms, and NGOs are considered societal. There are two caveats to this strict separation of sectors. First, we ignore the fact that some societal organisations, such as firms and consultancies, do in-house research. Second, some people have a dual affiliation with an academic and a societal organisation. For each project, we have calculated the percentage of participants that is affiliated to a societal organisation, including those who have a dual societal-academic affiliation. This percentage reflects the formal involvement of societal actors.

The project database also produces information on three control variables: project team size, project budget, and programme. Project team size and project budget may have an effect on impact independent of societal actor involvement (e.g. larger teams may have access to larger social networks). We will also control for programme, because the programmes use somewhat different strategies to achieve their societal aims.

3.4.2 Survey

Data on societal actor involvement and societal benefits were collected using a survey among 1,382 participants from 316 projects. Questions and answer categories were constructed based on 23 exploratory interviews with programme management, scientists and societal actors involved at the level of programmes and projects (Merkx et al. 2011).

The involvement of societal actors was measured using four groups of questions:

1. *The number of types of societal actors that were informally involved* was measured by asking respondents to identify which of 22 categories of societal actors were not part of the project team but were involved in the project in some other way, leaving room for open answers.
2. *The role of societal actors in the research process* was measured by asking respondents about the involvement of societal actors in four tasks: (a) formulating research questions, (b) developing the research design, (c) conducting research, and (d) disseminating results.
3. *The actual influence of societal actors* was measured by asking respondents to what extent the interaction between scientists and societal actors resulted in (a) changes in research questions, (b) changes in research subjects, (c) improved insight into societal actors' knowledge needs, (d) acquisition of relevant knowledge from practice, (e) and improved capacity to translate research results into practice.
4. *Efforts to communicate results to societal actors* were measured by asking respondents to identify which of 13 non-scientific research outputs were used to communicate about the project with societal actors. These include publications, lectures, advisory work, climate adaptation and mitigation strategies, several types of models and decision tools, databases and cost-benefit analyses.

The programmes are expected to produce two types of societal benefit: impact on the problem and an improvement of the knowledge infrastructure.

1. *Societal impact* was measured by asking respondents to indicate to what degree project results were used to achieve five specific types of societal impact that were identified in the preparatory interviews and that together reflect the societal impact of a project. These five types of impact are that project results (a) were used in societal debates, (b) contributed to including climate change knowledge in investment decisions, (c) created political support for climate adaptation measures, (d) helped to postpone or cancel climate adaptation measures, and (e) produced climate adaptation measures and strategies that were implemented.
2. *Contribution to the knowledge infrastructure* concerns the creation of new contacts and the improvement of existing contacts resulting from a project. Respondents were asked to

indicate whether new or improved contacts were achieved for 22 categories of societal actors as well as an open category.

The survey was pretested to ensure that respondents would understand the questionnaire as unambiguously as possible. A number of questions was rephrased, additional response categories were added, and the order of questions was changed.

The survey measures self-reported impact from the perspective of scientists participating in the projects of CcSP and KfC. It was distributed in January 2013 to 1,382 participants with a scientific affiliation. These are the agents who are expected to do most of the work and whose behaviour is a prime target of the FES policy scheme. Although it is common to query self-reported impact, we did consider extending the survey to include participating societal actors.

However, where scientists take part on an individual or group basis, many societal actors represent participating organisations. Their responses would consequently be different in nature from those of scientists and including them would have lowered the consistency of responses. Representatives changed during the programmes' duration and a random check of the background of individual participants from societal organisations (using LinkedIn) produced a fair number of secretaries.

Not all projects were finished at the time, but we expected most benefits to have occurred or to have become clear to project participants. Also, we had to take into account that a number of CcSP projects finished a few years earlier. Postponing the survey until all KfC projects had finished could increase hindsight bias (Sanna & Schwarz 2003).

