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Conceptualising joint knowledge production in regional climate change adaptation projects: success conditions and levers for action

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ABSTRACT

Matching supply and demand for knowledge in the fields of global change and sustainability is a daunting task. Science and public policy differ in their timeframes, epistemologies, objectives, process-cycles and criteria for judging the quality of knowledge, while global change and sustainability issues involve value pluralities and large uncertainties. In literature and in practice, it is argued that joint knowledge production in projects through collaboration between (and within) science and policy serves as a means to bridge the gap between the two domains. However, an assessment framework for analysing the merits and limitations of such projects, identifying good practices and enabling adaptive management as well as social learning had not yet been developed. This paper aims to develop such a framework. We portray joint knowledge production projects as policy arrangements in which the degree of success depends on the actors involved, contents of dominant discourses, presence of rules and the availability of resources. Literature was discussed to specify these four dimensions into seven success conditions for joint knowledge production. Scholars, boundary organizations and actors in projects can use the framework for retrospective analyses of projects, providing joint knowledge production with the empirical basis it still requires. The framework can also be used for promoting reflection in action as well as for formative assessments enabling social learning.

1. Introduction

Global change and sustainable development require new types of knowledge and new ways of knowledge production, as old forms of knowledge production are believed to be inadequate (Biesbroek et al., 2010; Funtowicz and Ravetz, 1993; Gibbons et al., 1994; Kemp and Martens, 2007; Kemp and Rotmans, 2009; Scholz and Marks, 2001). Moreover, global change and sustainability issues have to cope with the complexities inherent in connecting science and policy: research-based knowledge may fail to match expectations of policy actors; it may be used differently than was expected or intended; science is fragmented across disciplines (Herrick and Sarewitz, 2000); and the interaction between science and policy is neither simple nor linear due to differences in time frames, reward structures, goals, process cycles and epistemologies (Edelenbos et al., 2011; Mostert and Raadgever, 2008; Van den Hove, 2007; Weichselgartner and Kasperson, 2010).

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In literature (e.g. Pohl et al., 2010; Regeer and Bunders, 2009; Van Buuren and Edelenbos, 2004; Vogel et al., 2007) and in practice joint knowledge production is endorsed as a potential way to deal with these challenges. Joint knowledge production implies that scientists, policymakers and sometimes other societal actors cooperate in the exchange, production and application of knowledge (Cash et al., 2003; Edelenbos et al., 2011; Van den Hove, 2007; Van Kerkhoff and Lebel, 2006). Such cooperation takes place at the 'science–policy interface' and involves 'social processes which encompass relations between scientists and other actors in the policy process, and which allow for exchanges, co-evolution and joint construction of knowledge with the aim of enriching decision-making' (Van den Hove, 2007). Dutch and German climate research programs such as 'Climate Changes Spatial Planning', 'Knowledge for Climate' and 'Klimzug' in which universities, research institutes, governments and boundary organisations collaborate, aim explicitly at joint knowledge production. The establishment of these programs entails a redistribution of funding from disciplinary and fragmented research efforts to research activities that intend to be more practically oriented, collaborative and participatory. This shift may be seen as part of what some (e.g. Bäckstrand et al., 2010) term a deliberative turn in environmental governance. The programs include projects in which scientists, policymakers and sometimes other actors engage in joint knowledge production for climate proofing specific regions.[1]

We argue that a specific framework for retrospective analysis of such regional projects is lacking. Existing frameworks for analysing science-policy relations in environmental governance have different empirical foci, including international climate regime formation (Andresen et al., 2000), global change assessments (Committee on analysis of global change assessments, 2007), global environmental governance (Jasanoff and Martello, 2004), the co-production of European climate policy and climate science (Lövbrand, 2011), or assessments of the relationship between science policy and climate policy (Sarewitz and Pielke, 2007). Although studies such as the ones cited above provide relevant insights, the frameworks developed are not specific enough for analysing joint knowledge production in regional climate change adaptation projects. A framework specific for this aim would enable scholars, research funders and reflexive practitioners to analyse and reflect on project experiences, thus facilitating social learning and adaptive management (Folke et al., 2005). This would maximize the potential merits (e.g. production of more policy relevant knowledge) and minimize the potential drawbacks (e.g. science becoming tainted with politics) of such projects (McNie, 2007; Sarewitz and Pielke, 2007).

This paper aims to develop an assessment framework for *retrospective analysis* of regional joint knowledge production projects. The framework will identify *success conditions for joint knowledge production*. Furthermore, we will try to specify *levers for action* by indicating to what extent actors (e.g. scientists, policy makers, and financiers) could influence these success conditions. The conditions are based on a review of existing literature. Various lessons can be derived from empirical papers analysing different forms of science-policy interaction (e.g. Jones et al., 1999; Roux et al., 2006; Steyaert and Jiggins, 2007; Steyaert et al., 2007; Sundqvist et al., 2002) and from conceptual analyses of science–policy relationships (Hoppe, 2005; Van den Hove, 2007; Van Kerkhoff and Lebel, 2006). We will illustrate each success condition with an empirical example from Dutch climate change adaptation projects. Most projects are part of the 'Knowledge for Climate' research program.[2]

To achieve the research goal the following steps have been taken. First, Section 2 introduces our central concept of joint knowledge production and embeds this in existing conceptualisations of science–policy relationships. Next, we define and operationalize 'successful joint knowledge production', our dependent variable (Section 3). We then go on by introducing our general framework for discussing literature findings, which is inspired by the policy arrangements approach (Van Tatenhove et al., 2000; Arts et al., 2006; Liefferink, 2006) (Section 4). In Section 5, we identify our 'independent variables' and classify them in actor-; discourse-; rule- and resource-related success conditions. These success conditions will be formulated in the form of seven propositions to be used as heuristic tools in empirical research. We end with a discussion (Section 6) followed by some concluding remarks about the levers for action (Section 7).

2. Joint knowledge production: conceptual clarification

The discourse on what we term 'joint knowledge production' is part of broader scholarly debates on knowledge production and the relationship between science, policy and society (see Driessen et al., 2010 for an overview). Sociologists like Gieryn (1983), Guston (2001) and Miller (2001), have for instance focused on the role of boundary work and boundary organizations in mediating the boundaries between science and policy, while policy analysts (e.g. Hoppe, 2005) have developed typologies of science–policy interactions.

