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Editorial
(Con-)Testing theories – (re-)thinking mode 2

More than 15 years ago, Michael Gibbons, Helga Nowotny and others coined the term "mode 2", arguing that a new mode of production of scientific knowledge had emerged. In the era of mode 1, science had been able to safeguard its autonomy and almost exclusively relied on internal mechanisms of quality and relevance assessment. Mode 2, however, means that scientific knowledge has to be socially robust, counting more and more on the participation of lay-people from different parts of society. The mode 2 thesis thus reflects a fundamental transformation of the relation of science and society.

The current issue of STI-Studies contains two articles that deal with mode 2 issues, one on a theoretical basis, the other presenting findings of a comparative empirical study. Both point at some weaknesses of the mode 2 thesis, thus re-opening the debate.

In his article *"Mode 2, systems differentiation and the significance of politico-cultural variety"*, Janus Hansen argues that the mode 2 thesis is based on an unacceptable generalization and extension of trends to the socio-structural level of society, which mostly take place at the organisational level. Hansen also calls into question the implicit assumption of a universal trend toward mode 2 and a resulting convergence of modern societies as regards the science-society relation. Therefore he calls for an in-depth analysis of cross-national varieties.

Voilá! STI-Studies is very proud to present an answer to these questions in the same issue. In her paper *"Nanotechnology governance"*, Monika Kurath presents the results of an international comparison of deliberation-oriented and public engagement projects in the field of nanotechnology regulation. Her article can be regarded as an empirical test of the mode 2 thesis. She applies a technique of rating the social robustness of different participatory discourses, concluding that self-regulation performs better than deliberation. However, only a few of these new modes of governance can be regarded as – at least partially – socially robust. Thus Kurath pours a lot of water into the wine of mode 2 proponents.

The third article also contains a test of a big theory. In their article *"Technology adoption in small-scale agriculture"*, Genesis T. Yengoh, Armah Frederick Ato and Mats G. E. Svensson investigate the question, why technology adoption in sub-Saharian Africa does not work according to Rogers' general model of the diffusion of innovations. By modifying the model and identifying additional factors and drivers, they show – via computer simulation – that a refined model can explain the decelerated process of technology adoption, thus identifying loci for political intervention.

(Con-)Testing theories via empirical analysis is one of the paramount tasks of scientific research. All authors of the three articles in the current issue contribute to this task and show the productive results of a stimulating combination of theoretical analysis and empirical studies.

Many thanks to Peter Goldberg for his language assistance.

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Mode 2, Systems Differentiation and the Significance of Politico-Cultural Variety

Reflections on the theoretical foundation of comparative analysis of public engagement practices

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Abstract

The article suggests that research on public engagement with science and technology suffers from an unfortunate deficit of (cross-national) comparative research. It examines the so-called 'mode 2 diagnosis' (Nowotny et al. 2001) and the the relevance of the concept of 'socially robust' knowledge production for comparative research on public engagement practices. While providing a stimulating perspective on the novel ways in which techno-scientific innovation must be legitimised in contemporary society, the diagnosis suffers from certain conceptual deficits, which inhibit the ability to conceptualise cross-national variation in a systematic manner. Through a confrontation of the mode 2 thesis with competing theoretical approaches, the article suggests that, rather than assuming transgressions between 'science' and 'society', research must distinguish between societal (de-)differentiation and organisational reconfigurations (Luhmann). Furthermore, the concept of political culture (Jasanoff) is discussed as a tool with which to examine cross-national variation in public engagement practices. Towards the end, suggestions for empirical research building upon the discussed concepts are briefly outlined.

1 Introduction

A significant current of STS is devoted to examining how contemporary developments in the relations between 'science' and 'society' have resulted in a rising demand for new, more inclusive modes of governance of science and innovation. It is often argued that an expanded *public engagement* with science and technology is desirable for both normative and pragmatic reasons (e.g. Renn et al. 1995, Durant 1999, Pellizzioni 1999). Such arguments have initiated a lot of normative reflection on the benefits of public participation (e.g. Sclove 1995, Fischer 2000), a search for evaluative yardsticks for participatory processes (e.g. Rowe and Frewer 2000) and a plethora of case studies on public engagement practices. Much of this literature, however, seems to fall into one of two categories.