Many respondents were involved in multiple projects. To minimize their workload, projects were specifically assigned to respondents to ensure that no one had to respond to more than one questionnaire and that there was at least one respondent per project, preferably the project leader. The survey produced 440 partly and fully completed questionnaires, corresponding to a response rate of 32 per cent for the survey as a whole, with different response rates per question. Individual responses were transformed to average scores per project.[17]

Where multiple survey items were used to measure an aspect of transdisciplinary research or societal benefit, factor analysis was used to test whether they measure the same phenomenon. The four items on the role of societal actors in the research process load on a single component. Their average score represents the construct *prominence of societal actors in the research process* (standardized Cronbach's α=.808). The five items for the actual influence of societal actors load on two factors, but the internal consistency of the resulting constructs is poor. The average score of the five items represents the construct *influence of societal actors on the research process* (standardized Cronbach's α=.801). *Societal impact* is a construct comprising the average score of four of the five types of societal impact (standardized Cronbach's α=.862).

17 Where a project was represented by a single respondent per project, that respondent's response reflects the project score.

There were not enough responses to the question whether a project helped to postpone or cancel climate adaptation measures and variation in responses was low, so this type of impact was excluded. The items measuring the project's contribution to the knowledge infrastructure were averaged, resulting in a construct labelled *contribution to knowledge infrastructure* (standardized Cronbach's α=.787). Constructs were created by calculating an unweighted average of available scores, also when an individual item was missing. The variables *informally involved societal actors* and *societally aimed output* were constructed by counting the number of categories selected by respondents.

3.4.3 Data description

The resulting variables and their descriptives are listed in Table 3.1. In total, we have (partial) data for 178 out of 316 projects (56%), 52 (29%) from CcSP and 126 (71%) from KfC. According to the project database, 53 projects have a transdisciplinary label (hotspot and communication projects). The average project team is dominated by scientists, although there are projects without any scientific team member. Typical projects involve three societal actor types that are not part of the project team. On average, societal actors have considerable influence on the research process. Projects produce three to four publication types aimed at society. The average project had moderate societal impact and resulted in improved or new relationships with five types of organisations.

3.5 Results

In this section we present the statistical results in two parts. First, we test if societal actor involvement is a token activity or a substantial component of the research process. Then, we examine whether and under which conditions societal actor involvement produces the expected benefits.[18]

The correlations in Table 3.2 provide some initial insights into the relationships between design, impact, and project size. There is a modest association between the participation, prominence and influence of societal actors. Participation is a precondition for prominence and influence, while influence requires that societal actors have a specific role or function (prominence). As expected, there are significant correlations between societal impact and informal involvement, prominence, influence and diversity of output. However, a counterintuitive result is that societal impact is negatively associated with the share of societal actors in project teams. The impact of projects on the knowledge infrastructure (new or improved contacts) matches our expectations: a strong, positive association with the influence of societal actors in project teams, the number of societal actors that is informally involved, and the diversity of output.

The share of societal actors in project teams is positively related to the number of project members. Larger teams may provide better opportunities for organising the involvement of societal actors, but this result can also be read as an indication that such involvement is a mere add-on. Larger projects also produce a lower diversity of outputs, while diversity and the number

18 Sensitivity analysis was done to verify the results. The models were constructed from scratch by another researcher on the team, using different approaches and testing alternative definitions of the dependent variables. The results were confirmed.

of informally involved societal actors are positively related. This association can work in two directions: projects that produce a larger variety of outputs can reach a wider range of societal actors and the wider involvement of societal actors may elicit a more diverse set of outputs. Finally, the strong correlation between project budget and the number of project members originates in the fact that salaries account for the bigger part of project costs. In our statistical analyses we only use the number of members to measure project size.