Transdisciplinarity scholars (Pohl and Hirsch Hadorn, 2007; Scholz and Marks, 2001) have developed approaches to link abstract and case-specific knowledge in order to grasp the complexity of real-world problems and to take into account the diversity within and between scientific and life world perceptions of problems. Public participation scholars have focused on the inclusion of non-scientists in knowledge development (Irwin, 1995).

These and other contributions have convincingly shown that what Beck (2011) calls the 'linear model of expertise' does not adequately conceptualize the relationship between science and policy. This linear model uses various assumptions which have proven to be inadequate: the assumption that a sharp distinction can be drawn between science and power (Jasanoff and Wynne, 1998); or the assumption that science compels policy (Bolin, 1994; Pielke, 2005). Latour (1987) stresses that scientific agendas are socially constructed through various complex mechanisms and the results of scientific research are reinvented and contextualized. Hence,

[1] E.g. http://climatechangesspatialplanning.climateresearchnetherlands.nl/.

[2] http://knowledgeforclimate.climateresearchnetherlands.nl/.

co-evolution or co-production between science and society always takes place at least to some extent (e.g. Andresen et al., 2000; Jasanoff, 2004; Jasanoff and Martello, 2004; Latour, 1987). Co-production mechanisms are often indirect and hard to discern. Our paper takes an opposing position by focusing on a very direct and recognizable form of co-production: direct collaboration between scientists, policymakers and other societal actors in specific projects (Van Buuren and Edelenbos, 2004; Edelenbos et al., 2011). Some authors (e.g. Pohl et al., 2010) label this phenomenon with the term knowledge co-production. We deem this term confusing because of its resemblance with the notion of co-producing social order (e.g. Jasanoff, 2004; Jasanoff and Martello, 2004; Latour, 1987). We therefore prefer to use the concept joint knowledge production.

Joint knowledge production can be considered a manifestation of both Mode 2 research (Gibbons et al., 1994; Nowotny et al., 2001) and post normal science (Funtowicz and Ravetz, 1993). According to Gibbons et al. (1994) 'Mode 2′ research is contextualized, transdisciplinary, heterogeneous, socially accountable and involves new modes of quality control. Proponents of post-normal science claim, amongst others, that an extended peer community is needed which is capable of contributing contextualized local knowledge in scientific debates (Ravetz, 1999).

3. Determining the success of joint knowledge production in projects

For two reasons we deem a *constructivist* approach most appropriate to determine whether joint knowledge production has been successful or not. First, actors can be expected to have *different knowledge interests*, so their criteria for what is relevant knowledge may differ. Within a project, regional governments may for instance be interested in flood safety of the area for which they are responsible, while participating earth system scientists' main interests concern the development of new global change modelling techniques which they can publish about. Only if knowledge interests can be met to at least a minimal extent, will actors remain committed to climate change adaptation projects in the sense that actors stay on board and – ideally – express interest in further cooperation. Second, regional climate change adaptation projects involve high decision stakes, uncertainties and contested values, complicating 'objective' scientific evaluation of the output of joint knowledge production projects in a Popperian sense.

Hence, we focus more on the *process* of joint knowledge production projects rather than on their products (compare Hegger et al., 2011). We do not assess environmental effectiveness *as such* or what evaluation literature (Walter et al., 2007; Spaapen et al., 2007) calls 'the broader impact of research', although we deem it plausible that a successful process contributes to these issues. Instead, we conceptualise successful joint knowledge production as a process which should be acceptable for all participating actors (extended peer community) (Ravetz, 1999).

Cash et al. (2002, 2003) have found that production and mobilisation of knowledge across boundaries of science and action will likely be effective when criteria of salience, credibility and legitimacy can be met simultaneously for all actors involved. As we illustrated above, actors involved will have different *criteria* and *thresholds* for credibility, salience and legitimacy. Credibility refers to the perceived adequacy of the knowledge produced and salience to its perceived relevance. Legitimacy refers to the extent to which knowledge production has been respectful of the divergent values and beliefs of stakeholders, unbiased in its conduct and fair in its treatment of opposing views and interests (ibid). In their original formulation, Cash et al. (2002, 2003) portrayed credibility as a scientific interest; and salience and legitimacy as 'societal' interests. Our starting point, however, will be that all actors may have criteria related to all three concepts (Roux et al., 2010; White et al., 2010). Successful joint knowledge production requires that at least actors' *thresholds* regarding the credibility, salience and legitimacy of the knowledge produced are met (Hegger et al., 2011). This will necessitate a reconciliation of the *criteria* of the participating actors. Actors may utter statements on the credibility of knowledge produced (this may be codified, explicit, as well as tacit knowledge), on the credibility of people participating in the project; on the salience of the knowledge produced as well as on the perceived legitimacy of the process. In all these cases, they implicitly give their perception of the joint knowledge production *process*.

It is an empirical question if it is possible to set up and implement regional climate change adaptation projects in such a way that all three criteria can be met simultaneously. Is it for instance possible to scientifically underpin certain planning procedures (credibility)? Can a scientific concept such as 'resilience' be put to practical use in a certain area (salience)? Which area-specific knowledge is scientifically interesting and provides input for journal articles (salience)? How can we ensure that the interests of minority groups are taken into account (legitimacy)? As literature suggests, there can be trade-offs as well as synergies between the criteria (Cash et al., 2002, 2003; White et al., 2010). On the one hand policymakers may use knowledge which lacks credibility in the eyes of scientists. But on the other hand, credibility and salience can reinforce each other if multiple disciplines and approaches are complementary in the types of questions asked, or if formerly not included place-based knowledge is used in the process of knowledge development. The latter can also enhance legitimacy through inclusion of formally excluded groups. If we accept synergies of the latter type as an ideal to aspire to, successful joint knowledge production can be defined as a process in which the *actors involved have managed to maximize synergy and minimize tradeoffs between the salience and credibility of the knowledge produced as well as the legitimacy of the process*. The less participants of a joint knowledge production project define the outcome in terms of 'winners' and 'losers', the more successful the project has been, and vice versa.