- It either argues in a rather abstract and generalising manner – seemingly context-independent (e.g. Joss 2002, Edwards 1999, Hennen 1999) –
- or it pertains to specific single-case studies, which are by nature analytically inseparable from their politico-cultural contexts (e.g. Marris and Joly 1999, Guston 1999).

Surprisingly little research on public engagement practices proceeds in a comparative manner between these two poles (see, however, Joss and Bellucci 2002). This contrasts notably with other areas of STS, e.g. analysis of science and innovation policies or risk governance, where there is a well-established tradition for cross-national comparisons. Comparisons exist between different procedural designs for public participation (e.g. Renn et al. 1995, Bora and Abels 2004), but they rarely contain systematic examinations of the interaction between such procedures and the surrounding politico-cultural environment (see, however, Bora and Hausendorfer 2006, Dryzek et al. 2009).

This is both puzzling and unsatisfactory as comparisons provide rich sources of data and experience, likely to help better understand the potentials and limitations of different modes of engagement in different contexts (e.g. Hansen 2006). In this paper I argue that in the future, research on public engagement practices ought to be strengthened through comparative approaches, and I discuss some theoretical tools that might facilitate such research.

Challenges of comparative research

Comparative research, however, presents its own challenges. In this paper I address an important epistemic challenge relating to this kind of research for which the dominant theoretical perspectives in this area provide little assistance. This concerns the problem of how to calibrate our tools of observation.

- On the one hand these tools must enable us to pay proper attention to the specificities of particular cases embedded in a particular politico-cultural context.
- On the other, this must be balanced with the need to render cases comparable along dimensions of general analytical relevance.

In short, how do we distinguish between what is particular and what is common to processes of public engagement when researching across different contexts?

Mode 2 thesis

The starting point for this discussion is the account of the rising demand for public engagement that can be found in the influential diagnosis by Gibbons, Nowotny and colleagues (Gibbons et al. 1994, Nowotny et al. 2001). They claim that we are moving from a 'mode 1' to a 'mode 2' type of knowledge production, which impinges significantly on the ways in which techno-scientific innovation can, and must be legitimised. This diagnosis delivers an original and stimulating perspective that promises to ground the normative, cognitive and pragmatic dimensions of public engagement procedures in a dynamic understanding of wider ongoing changes in science/society interactions. However, it also entails some overtly homogenising assumptions, which are less conducive for the kind of cross-national comparisons I am pleading for, as politico-cultural differences seem to drop below the research radar in their analyses.

The point I wish to argue, in short, is that the mode 2 diagnosis – along with similar concepts currently informing STS research – entails some important observations of the social transformations which today make public engagement seem indispensible. However, in its eagerness to capture what is novel, the diagnosis neglects to examine how these changes operate in different settings, thus devoting insufficient attention to the potential of comparative research. For instance, an otherwise stimulating and innovative research project in this STS tradition on 'Participatory Governance and Institutional Innovation' seems more preoccupied with establishing communalities across cases that indicate a general 're-thinking of political space' than with examining diversities in the appropriation of new life science developments across Europe (Gottweis and Brown 2007, Gottweis 2008).[1] In the mode 2 framework, this problem, I will argue, is attenuated by an insufficient social-theoretical grounding of the diagnosis, which hinders rather than facilitates its empirical applicability. Therefore, the diagnosis needs to be conceptually sharpened and sensitised towards politico-cultural variation (see also Shinn 2002).