Table 3.1 Variables and their descriptive statistics

Variable	Definition and scale	N	Mean	Median	St. dev.	Min.	Max.
Design variables							
SHARE_SOCIETAL	Share of societal actors in project members	171	0.167	0.056	0.235	0	0.913
INFORMAL_INVOLVE	Number of societal actor types informally involved (out of 22 categories)	94	3.649	3	2.850	0	13
PROMINENCE	Prominence of societal actors in research process (construct; from 1=scientists only to 5=societal actors only)	98	7.198	1.75	15.392	1	75
INFLUENCE	Influence of societal actors on research process (construct; 1=hardly any influence to 10=very strong influence)	76	8.708	7.1	8.253	1.8	44.2
DIVERSITY_OUTPUT	Number of publication types aimed at non-scientific audience used (out of 13 types)	69	3.435	4	1.440	1	7
Societal benefit variables							
SOCIETAL_IMPACT	Societal impact (construct; scale of 1 to 10; average of available responses)	60	5.767	6	2.308	1	10
CONTACTS	New or improved contacts as contribution to the knowledge infrastructure (construct; up to 23 categories)	67	5.507	5	3.249	1	14
Control variables							
PROJECT_BUDGET	Budget in euros	151	681578	351766	948886	58843	5657927
PROJECT_MEMBERS	Number of project members	171	18.409	7	24.978	1	142
Specific benefits							
IMPACT_1	Results were used in societal debates	55	6.509	7	2.705	1	10

Vervolg op de volgende pagina ›

Variable	Definition and scale	N	Mean	Median	St. dev.	Min.	Max.
IMPACT_2	Results contributed to including climate change knowledge in investment decisions	53	5.358	6	2.440	1	10
IMPACT_3	Results created political support for climate adaptation measures	49	5.745	6	2.775	1	10
IMPACT_4	Results were used to support a decision to postpone climate adaptation measures	43	3.209	3	2.426	1	10
IMPACT_5	Project resulted in climate adaptation measures and strategies that were implemented	45	5.011	5	2.946	1	10
CONTACTS_NEW	New contacts were made	68	5.081	4	3.264	0	14
CONTACTS_IMPROVED	Existing contacts were improved	68	3.370	3	2.589	0	11

Table 3.2 Correlations between design variables, impact variables, and control variables (Spearman's rho)

	SHARE_ SOCIETAL	INFORMAL_ INVOLVE	PROMINENCE	INFLUENCE	DIVERSITY_ OUTPUT	SOCIETAL_ IMPACT	CONTACTS	PROJECT_ BUDGET	PROJECT_ MEMBERS
SHARE_SOCIETAL	1 (171)	.164 (94)	.180* (103)	.249** (76)	.034 (69)	0.117 (62)	-.026 (67)	.167** (151)	.547*** (171)
INFORMAL_INVOLVE	.164 (94)	1 (94)	-.073 (92)	.147 (73)	.414*** (66)	.379*** (59)	.562*** (65)	-.066 (88)	-.072 (94)
PROMINENCE	.180* (103)	-.073 (92)	1 (98)	.397*** (76)	.187 (69)	.482*** (62)	.150 (67)	-.033 (92)	.065 (98)
INFLUENCE	.249** (76)	.147 (73)	.397*** (76)	1 (76)	.227* (64)	.500*** (59)	.407*** (62)	.062 (71)	.115 (76)
DIVERSITY_OUTPUT	.034 (69)	.414*** (66)	.187 (69)	.227* (64)	1 (69)	.314** (60)	.552*** (64)	-.309** (65)	-.356*** (69)
SOCIETAL_IMPACT	0.117 (62)	.379*** (59)	.482*** (62)	.500*** (59)	.314** (60)	1 (62)	.465*** (59)	-0.007 (58)	0.016 (62)
CONTACTS	-.026 (67)	.562*** (65)	.150 (67)	.407*** (62)	.552*** (64)	.465*** (59)	1 (67)	-.144 (64)	-.176 (67)
PROJECT_BUDGET	.167** (151)	-.066 (88)	-.033 (92)	.062 (71)	-.309** (65)	-0.007 (58)	-.144 (64)	1 (151)	.590*** (151)
PROJECT_MEMBERS	.547*** (171)	-.072 (94)	.065 (98)	.115 (76)	-.356*** (69)	0.016 (62)	-.176 (67)	.590*** (151)	1 (171)

* =p<.1 **=p<.05 ***<.01
Note: The shaded areas indicate correlations within the three categories of design, impact, and control.