4. Joint knowledge production projects as policy arrangements

Having determined a potential way to define successful joint knowledge production, our 'dependent variable', the next

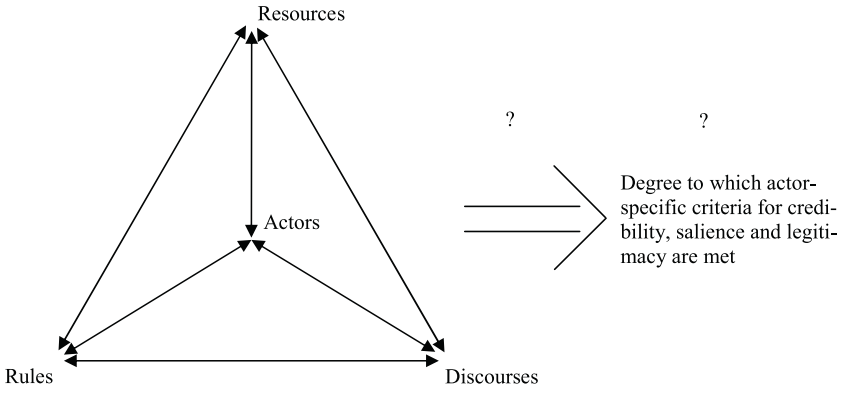

Fig. 1 – Understanding joint knowledge production dynamics.

question is what would be *success factors* (our 'independent variables') and to what extent actors would be able to influence them. To enable a comprehensive assessment of these success factors, we will turn to the four analytical dimensions of the policy arrangements approach (Van Tatenhove et al., 2000; Arts et al., 2006; Liefferink, 2006). Within this approach, the relationship between actors and their structural context is conceptualized as a dynamic interplay between four dimensions (Arts et al., 2006; Liefferink, 2006):

- The *actors* and actor coalitions involved in a policy domain;
- The current policy *discourses* and programs (problem perceptions, norms and values, worldviews, storylines and narratives of the actors involved);
- The *rules* of the game currently in operation (division of responsibilities, formal and informal rules of interaction, the political embedding of the process);
- The *resources* available (money, competences, facilities, organizational embedding), whereby the original policy arrangements approach emphasizes the importance of power relations and resource dependencies.

As Fig. 1 illustrates, the process under study (joint knowledge production projects in our case) includes factors belonging to all four dimensions. We expect that different interplays between these dimensions result in different degrees to which actor-specific criteria for credibility, salience and legitimacy can be met.

The policy arrangements approach has been applied in earlier studies of environmental policies, nature conservation and water management (Arts et al., 2006; Arnouts et al., 2011; Wiering and Arts, 2006; Wiering and Immink, 2006). The use of the policy arrangements approach for analysing joint knowledge production dynamics is an innovative step. One can argue that *knowledge production* projects, due to the inherent involvement of public policy actors, can be seen as policy arrangements. But the main argument for using the approach is its analytical strength from a social theoretical perspective. First, it is an 'actor in context' approach acknowledging what Giddens (1984) terms the duality of structure: the approach pays attention both to the day-to-day actions of individuals (with which they can reinforce or alter existing structures); to these structures themselves; and to the interactions between actor and structure. It is assumed that actors are not only participants (part of the system) but also agents with the possibility to change these systems (ibid).

Second, the approach stresses that stability and change in policy arrangements can be induced through each of the four dimensions, whereby changes in one dimension may invoke a chain reaction in the other ones. For instance, actors may contribute new elements to dominant discourses or be the carriers of resources (money, expertise).

Third, policy arrangements have been defined as temporary in nature (a stabilization point or a stage of development in an ongoing social practice) (Arts et al., 2006). This, in our opinion, does justice to the fact that joint knowledge production *projects* do not take place in a temporal vacuum, but have been preceded by societal developments and give rise to future developments.

5. Success conditions for joint knowledge production in projects

This section further discusses the four dimensions introduced in the previous section. This discussion results in seven success conditions for joint knowledge production in regional climate change adaptation projects.

5.1. *Actors: who participates?*

One could argue that a broad actor network leads to more 'socially robust' knowledge. As Nowotny (2003) writes (additions between brackets are added by the authors) 'socially robust knowledge has three interrelated aspects: it is tested for validity outside as well as inside the laboratory (potentially enhancing salience and credibility); it is most likely to be achieved by involving an extended group of experts (enhancing credibility, legitimacy and salience); it results from having been repeatedly tested, expanded and modified (credibility and salience)' (p. 155).

The question then is, which actors have to be selected to develop socially robust knowledge? Specifically in the context of regional climate change adaptation, relatively little is known about this. From literature on stakeholder participation and network management, however, we can derive four

principles for actor selection (Driessen and Vermeulen, 1993; Lamers et al., 2010).

First, the 'crucial' actors should be involved (Driessen and Vermeulen, 1993). In the case of regional climate change adaptation, these would include actors with a (knowledge) interest in the area under consideration; parties which can provide contra-expertise and practical knowledge (these may be stakeholders as well); and knowledge institutes. In the Dutch empirical context various actors are involved in regional climate change adaptation projects. These include university departments (e.g. earth system science, environmental economics, environmental policy, ecology, urban planning and various others) as well as public policy bodies such as provinces (regional governments), water boards, and (consortia of) municipalities. We also see applied research institutes participate (in The Netherlands amongst others Alterra, Deltares, TNO, Agricultural Economics Research Institute, Dutch Meteorological Institute) as well as consultancy companies. To a lesser extent, regional environmental NGOs and various others participate. Determining how 'crucial' certain actors are, or how relevant their expertise is, is likely determined through a strategic process of boundary work in which power relations play an important role (Gieryn, 1983; Kloprogge and Van Der Sluijs, 2006). Second, actors need to be prepared to participate (Driessen and Vermeulen, 1993). Only if actors have good reasons to expect the participation to result in 'win–win' situations, their participation will be advisable. Actors will not always and not in each stage of a project be willing to participate, for instance if they do not see themselves as a 'problem owner' (Lamers et al., 2010). Third, non-selected actors may be an important source of opposition, because of self-interest, or because of frustration about 'not being selected' (Driessen and Vermeulen, 1993). This may be a reason to try to include these actors in the project, but as noted above, actors may be unwilling to show up. Fourth, in any collaborative process the number of actors needs to be limited to keep the process manageable (Driessen and Vermeulen, 1993; Lamers et al., 2010).