Content

To clarify this argument I will proceed in three steps: firstly, I will briefly recount the central claims of the mode 2 diagnosis and why this kind of reasoning has become central to the study of public engagement processes (Chapter 2). Then I address some conceptual problems entailed in the theoretical grounding of the diagnosis. For this purpose I rely on the work of the German sociologist Niklas Luhmann, which will be used to suggest an alternative and conceptually more stringent view on the social dynamic involved in contemporary science/society interactions (Chapter 3). However, Luhmann also operates at a rather general level of theorising. Therefore, thirdly, I will discuss the concept of political culture as it has been reintroduced in STS by Sheila Jasanoff (Chapter 4). I use this to suggest a more systematic approach to observing variations in the politico-cultural contexts of public engagement processes, which is compatible with the systems theoretical understanding of the interaction between 'science' and 'society'. The argument of the paper is conceptual, but towards the end I offer some suggestions for a comparative research agenda on public engagement with science.

2 Public engagement as the product of changing relations between science and society

The pleas for expanded public engagement with science and technology are usually linked to changes in the role played by science in society. Influential contemporary contributions in STS suggest that in the past, science constituted an isolated and autonomous space adhering primarily to its own logic, whereas the safeguarding of legitimacy of its use in technological innovation was a matter for politics. Now, in contrast, knowledge producers and innovators are allegedly confronted much more directly with demands from stakeholders and the general public.

Analyses of these developments are found under headings such as 'mode

[1] Admittedly, the project quoted here does not rely on the mode 1/mode 2 distinction, but it nonetheless embodies similar assumptions about a fundamental reconfiguration in the relationship between science and society, as "Governance is faced with new challenges in this newly developing setting of 'blurred boundaries' between science and politics. . . " (Gottweis 2008: 267), while paying only superficial attention to any cross-national variation, which is clearly visible in the reported empirical material.

2 knowledge production' (Gibbons et al. 1994, Nowotny et al. 2001), 'Post-normal science' (Funtowicz and Ravetz 1993), 'Triple Helix' (Etzkowitz and Leydesdorff 2000) and the image of a shift from 'science' to 'research' (Latour 1998).[2]

Social robustness

Claims that a transformation or possible breakdown of previously well-established disciplinary boundaries and institutional frameworks is taking place are common to these approaches. This creates a larger role to the various users and publics of scientific knowledge. In short, the *making* and *quality assessment* of new knowledge is said to become more directly implicated with the public *acceptability* and *legitimacy* of its application through techno-scientific innovation. To describe such novel quality requirements for knowledge and innovation, Nowotny and colleagues have coined the term 'social robustness'. By *social robustness* they understand a particular social quality of process of knowledge production. Social robustness ensures innovations are likely to be met with acceptance among those affected by it. In contrast, such acceptance is more difficult to ensure for knowledge claims, products and modes of governance that rely only on a conventional cognitive authority of scientific expertise (see also Ravetz 2004).

The concept of 'social robustness' seems to capture the central goal of most public engagement processes very well. It has become a topic widely used in discussions on how to deal with controversies over new technologies, though mostly in a heuristic fashion (see e.g. the discussion in Wynne et al. 2007). Here, however, I intend to examine the analytical value of the diagnosis for a comparative research agenda more closely.

2.1 Science/society interactions changing from mode 1 to mode 2

The mode 2 diagnosis has been set out in two books and a number of papers. In particular, *Re-thinking Science* (Nowotny et al. 2001) attempts to provide the thesis with a more solid sociological foundation, and this is the work I will primarily refer to. In order to set the stage, let us briefly recount the four inter-related processes allegedly constituting the epochal change from 'mode 1' to 'mode 2'.

Co-evolution

Firstly, the authors suggest that science and society have entered a process of co-evolution. Whereas science in classical modernity (mode 1) historically fought for, and achieved cognitive autonomy from the surrounding society, and this society was a mostly passive recipient of the knowledge produced, the two are now much more closely connected. Due to the intertwining of science and technology into 'techno-science' (e.g. Haraway 1997), scientific knowledge production now has a much more direct impact on society than was the case earlier. 'Society' therefore reacts with attempts to influence science much more vigorously than before. These attempts are successful to the extent that the two now co-evolve, making it difficult to separate developments in the two domains from each other. The increased interaction is summed up in an often quoted passage: "In modern times science has always 'spoken' to society... But society now 'speaks back' to science" (Nowotny et al. 2001: 50).