3.5.1 Is transdisciplinarity real or token?

If hotspot projects are really transdisciplinary, we expect to find a difference between projects that were labelled as thematic and those labelled as hotspots. We first statistically compare the characteristics of the two types of projects. Since the data are not normally distributed, we use non-parametric independent samples tests (Mann-Whitney) to evaluate differences.[19] The results are presented in Table 3.3.

Societal actors are better represented, more involved (prominence), and have slightly more influence in hotspot projects than in thematic projects. This matches our expectation of transdisciplinary projects. However, the programme also required thematic projects to involve societal actors. As a result, societal actors had considerable influence in thematic projects. There is also no difference in the number of societal actors that were informally involved, in the diversity of output, or in the impacts on the knowledge infrastructure.

Surprisingly, there is no difference between hotspot projects and thematic projects in overall societal impact (averaged across five different types) or in their overall contribution to the knowledge infrastructure (averaged across two different types). When we examine the specific types of societal impact, the differences that remain relate to IMPACT_2 (results contributed to including climate change knowledge in investment decisions) and IMPACT_3 (results created political support for climate adaptation measures) where hotspot projects report higher impact. Hotspot projects also report a stronger improvement in contacts than thematic projects. The differences are, however, relatively small.

This comparison shows that there are clear differences in the design and size of academic and transdisciplinary projects, but few differences in their societal benefits. How well can we predict if a project has an academic or a transdisciplinary label in CcSP or KfC just by looking at design and size? We use forward binary logistic regression to test whether and, if so, with which variables we can predict if a project is transdisciplinary or academic. The model does not predict project labels very well. It has an initial accuracy of 76.2 per cent (assuming all projects are academic) and a final accuracy of 81 per cent. Out of 63 projects (48 thematic and 15 hotspots), 7 of the 15 hotspots (46.7%) were accurately classified, whereas 4 thematic projects (8.3%) were mistakenly classified as hotspots.[20] Control variables had no effect.

The only variable that seems to matter is the share of societal actors. Projects differentiate only by the most basic characteristic of transdisciplinary science (participation of societal actors) and not their role or influence, their informal involvement, or the diversity of output and size of projects. In short, we cannot predict based on design or size whether a project in our sample has an academic or a transdisciplinary label. In Mobjörk's (2010) terminology, this suggests that

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19 Effect size is defined as small when $r \leq 0.1$, medium when $r \leq 0.3$, large when $r \leq 0.5$, and very large when $r \leq 0.7$ (Rosenthal, 1996). Please note the term 'effect' refers to a relationship, which may not necessarily be a causal relationship.

20 Dependent variable is PROJECT_TYPE and independent variables are SHARE_SOCIETAL, INFORMAL_INVOLVE, PROMINENCE, INFLUENCE, DIVERSITY_OUTPUT, PROJECT_MEMBERS. Results: N=61, model χ^2=111.698 (p=.001), Nagelkerke R^2 .270, Hosmer & Lemeshow p=.071.

societal actors within the programmes mainly have a consultancy role and do not really participate in research. This indicates symbolic involvement (Elzinga 2008) or symbolic compliance in terms of principal-agent theory (Leisyte 2007). The large share of projects with an intentionally academic focus appears to confirm Weingart's (1997) concern.

Table 3.3 Comparison of medians per variable for academic and transdisciplinary projects

	Thematic projects (academic)	**Hotspot projects (transdisciplinary)**	**Results of Mann-Whitney test**
SHARE_SOCIETAL	0 (118)	.2668 (53)	.000***
INFORMAL_INVOLVE	3 (75)	4 (19)	.397
PROMINENCE	1.75 (77)	2.25 (21)	.014***
INFLUENCE	6.8 (59)	7.6 (17)	.026**
DIVERSITY_OUTPUT	3.5 (54)	4 (15)	.288
PROJECT_BUDGET	392083.3333 (116)	293855 (35)	.027**
PROJECT_MEMBERS	4 (118)	18 (53)	.000***
SOCIETAL_IMPACT	5.375 (47)	6 (15)	.130
IMPACT_1	7 (43)	6.25 (12)	.934
IMPACT_2	5 (41)	6.75 (12)	.068*
IMPACT_3	6 (36)	7 (13)	.086*
IMPACT_5	5 (35)	6 (10)	.457
CONTACTS	4 (54)	6 (13)	.522
CONTACTS_NEW	4 (55)	5.67 (13)	.546
CONTACTS_IMPROVED	3 (55)	4.67 (13)	.093*