The Dutch research program 'Knowledge for Climate' illustrates how a strategic process of actor selection may work out in practice. The program comprises nine regional 'hotspot' teams[3] in which representatives of regional actors as well as representatives of science collaborate. In itself, this can be considered a useful way to develop a shared research agenda. However, although the hotspot teams are expected to develop regional adaptation strategies (policy) on the basis of the research results, no administrative representatives are present in the teams. This compromises the political legitimacy of the process.

The selection principles as well as the illustration provided above bring to light the central dilemma when recruiting actors for joint knowledge production projects. In principle, one would like to broaden-up the process as much as possible by including all relevant actors in order to arrive at socially robust knowledge. But there are some inherent limitations in how many, and which actors can participate. We conclude that empirical analyses of joint knowledge production projects will have to pay ample attention to issues such as *how* actor selection has to be done to enhance the chance for win–win situations (we will return to the issue in Section 5.3). At this point, however, we can formulate the following proposition:

Proposition 1. *The success of joint knowledge production projects is enhanced in cases in which the broadest possible coalition of actors is formed, within the practical and strategic limits present. This likely entails both in- and exclusion of actors.*

5.2. *Discourses*

Discourses can be defined as 'ensembles of ideas, concepts and categories though which meaning is given to social and physical phenomena, and which is produced and reproduced through an identifiable set of practices' (Hajer and Versteeg, 2005, p. 175). An important message to be derived from the work of discourse analysts is that sense making by societal actors is crucially important. Language shapes one's view of the world and of reality, rather than being a neutral medium mirroring it. Discussions (the object of analysis of discourse analysts) may vary in the extent to which they have deliberative quality, that is, are open, accountable, reciprocal and fair, enabling participants to learn through an iterative dialogue (ibid, p. 176). With these basic lessons of discourse analysts in mind, let us now turn to two specific aspects of regional joint knowledge productions projects, the process of defining the problem (Section 5.2.1), and the recognition of actor perspectives (Section 5.2.2).

5.2.1. *The process of defining 'the problem'*

The nature of policy problems differs (Hisschemöller and Hoppe, 2001) and with this the type of output to be expected from joint knowledge production projects. In a well-known typology of policy problems, Hisschemöller and Hoppe (2001) distinguish between unstructured, badly-, moderately- and well-structured problems. In the latter case, actors agree on policy goals and means and they can aim at *solving* policy problems (global change problems are generally not of this kind). In case of moderately-structured problems there is agreement on either means or goals. Research-based knowledge can then be used to identify and back-up *arguments*. Badly- or unstructured problems are characterized by the fact that there is neither agreement on means nor goals. Consequently, actors are undecided about the relevance of expertise; whether issues should be labelled as values or facts; how problems interrelate or even who the stakeholders are. To deal with badly- or unstructured problems, ideas or concepts may be needed, enabling actors to critically examine and reframe their own problem definition, to gain understanding of the viewpoints of other actors or to achieve closure on problem definitions.

Not only do policy problems and knowledge needs vary in realist terms. Also, actors may have different problem *perceptions* or different ways to *frame* problems. Actors may 'choose the wrong problem' due to lack of insight or they may have political or strategic reasons to frame a problem in a particular way (Hisschemöller and Hoppe, 2001): values can be

[3] Schiphol Mainport; Haaglanden region; Rotterdam region; Major rivers; South-west Netherlands delta; Shallow waters and peat meadow areas; Dry rural areas; Wadden Sea; Delta alliance.

labelled as facts; the relevance of certain expertise can be questioned or presented as taken for granted. Problems may be portrayed as unstructured or well-structured for strategic reasons, undermining the perceived salience or credibility of the knowledge produced in a project.

A quick look at different types of regional climate change adaptation projects in The Netherlands illustrates that the goals of projects as well as actors' opinions on the relative importance of certain goals can vary. The recently finalized research program Climate Changes Spatial Planning, for instance, included various so-called 'Hotspot' projects in which researchers and consultants provided feedback on running spatial planning processes or on provincial plans which were in preparation (Climate Changes Spatial Planning and Knowledge for Climate, 2009). Project goals included, but were not limited to, assessing the 'climate resilience' of existing planning processes, developing new measures for enhancing resilience, and evaluating the desirability of these measures under different climate scenarios. For the program bureau, it was an explicit goal to put 'climate change' on the agendas of regional governments. Problem definitions of actors differ, and achieving closure on problem definitions (e.g. acknowledging that a problem such as soil subsidence in low lying areas does exist) can in some cases be the main outcome to be achieved from a project.

Bringing actors together around a certain problem can be expected to be an active process, requiring various kinds of boundary work (Gieryn, 1983). As we highlighted in Section 5.1, the selection of participating actors is of importance for this. Boundary organizations (Guston, 2001; Miller, 2001) can play a crucial role in selecting actors. As an example from the Dutch context, some provinces have so-called transdisciplinary innovation labs (e.g. Xplorelab in the province of Zuid-Holland) which have purposefully been placed outside of formal decision-making structures. Such boundary organizations likely play a key role in pre-structuring problems and thereby defining who should be represented, and which expertise is considered relevant.

Once actors are brought together, however, they will not automatically have shared problem definitions (and in some cases reconciliation turns out to be impossible). One can expect though, that the process of finding shared problem definitions can be influenced to some extent by purposefully managing expectations regarding the outcomes of a process (Weichselgartner and Kasperson, 2010). This could be done by keeping 'what the project should lead to' constantly on the agenda, allowing for adaptations in the problem goals in the course of a project (Committee on the analysis of global change assessments, 2007). A prominent example from the Knowledge for Climate research program are the so-called regional 'Climate Impact Atlases' visualising regional climate change vulnerabilities. In various projects, these atlases were successfully used to arrive at shared problem perceptions. These and other initiatives may counteract actors' tendency to take their own definition of the problem for granted and not to become aware of the differences between their expectations and those of other actors. The qualities of project leaders and participants in managing expectations and looking for win–win situations are likely of key importance in a project.