Contextualization

Secondly, and closely related, knowledge production is increasingly 'contextualised'. Scientific research is shift-

[2] In the remainder of the paper I take the 'mode 2' framework as symptomatic of this broader trend. It is of course debatable how representative the mode 2 framework is for the wider thinking in STS. However, it is striking how often one comes across reference to the concepts of 'mode 2' and 'social robust knowledge' in the literature – often quoting the diagnosis as if it was in fact a proven state of affairs (for an assessment of the impact of the diagnosis see Hessels and van Lente 2008).

ing focus from 'deciphering' the mechanisms of nature to actively 'producing' them. For instance, science no longer aims only to understand chemical and biological processes; it actively creates them in, for example, genetic engineering and nanotechnology. As a consequence, the traditional distinction between 'context of discovery' and 'context of justification' is circumvented and the validation of knowledge is increasingly undertaken in a 'context of application', where knowledge claims are evaluated not by their epistemic truth-content, but by their ability to facilitate instrumental mastery over physical, chemical and biological processes. In this process, the practices of knowledge production are spreading beyond their traditional institutional location in universities and public research institutes into much wider networks of activities and organisations.

Applicability

Furthermore, therefore, the principles of quality assessment in knowledge production are changing. In mode 2 the mechanisms of peer-review are being replaced by assessments of applicability of the produced knowledge. This makes forms of knowledge that are not only cognitively reliable but 'socially robust' the ideal. In effect, scientific credentials are no longer sufficient to ensure the acceptance of knowledge claims and products of innovation. These are now required to win the acceptance of broader circles of stakeholders, usually on a more varied basis, including ecological, ethical and socio-economic criteria. This argument is not dissimilar to what Funtowicz and Ravetz (1993) call 'extended peer review' and, as I understand it, Latour's more metaphorical notion of a 'Parliament of Things' (Latour 2004).

Socially distributed expertise

In addition these developments change the role of experts and the use of expertise throughout society. Expertise becomes, as the authors formulate it, 'socially distributed'. The links between individual experts and their disciplinary and institutional background become much more fragmented than before. Expertise is becoming 'transgressive', as experts are expected to provide answers to pressing public issues that lie beyond their disciplinary background, even beyond what is normally considered the domain of science (Nowotny 2000). Likewise, persons without scientific credentials are increasingly consulted as experts, such as journalists, practitioners of alternative medicine, representatives of NGOs and patients' organisations. As a consequence, the performance of expertise is moved into the public sphere (or the *Agora*), where different selection criteria are applied to determine relevance and validity of the contributions than in traditional contexts of scientific communication.

The effect of this alleged shift from mode 1 to mode 2 is that "(i)nstead of being clearly demarcated from other forms of social practice, and far from being uniform or unified, science itself now consists of a set of complex practices, deeply embroiled, integrated and implicated with society" (Nowotny et al. 2001: 230). This, in effect, amounts to processes of transgressions of institutional boundaries and a wide-ranging societal de-differentiation (ibid: 32, Shinn 2002).

This diagnosis is highly relevant for the study of public engagement processes for two reasons.

Public involvement

Firstly, the image of 'social robustness' captures well the overall ambition of most public engagement processes whatever their specific format (Hansen 2006, Hansen, *forthcoming*). The aim of most public engagement processes – at least according to their self-understanding – is to draw in various ways upon the experiences, knowledge and concerns of 'ordinary people' in order to develop science and technology in better accordance with the broader values and goals of the societies into which they are introduced.

Society speaking back

Secondly, public engagement exercises constitute institutional loci where 'society' is actually given an opportunity to 'speak back' to science – even if this 'speaking back' is often mediated via politics, which is usually the immediate addressee of public engagement exercises, such as consensus conferences, citizen juries, participatory technology assessments or large-scale, organised public debates such as 'GM Nation?' in the UK (Horlick-Jones et al. 2007).

However, the ambition is that such forums of articulation operate as part of the *Agora* and will have effects on the processes of techno-scientific innovation. If the 'speaking back' thesis is correct, public engagement processes should therefore be one of the places to study how this actually happens in more detail.