* =p<.1 **=p<.05 ***<.01

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From an inverse point of view, symbolic compliance may in fact be actual compliance. The academic projects in the two transdisciplinary research programmes also have characteristics associated with transdisciplinarity. They informally involve societal actors, they report considerable influence of societal actors on the research process, and produce about as many output types aimed at societal actors as transdisciplinary projects. Academics working in the environment created by CcSP and KfC, in close (institutional) proximity to hotspot projects, may have been infected with transdisciplinarity.

3.5.2 Do transdisciplinary projects produce the expected benefits?

The projects in CcSP and KfC can consequently be considered as a single group of similar projects in terms of societal actor involvement. What is the relationship between the design characteristics of transdisciplinary science and the expected benefits? The purpose of involving societal actors in the two programmes is to achieve a number of societal impacts and to contribute to the development of a knowledge infrastructure.

We have used backward linear regression to examine this relationship for the entire sample of projects. The results are presented in table 3.4. The model for societal impact shows that the number of societal actors informally involved and their prominence have fairly strong effects on societal impact. What is remarkable is that the share of societal actors has a significant negative effect. The model for the contribution to the knowledge infrastructure shows that this particular benefit requires a different strategy. New and improved contacts are associated with the number of societal actors informally involved and the number of publication types aimed at non-scientific audiences. Controlling for budget, number of project members, and project type had no effect on the results. Respondents from the KfC programme report lower societal impact than those of the CcSP project, but this effect may be due to a time lag: KfC was still running, while CcSP projects are largely finished and have had more time to accumulate impact.

Table 3.4 Results of backward linear regression analysis at construct level (standardised coefficients)

Variables	SOCIETAL_IMPACT	CONTACTS
SHARE_SOCIETAL	-.244* (-1.774)	
INFORMAL_INVOLVE	.344* (2.741)	.313*** (2.843)
PROMINENCE	.449*** (3.369)	
DIVERSITY_OUTPUT		.454*** (4.117)
R^2	.268	.383
Adjusted R^2	.224	.360
F (p)	6.096 (.001)	17.041 (.000)
N	54	58

Note: t-values between brackets. p<.000. * =p<.1 **=p<.05 ***<.01.
The variables PROJECT_MEMBERS, PROGRAMME, and PROJECT_TYPE had no effect.

Societal impact and the contribution to the knowledge infrastructure are constructs based on items in the survey. Impact consists of four different items and contributions to the knowledge infrastructure of two. Table 3.5 shows that the impact variables are highly correlated, but also that the correlations are by no means perfect. Although one impact may contribute to another, they measure different dimensions of impact and are worthwhile studying separately (Martin 1996).

Table 3.5 Correlation between societal impact items (Spearman's rho)

	IMPACT_1	IMPACT_2	IMPACT_3	IMPACT_5	CONTACTS_ NEW	CONTACTS_ IMPROVED
IMPACT_1 (Results were used in societal debates)	1 (55)	.550*** (50)	.664*** (47)	.393** (40)	.537*** (53)	.531*** (53)
IMPACT_2 (Results contributed to including climate change knowledge in investment decisions)		1 (53)	.810*** (45)	.474*** (41)	.332** (51)	.326** (51)
IMPACT_3 (Results created political support for climate adaptation measures)			1 (49)	.612*** (39)	.621*** (47)	.325** (47)
IMPACT_5 (Project resulted in climate adaptation measures and strategies that were implemented)				1 (45)	.479*** (44)	.292** (44)
CONTACTS_NEW (New contacts were made)					1 (68)	.649*** (68)
CONTACTS_IMPROVED (Existing contacts were improved)						1 (68)

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* =p<.1 **=p<.05 ***<.01

Will an analysis at item level reveal the same patterns between the design variables and benefits as were found on the construct level? We repeated the backward linear regressions for each of the societal impact items and knowledge infrastructure items. Each benefit is associated with a different set of variables (Table 3.6), which suggests that each requires a special strategy.