Proposition 2. *The chance that joint knowledge production is successful is enhanced in cases in "which participating actors deliberate on the nature and denomination of the policy problem (un-, badly-, moderately- or well-structured) and the type of outcome? (ideas, closure on problem definition, concepts, arguments or solutions) to be expected.*

5.2.2. *Recognition of differences in actor perspectives*

Scientists, public policymakers, businesses, and NGO officers have differing, often implicit, *perspectives* on the world around them and one could even say that these actors belong to communities with different epistemologies (Hoppe, 2009). This makes it important not only to address problem perceptions, but also the broader actor perspectives of which they are a part. Raadgever et al. (2008) define stakeholder perspectives as 'the cognitive representation that a stakeholder makes of the external reality and his or her position in this reality. It includes the stakeholder's preferences concerning management options, as well as the values, specific interests, and knowledge that underlie these preferences'. When (differences in) perspectives are recognised and better understood by participants, it might be easier to ensure success across these perspectives.

Boundary objects can have a mediating role in the development of co-production narratives. Boundary objects have been defined as concepts adaptable to different viewpoints but at the same time robust enough to maintain identity between them (Star and Griesemer, 1989). Concepts such as eco-indicators and critical loads form working examples. The former are said to be in need of stakeholder involvement, as they cannot be evaluated according to scientific criteria alone: they are a proxy for a complex reality (ecosystems) and have a strong normative component (Turnhout et al., 2007). Scientists disagree on the adequacy of eco-indicators for determining the state of the environment, while political considerations for protecting certain species or types of nature co-determine the use of these indicators.

Sundqvist et al. (2002), when discussing the concept of critical loads, note that '...there is a certain amount of interpretative flexibility surrounding the concept of critical loads, its usefulness and applicability. The vagueness of the concept at this level of analysis is what makes the connection and proliferation of knowledge possible' (p. 154). Kloprogge and Van Der Sluijs (2006), Steyaert and Ollivier (2007), and Steyaert et al. (2007) make similar points. Boundary objects (besides concepts one can also think of texts or computer tools) are said to allow for interpretative flexibility and to provide room for negotiation. Hence, such boundary objects enable communication between multiple communities with different epistemologies.

Examples of boundary objects in the field of regional climate change adaptation are formed by site visits to the areas under study, or interactive GIS maps; but also ambiguous (intentionally vague) concepts. The concept of 'climate proofing' (Kabat et al., 2005) forms a working example from the Dutch climate change adaptation community. This concept is said to have worked as a catalyst in regional planning. Actors are free to operationalize the concept of climate proofing according to their own insights, but through its function as a

boundary object the concept may help to strengthen adaptation policies.

Proposition 3. *Actors in joint knowledge production projects can be expected to have diverging and implicit perspectives on the world around them. The success of joint knowledge production will be enhanced if the different perspectives of stakeholders are recognised and taken into account. In this, boundary objects can play a mediating role.*

5.3. *Rules*

This section zooms in on three specific rules of the game which can be thought to be of relevance for understanding the dynamics in joint knowledge production projects: the division of responsibilities between actors (Section 5.3.1); the roles of researchers and their knowledge (Section 5.3.2); and reward structures (Section 5.3.3).

5.3.1. *Division of responsibilities*

The task division between scientists and others in joint knowledge production projects can be shaped in different ways. On the one extreme, one could choose for a very strict separation between knowledge production and use, as exemplified with Vannevar (Bush, 1945) notion of science as an endless frontier (presupposing trickle-down and enlightenment models of the relationship between science and society). This extreme cannot be found in joint knowledge production projects which by definition focus on collective endeavours of scientists, policymakers and other actors as they are described, amongst others, in literature on participatory action research (Termeer and Kessener, 2007), transdisciplinarity (Pohl, 2008), Mode-2 knowledge production (Lemos and Morehouse, 2005; Pohl, 2008; Pohl et al., 2010; Roux et al., 2006; Turnhout et al., 2007) and post-normal science (Funtowicz and Ravetz, 1993). Within these streams of thought, we can find different degrees and forms of cooperation (e.g. Van Kerkhoff and Lebel (2006) distinguish between participation, integration, negotiation and learning[4]), differing in the extent to which scientists, policymakers and practitioners engage in shared practices. Which degrees and forms of cooperation would be conducive to successful joint knowledge production?

Literature provides some arguments in favour of intensive collaboration. This is said to be necessary to arrive at mutual understanding and to learn to speak each other's language (Van Kerkhoff and Lebel, 2006). Some authors report positive experiences with researchers pursuing other roles (e.g. facilitator or mediator) next to their role as *researcher only* (Pohl et al., 2010). This was said to enable other actors to have a discussion on a more equal basis.

On the other hand, arguments can be found suggesting that collaboration can and maybe should not be too intensive. Van Kerkhoff and Lebel (2006) point at the merit of maintaining a 'healthy tension' between the domains of science and policy: one can challenge the other. Further, researchers and policymakers may want to remain in their comfort zone and maintain their own identity (Roux et al., 2006; Sundqvist et al., 2002) which can be thought to limit the willingness of actors to engage in intensive collaboration. Also, more distance between science and policy could stimulate curiosity-driven research leading to serendipity (but researchers can also use the latter as a false argument 'to remain in their comfort zone') (Van den Hove, 2007). Finally, close connections between science and policy increase the need to 'fit' languages and process cycles, which is difficult and can easily go wrong (Jones et al., 1999; Lemos and Morehouse, 2005; Roux et al., 2006; Steyaert et al., 2007).

In the context of Dutch projects dealing with regional water management and climate change issues, we see that responsibilities are divided in different ways. Examples include very 'knowledge-driven' policymakers (e.g. in the previously mentioned regional 'Hotspot studies' of the Climate Changes Spatial Planning program) but we also see examples of researchers with a strong interest in the practical application of their work, providing input to policy documents. On the other hand, there are projects in which researchers and policymakers remain in their traditional roles of knowledge producers and knowledge users respectively, whereby knowledge exchange and translation takes place through knowledge brokering (e.g. the Routeplanner project, translating the findings of three Dutch climate research programs to policy input for the Dutch national adaptation strategy (Van Drunen et al., 2009)).

On the basis of this discussion, no single best way to divide responsibilities in joint knowledge production projects can be identified. Neither do we deem it likely that such a best way exists. It seems more likely that different role divisions are conducive in different contexts, and the question 'which role division in which context' seems to be an empirical one. What literature convincingly shows, however, is that openness of actors regarding what their intentions and expectations are, is crucially important (Lee, 1993; Sarewitz, 2004; Weichselgartner and Kasperson, 2010). If policymakers use scientists (unknowingly) to legitimize a certain course of action, or if scientists pursue what Pielke (2007) terms 'stealth issue advocacy', this may in the end hamper the perceived legitimacy of joint knowledge production projects.

A starting point for arriving at the needed openness would be that actors choose, consciously and reflexively, which role to pursue in a project, how to define their identity in relation to other actors, and to make these choices known to these other actors (Mostert and Raadgever, 2008). As Jasanoff (1990) has found, science-policy collaboration is likely most effective if negotiation and boundary are used reflexively to adapt roles and responsibilities to new framework conditions. In the Knowledge for Climate research program we find an illustrative example of how this can be done. In the program, actors can only participate if they contribute financially to projects to a minimal extent (25–50%). This way, it is ensured that actors share responsibilities, whereas all actors can enforce research results that are useful for them (compare the recommendations from the Committee on the analysis of global change assessments, 2007).

[4] Van Kerkhoff and Lebel further distinguish 'trickle down' and 'translate' levels of cooperation, which can, however, not be seen as 'joint knowledge production in research projects' as they involve no direct collaboration between scientists and policymakers.

Proposition 4. *The chance that joint knowledge production is successful is enhanced if actors decide, consciously and reflexively, which role to pursue in a project, how to define their identity in relation to the other actors, and to make their choices known to these other actors.*

5.3.2. *Roles of researchers and of research-based knowledge*

Having outlined the need for clear role divisions in projects, let us look a bit more specifically at the role of researchers and research-based knowledge in joint knowledge production projects. In principle, the role of scientists would be to inform policy (Gieryn, 2002; Pielke, 2007) whereas the question 'what to do' is addressed through a political process of bargaining, negotiation and compromise. What science can do in the face of uncertainty and contested values is to contribute to the development of new and innovative policy options that might allow for compromise between opposing parties. One of the important roles of science in policy-making is to inform expectations about choices and their possible outcomes. Questions of desirability of the outcomes and acceptability of risks must be handled through political processes (Pielke, 2007). Pielke distinguishes between four ideal typical roles for scientists: 'pure scientist'; 'science arbiter'; 'honest broker' and 'issue advocate'. The former two roles would be most logical in cases of value agreement and low uncertainties, whereas the latter two roles would be most logical in cases of value pluralities and high uncertainties (ibid). The latter condition can be thought to be present in the regional climate change adaptation projects we are considering.

In which ways can science inform policy in such joint knowledge production projects and which roles can be played by researchers and their knowledge? First, researchers can provide *data* to actually solve policy problems (Hisschemöller and Hoppe, 2001). This role seems to be reserved, however, for well-structured problems, while un-, badly- or moderately structured problems require researchers to play other roles. Hence, such a science arbiter role for researchers seems rather unlikely in regional climate change adaptation projects.

Second, research can provide *concepts* to gain insight into problems or to structure them through a discourse coalition model (Hoppe, 2005; Kemp and Rotmans, 2009). These concepts may function as bridges between originally separate fields of knowledge and action. In so doing, the role of researchers is not restricted to providing *explicit scientific knowledge*. With their concepts, researchers can also unearth *other types of knowledge*, such as tacit knowledge, beliefs and values, of non-scientific stakeholders. Science can produce various boundary-ordering objects, packages or devices like texts, documents, procedures, standardized practices, or overlapping memberships by experts and policy entrepreneurs. Thus, scientists can play the role of issue advocates and honest brokers.

Third, researchers need not restrict themselves to the development of concepts, but they can also contribute to social learning by developing shared concepts and strategies and applying them to the policy process. Then, the policy process is treated as a research process in which a policy is seen as a set of hypotheses about the causal links between acts and a specified (desirable) future state of affairs, thus policy-making is seen as social experimentation (Hoppe, 2005). This resonates with the notion that ex-post evaluations may provide valuable contributions to social learning (Lee, 1993; Herrick and Sarewitz, 2000).

Finally, scientists play a role in *communicating with policy*, to make scientific knowledge policy relevant (Pielke, 2007). Researchers can provide *arguments* and function as issue advocates (ibid.)

Cross-cutting all these roles is the point, made in Section 5.3.1, that researchers can assume a broader role than that of researcher only. They can act as *mediators* or *process organisers* that structure knowledge. They can offer leadership in projects as independent facilitators and mediators; assure transparency, credibility, and robustness to sustainable development processes; provide technical expertise; supply knowledge about data sources and their use; and afford access to international networks (Mickwitz and Melanen, 2009; Ramos, 2009; Zilahy and Huisingh, 2009; Zilahy et al., 2009).

We believe that in principle all the roles discussed above could be compatible with successful joint knowledge production and we do not see an a priori reason to deem any of these roles less desirable. We also see these roles occurring in practice, as the examples given in Section 5.3.1 may illustrate. But it is obvious when and why things could go wrong. Scientists can become issue advocates without being explicit about this or without other actors recognizing it (stealth issue advocacy), compromising the perceived credibility and legitimacy of researchers and their knowledge. It may become difficult to distinguish the voice of science as providing guidance to policy, from those seeking to gain political advantage. Gieryn (2002) argues that what makes scientific knowledge useful for politics is 'not just its content but its putative objectivity or neutrality. Science can only legitimize policy if scientists are not treated as just another interest group and their technical input is not defined as just another opinion' (Gieryn, 2002, p. 436). Researchers thus need to be as explicit and clear as possible about what they perceive to be the role of themselves and their knowledge and other actors need to be clear regarding their expectations about this (see also the recommendations of the Committee on the analysis of global change assessments (2007)). Empirical examples of how this can be done are needed. One example is to set up procedures to invite researchers to be receptive to the needs of societal actors. In the Knowledge for Climate program, knowledge institutes 'translated' the questions of the regional hotspot teams (see Section 5.1) into scientific research questions. Subsequently, these institutes have to deliver products which should be applicable for policymakers and practitioners.

Proposition 5. *The chance that joint knowledge production is successful is enhanced in cases in which the role of researchers and their knowledge is clear.*

5.3.3. *Reward structures*

Another question is to what extent joint knowledge production in regional climate change adaptation projects is actually rewarded. What would be the reward for researchers, policy makers and other societal actors for co-producing knowledge?