Implementation of results profits (1) from a lower percentage share of societal actors who are, however, prominent involved in the project, and (2) from a larger number of informally involved societal actors. The first may relate to the effectiveness of translating project results into practical solutions; in complex problem areas with many societal actors, it is a challenge to turn available knowledge into actions (Nelson 1974; 2011). The second may relate to broader support for the solution in its context. This negative effect of the share of societal actors is only found for the implementation of project results.

Informal involvement and output diversity are the most pervasive design variables, affecting all but one or two impacts. These two variables are particularly associated with new or improved contacts and contributions to societal debates. Since informal involvement and output diversity are the most outward-oriented variables, this association seems logical.

Table 3.6 Results of backward linear regression analysis at item level (standardised coefficients)

	Societal debate	**Investment decisions**	**Political support**	**Implement-ation**	**Improved contacts**	**New contacts**
SHARE_SOCIETAL				-.439*** (-2.866)		
INFORMAL_INVOLVE	.381*** (3.162)			.427*** (3.068)	.215* (1.859)	.313*** (2.873)
PROMINENCE		.281* (1.992)	.264* (1.836)	.608*** (4.203)		
INFLUENCE	.286** (2.570)					
DIVERSITY_OUTPUT	.444*** (3.652)	.324** (2.296)	.386** (2.685)		.461*** (3.993)	.456*** (4.182)
R^2	.488	.236	.287	.409	.316	.389
Adjusted R^2	.452	.200	.250	.358	.291	.367
F (p)	13.634 (.000)	6.497 (.003)	7.834 (.001)	8.065 (.000)	12.922 (.000)	17.833 (.000)
N	47	45	42	39	59	59

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Note: t-values between brackets. p<.000. * =p<.1 **=p<.05 ***<.01.
The variables INFLUENCE, PROMINENCE, PROJECT_MEMBERS, PROGRAMME, and PROJECT_TYPE had no effect.

Giving societal actors a role in the research process (prominence) supports investment decisions and especially the implementation of results. At the construct level, there was no association between the two benefits and the influence of societal actors. However, this association does emerge when we distinguish very specific types of impact: giving societal actors influence is beneficial for using the results in societal debates. This tempers the suggestion that societal actors should be influential in all research phases and that the context of application should be taken into account from the outset to generate socially robust results (Gibbons *et al*. 1994; Pohl & Hirsh Hadorn 2008).

In short, there is an association between the archetypical properties of transdisciplinary research and the expected societal benefits. Explained variance of the models ranges from 20 per cent(investment decisions) to well over 40 per cent (societal debate). Controlling for number of project members, project type, or programme had no effect on the results. Roughly 55 per cent to 80 per cent remains to be explained.

In contrast to earlier findings (Walter *et al*. 2007), our results suggest that societal benefit is associated mainly with the characteristics of consulting transdisciplinarity rather than participatory transdisciplinarity. Benefit is achieved through informal involvement and a diversity of outputs, and much less by giving societal actors a prominent role or influence in the research process.

3.6 Conclusion and discussion

Scientists are expected to produce benefits for society and, in evaluations and grant proposals, prove that they did. They need to take this expectation seriously: token compliance is no longer sufficient. Realising societal benefits requires a custom design: it must be embedded in the organisation of research, particularly by involving societal actors in the research process. Societal actor involvement is considered an effective approach to achieving societal impact.

In this paper, we have examined two strategic research programmes in the Netherlands, Climate changes Spatial Planning (2004-2011) and Knowledge for Climate (2008-2014). These programmes take a transdisciplinary approach to climate adaptation research. With a combined budget of 180 milion euros, scientists may have been tempted to comply de jure rather than de facto with requirements to involve societal actors. Using a survey among members and project leaders of 178 projects, we have examined two questions related to compliance in the principal-agent relation between a programme and its projects. The first question concerns the risk of moral hazard: is societal actor involvement a token activity or a substantial component of the research process? The second question relates to possible adverse selection: does societal actor involvement produce the expected benefits and, if so, under which conditions?