Literature argues that reward structures for *researchers* still seem to have many Mode-1 characteristics. Research evaluations are ruled by bibliometric quality indicators favouring mono-disciplinary achievements to be published in high impact scientific journals (Hessels and Van Lente, 2008; Hessels et al., 2009). In many cases, researchers have a strong incentive for *promising* highly contextualised research, while the reward for fulfilling these promises is absent (ibid). Lemos and Morehouse (2005, p. 64) write for instance: 'careful attention must be paid to assuring that participation in interdisciplinary projects does not cause career-related problems, especially for junior/untenured faculty, postdoctoral researchers, and graduate students' (p. 64). In literature we find pleas for novel forms of social accountability and quality control to reward researchers, for instance to enhance the social robustness of ecological indicators (Turnhout et al., 2007), or to include non-specialist knowledge, wisdom and stakeholder perspectives in knowledge production processes (Roux et al., 2006; Kloprogge and Van Der Sluijs, 2006). However, actual examples of new forms of reward for researchers remain absent. This raises the question, whether large research programs as they have been initiated in The Netherlands and Germany may provide for new incentives for carrying out transdisciplinary research. It is an empirical question under which circumstances such programs contribute to a broadening up of reward structures.

Public policy bodies and *societal stakeholders'* are likely interested in perceived useful knowledge. They may also have a personal interest in the issues at hand, or be interested in expanding their networks. In some cases, funding structures may provide a (perverse) incentive for carrying out projects (e.g. to acquire additional finance). Also, projects may be carried out for strategic or symbolic reasons (Edelenbos et al., 2011). While participating in joint knowledge production or policy processes is considered an honorary activity for researchers and policy makers, this is not necessarily possible or acceptable for other types of stakeholders (Lamers et al., 2010).

To sum up, literature seems to stick to pleading for new reward structures or describing how to 'cope' with the current ones. Large climate change adaptation research programs provide a good departure point to start looking for innovations in reward structures. In several Dutch research programs,[5] for instance, it is tried to change reward structures by evaluating research proposals both on the basis of scientific and societal relevance. It is, however, an open question if such a change is helpful for researchers. For instance, it may increase their burden since *more* – not *different* – output (socially relevant knowledge AND journal articles) is expected of them.

Proposition 6. *The chance that joint knowledge production is successful could be enhanced through novel form's of reward structure, but more experience with such examples is needed.*

[5] E.g. 'Knowledge for Climate' http://knowledgeforclimate.climateresearchnetherlands.nl/; 'Sustainable Accessibility of the Randstad' http://www.nwo.nl/nwohome.nsf/pages/NWOA_794DXJ_Eng; 'Urban Regions in the Delta' http://www.nwo.nl/nwohome.nsf/pages/NWOP_88PJKB.

5.4. *Resources*

The original policy arrangements approach stresses the analysis of resource dependencies and power relations (Arts et al., 2006). In this paper, we aim to look at what *actors in joint knowledge production projects* can do to optimize resources for knowledge production. This perspective shifts the emphasis from macro questions (e.g. how much money is spent on large multi-actor programs) to the micro level of concrete projects and the organizations participating therein. In so doing, we stress the 'softer' resources which participants can influence. Literature from the sociology of knowledge mentions three such resources in particular:

First, boundary objects, which we discussed earlier as mediators of narratives, can be thought to have a material dimension as well. Concepts are written down in reports; and various objects can fulfil a mediating role between different epistemological communities. One can think of (GIS) maps, texts or computer tools. Also, actual site visits to low lying areas or areas risking drought can be ranked under the category of 'boundary objects'.

Second, it can be deemed important to provide for *facilities* and *forms of organizational embedding* stimulating the interfacing and sharing of (tacit and explicit) forms of knowledge (e.g. administrative support, places to meet, organisational forms allowing for out-of-the box thinking). The true effort required in interfacing knowledge across borders of science and action is often underestimated because only the explicit dimension of knowledge is taken into account (Nonaka and Takeuchi, 1995; Roux et al., 2006; Weichselgartner and Kasperson, 2010). Whereas it is relatively easy to pass explicit knowledge on to others, 'the transfer of associated tacit dimensions requires intimate human interaction. People need to spend time together, develop mutual trust, learn more about each other's contexts and jointly facilitate conversions of knowledge between tacit and explicit forms' (Roux et al., 2006, p. 7). Three types of space help to enable knowledge creation: physical space (e.g. meeting rooms), virtual space (e.g. computer networks), and mental space (e.g. common goals) (Nonaka et al., 2000). Physical proximity is found to be conducive for knowledge creation as face-to-face relations help to build trusting relationships that enhance the sharing of tacit knowledge. Again in the Dutch context, we see several examples which succeed in different degrees in meeting the framework conditions given above. The transdisciplinary innovation lab Xplorelab is a prominent example in which arrangements were provided to promote physical proximity of scientists and policymakers (see Section 5.2.1).

Third, as follows partly from the previous points, actors are in need of specific *competences* (e.g. in terms of negotiation, translation and mediation) related to the collaboration across different communities (Steyaert and Jiggins, 2007; Van den Hove, 2007). We can conclude that joint knowledge production projects are in need of other resources than the 'usual suspects' (e.g. finance, formal authority) only. Fruitful collaboration of actors in different communities (representing at least the domains of science and public policy) necessitates specific resources (boundary objects, facilities, organizational forms and competences) facilitating such communication as well as enough time to enable these processes. These resources can be provided by large research programs

Table 1 – Potential relationship between success conditions of joint knowledge production projects and the perceived credibility, salience and legitimacy of the knowledge produced (↑, conducive; ↓, negative influence; ↑↓, influence ambiguous).

Dimension	Expected success condition	Credibility	Salience	Legitimacy
Actors	(1) Broadest possible actor coalition within limits present	↑ through inclusion of place-based knowledge in science	↑ through inclusion of place-based knowledge in science ↓ due to large complexity	↑ through inclusion of various different perspectives in the knowledge production process ↓ due to the need to reconcile many different knowledge interests
Discourses	(2) Shared understanding on goals and problem definitions	↑ within project due to the absence of fundamental epistemological differences ↓↑ outside project context: knowledge may resonate with other actor groups epistemologies vs. presence of potential gaps with different knowledge coalitions	↑ knowledge resonates with needs as perceived by policymakers and societal stakeholders	↑ actors believe that the 'right' questions concerning the 'right' problem have been asked
	(3) Recognition of stakeholder perspectives	↑ through inclusion of place-based knowledge in science	↑ through inclusion of place-based knowledge in science ↓ due to large complexity	↑ through inclusion of various different perspectives in the knowledge production process ↓ due to the need to reconcile many different knowledge interests
Rules	(4) Organized reflection on division of tasks by participating actors	No straightforward relationship assumed	↑ due to synergetic task divisions	↑ due to mutual understanding of each others interests and explication of assumptions which would otherwise remain implicit
	(5) Role of researchers and their knowledge is clear	↑ due to enhanced trust in researchers (absence of 'stealth issue advocacy')	↑ clear what contribution of scientific knowledge could be	↑ due to enhanced trust in researchers (absence of 'stealth issue advocacy')
	(6) Presence of innovations in reward structures	No straightforward relationship as such, but willingness of actors to engage in joint knowledge production at all is likely enhanced		↑ since more actors are rewarded for their participation in co-production
Resources	(7) Presence of specific resources such as boundary objects, facilities, organizational forms and competences	↑ due to enhanced mutual understanding on viewpoints and interests; learning each others language; intimate human relationships; more efficient information transfer		

(prominent Dutch examples apart from 'Knowledge for Climate' are 'Climate Changes Spatial Planning' and 'Living with Water'.[6] Another example of specific resources for joint knowledge production projects is the emergence of communities of practice in specific domains (e.g. in Europe there exist various so-called 'urban living labs' focused on innovations in low carbon development).[7]

Proposition 7. *The chance that joint knowledge production is successful is enhanced through the availability of specific resources (boundary objects, facilities, organizational form and competences) facilitating communication between communities with different epistemologies.*

[6] http://knowledgeforclimate.climateresearchnetherlands.nl/; http://climatechangesspatialplanning.climateresearchnetherlands.nl/; http://www.levenmetwater.nl/home/.

[7] http://www.openlivinglabs.eu/livinglab/urban-living-lab-versailles-saint-quentin-en-yvelines.

6. Discussion

The four-dimensional policy arrangements approach has been used to systematically bring together existing literature from the fields of environmental governance, science and technology policy studies and the sociology of knowledge. This has resulted in seven propositions that can be used for retrospective analysis of joint knowledge production in regional climate change adaptation projects. We expect each of the success conditions specified in the propositions to increase the chance for success. Table 1 synthesizes the previous discussions and further specifies the relationship between the seven success conditions and the success of joint knowledge production projects.

We should stress that the framework, first and foremost, aims to fulfil the role of an *assessment framework*. STS and science policy studies scholars can use the framework for

identifying empirical examples of good practices. Empirical confrontation is needed to further test and refine the framework. The fact, however, that we were able to illustrate each success condition with at least one empirical example, may indicate that the framework forms a solid starting point for such analyses.

We foresee four potential outcomes of empirical confrontations. First, empirical situations may *nuance* the propositions. Researchers may for instance identify examples of projects in which a high degree of deliberation on goals and problem definitions (Proposition 2) is less essential as well as contexts in which such deliberation is crucial. Second, the propositions may be *refined* by further – more detailed – specifications of the success conditions listed in this paper. Third, insight can be acquired in the *relationship between the propositions*. Empirical research may for instance clarify that the inclusion of specific actors (Proposition 1) can be a way to ensure that certain resources are present in a joint knowledge production project (e.g. social scientists could be facilitators of reflection workshops; administrative representatives could enhance political legitimacy etc.). Finally, empirical research may identify *feedback loops between successful joint knowledge production and the independent factors*. Actors can for instance strategically influence the discourses by arguing that projects have been successful or not (see also: Van Assche et al., 2011). In so doing, they may have an impact on other actors' perspectives on the world around them (Proposition 3), and secure funding for future projects.

In sum empirical confrontations might give us a better insight into the different ways in which our success conditions can be met, that is, in *good practices*.

These good practices may give us more specific guidelines for enhancing the success of future regional climate projects, for instance for the boundary organizations involved (e.g. research programs, research funders). However, based on the identified good practices, we also expect to be able to derive more generic recommendations on 'how to do' joint knowledge production in the science–policy interface, ultimately leading to a more design-oriented framework.

Of course, such a design-framework will be stronger if empirical analyses do not solely focus on regional climate change adaptation projects, although these comprise a very suitable field due to their specific characteristics, including the presence of high decision stakes, large uncertainties, many stakeholders as well as the long-term orientation of the problem at hand. Other relevant empirical domains may include those of mobility, energy and sanitation, to mention a few. We expect that after some adaptation, the design framework may be useful for other scale levels as well including less place-based science policy interfaces (e.g. IPCC) or 'less wicked' problems (e.g. health care).

7. Concluding remarks

This paper has developed a framework for systematically analyzing the success of joint knowledge production projects, in the domain of regional climate change adaptation and beyond. As we highlighted in the introduction section, these projects can be seen as part of a broader deliberative turn in environmental governance. The question how deliberative projects *are* is an empirical one. What we can learn from the literature discussed in the current paper, however, is that joint knowledge production projects likely *require* a high degree of deliberation. An inclusive, accountable, fair and open process, enabling actors to engage in learning through iterative dialogue is likely conducive to successful joint knowledge production. At the very least, a high degree of deliberation can be thought to be necessary to assure long-term commitment of actors. That is why we set this deliberative quality element on the foreground, namely in our definition of success (Section 3) focusing more on process than on outcome evaluation; and in the success conditions which we denominated in Section 5. Although our framework takes the quality of *processes* as its starting point, it is our assumption that a lasting process ultimately pays off in terms of environmental effectiveness.

The actions required to achieve a high degree of deliberation can be derived from our success conditions. Levers for action include selection of grounded scholars or reflexive practitioners for the role of project leader (this can be done by program managers or other project participants); ensuring 'built-in' reflexivity in projects (e.g. through mediation or external feedback); creating 'protection' against conventional accountability mechanisms in science and policy (e.g. setting-up a transdisciplinary innovation lab); ex-ante evaluation of project proposals by research programs, paying attention to the deliberative quality of the project. And last but not least, successful joint knowledge production, in our opinion, requires that space is allowed for making – and learning from – mistakes. Joint knowledge production in projects involves complex, hard to predict processes. Learning how it can be done requires trial and error. But the need for socially robust knowledge for climate change adaptation makes the effort worthwhile.

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