There is no reason to suspect large-scale moral hazard (Guston 1996). A comparison of projects formally labelled as transdisciplinary and academic reveals that the former have characteristics typically associated with transdisciplinarity but also shows that academic projects share those characteristics. One reason for this similarity is that these particular academic projects were also required to involve societal actors. In fact, some of the academic projects are managed by societal actors. This supports the argument that research evaluations should consider the context of a project (De Jong et al. 2011). A mere focus on goals and outcomes may result in an inconclusive assessment. Another possibility is that elements of transdisciplinary research may have spilled over into the academic projects through the project members they share. A large proportion of the academics involved in the programmes is engaged in multiple projects, both academic and transdisciplinary.

There is also no reason to suspect adverse selection (Guston 1996). As expected, transdisciplinary research was found to have a positive effect on societal benefits. The design and organisation of projects in two climate adaptation programmes is associated with various types of societal benefit. They can be considered an appropriate approach to generating the societal benefits government expect of research programmes: share knowledge with relevant societal actors to facilitate innovation, and sustainably improve the knowledge infrastructure (Van der Meulen & Rip 1998).

Evaluating the societal impacts of research remains challenging. We have explored this relationship using quantitative analysis. Three limitations must be discussed. First, researchers in successful projects may have been more inclined to answer the survey than researchers in less successful projects. Non-response analysis in a comparable survey among participants in the same two programmes in 2010 suggests that this did not occur (Merkx *et al*. 2011). Second, some of the main variables are based on self-reporting by researchers. Societal impact is actually impact as perceived by scientists who participated in projects. We did not include societal actors in our survey, primarily because their responses are inherently different (they tend to provide the organisation's view rather than their own) and because representatives changed as the programmes progressed. A pragmatic argument is that self-reporting is a common approach (e.g. Pohl 2005; Landry *et al*. 2007; Masse et *al*. 2008; Pohl 2008; Van der Weijden *et al*. 2012; Olmos-Peñula *et al*. 2014). And third, self-reporting might guide the results: if the project was designed to produce an impact, then that impact must have been produced. However, projects and project members were queried individually, which means that respondents had no opportunity to scale or coordinate their responses.

Our discussion of the limitations suggests that a contribution to the literature which includes the societal actor perspective on the research process and the achieved benefits is urgently needed. In addition, our findings may be of value to many other fields – ranging from sociology to biotechnology – in which researchers are working to solve problems that involve a variety of affected actors (Whitley 2000). Future research should investigate how researchers in other fields and problem areas produce societal impact. Comparative studies are needed because the sectoral background of societal actors matters (Bekkers & Bodas Freitas, 2008). Finally, our models leave a substantial part of variance unexplained (between 6 per cent and 80 per cent). Even though this high percentage is quite common in social science studies, it begs the question what factors and circumstances account for the remainder. Possible answers are funding sources, research group size, and group leader experience (Van der Weijden *et al.* 2012), cultural barriers (Siegel *et al*. 2003), the quality of the scientific research (Hewitt-Dundass 2012), individual characteristics of researchers, such as previous experience in interacting with societal actors (D'Este & Patel 2007), and political and economic conditions. And even if all such variables had been included, a degree of variance would remain, because benefits can be generated by accident or serendipitously (Molas-Gallart *et al*. 2002).

Our results have implications that deserve consideration by policymakers. Firstly, the design of research programmes and projects must be customized towards the needs of the specific societal benefits they aim to generate. Societal benefit is a multidimensional concept. Each impact requires its own approach and what works for one type of benefit (e.g. informing societal debate) may not work for another (e.g. new contacts). Secondly, our advice is to reconsider the emphasis on formal involvement of societal actors in funding procedures. Formally involving societal actors is a common criterion in research funding science. Also, societal actors are regularly required to co-fund research. Our results suggest this may not have the expected result. It is important to be aware of and facilitate informal interactions (Olmos-Peñuela *et al.* 2014) as well as to assess strategies to informally involve societal actors, as this may be a source of additional gains.

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