2.2 Does mode 2 strike in the same way everywhere?

The analyses by Nowotny et al. have produced both a lot of enthusiasm and important criticism.[3] This shall not be reiterated here (see Hessels and van Lente 2008 for an overview). One issue, however, is absent from the discussions of the merits of the mode 2 diagnosis, namely to what extent these developments unfold in a homogeneous manner across different countries, regions and sectors (see, however, Shinn 2002). The proponents seem to be writing about everywhere and nowhere in particular, giving no indication of the scope or validity of their analysis.

Convergence?

This means that the diagnosis ends up reading like an *implicit thesis of convergence*, seemingly suggesting that all modern societies are affected by the transformations in equal measure and in similar ways.[4] While the attempt to bring together a lot of tendencies in one distinction clearly gives the framework a strong diagnostic edge which probably accounts for a lot of its popularity, it tends to conceptually obscure the fact that these developments may appear in different manners and at different rates in different contexts.

Meso and macro level

I will argue that this lack of attention to politico-cultural variety in science/society interaction can be attributed to an untenable extrapolation of empirical observations at the organisational (meso) level into theoretical propositions at the societal (macro) level, which makes 'local' variation seem analytically insignificant. The question in this context is thus how this implicit assumption of convergence can be transformed from a conceptual a priori into a question suitable for a theoretically grounded, empirical examination, while retaining the original insights and intuitions of the mode 2 approach.

Depending on theoretical perspective, there are undoubtedly several possible ways forward from this problem. In the

[3] The enthusiasm seems to emerge in part from policy analysts and research managers looking for new ways of understanding and governing a very dynamic knowledge producing landscape, and in part from disgruntled academics seeing mode 2 as a rather accurate description of processes they perceive to undermine academic freedom and critical inquiry. Much of the criticism, on the other hand, has emerged from scholars who argue that the diagnosis is largely impressionistic and unsubstantiated by more systematic historical and contemporary empirical inquiries, arguing that the tendencies are neither as new nor as strong as the proponents of mode 2 seem to suggest (Weingart 1997, Pestre 2000, 2003, Shinn 2002).

[4] To be fair to the authors, it should be noted that to my knowledge they do not anywhere explicitly claim that contemporary societies do in fact converge on a shared mode 2 pattern. Rather, it seems they abstain from addressing this issue altogether, which is why I suggest that the diagnosis entails an *implicit* thesis of convergence. However, in particular, since the diagnosis seems increasingly to inspire policy makers in quite different contexts, it may be considered as an important deficit that this issue is not addressed at all. If local circumstances and specificities are paid insufficient attention, unfortunate implications may be drawn for policy making.

following I will propose one based on a confrontation of the mode 2 thesis with the systems theoretical approach of Luhmann and scholars inspired by him. This confrontation will address two interrelated aspects of the mode 2 approach, which are problematic for a comparative research agenda, namely

1. that the diagnosis exaggerates the processes of societal de-differentiation in a manner that is conceptually paradoxical and
2. that it fails to distinguish analytically between changes in the mutual interaction between societal subsystems and changes occurring in the organisations producing and governing innovation.

I do not mean to suggest that a Luhmann-inspired framework is the only possible fruitful basis of a comparative research agenda on public engagement processes. However, I intend to show that it can provide some conceptual clarification, which might help balance research between shared analytical dimensions and the specifics of particular cases in a productive manner.

2.3 Are societal borders really transgressed?

In their attempt to provide their diagnosis with a sociological basis, the authors themselves make explicit reference to Luhmann's work on modern societies in several places (e.g. Nowotny et al. 2001: 34, 201–202, 236–237). However, they part with one of Luhmann's primary theoretical assumptions when they claim that processes of 'transgression' between different sectors of society render his analysis of societal differentiation outdated (Nowotny et al. 2001: 28, 32).

The Luhmannian conceptualisation of societal differentiation is certainly not uncontested. However, the general idea underlying it dates back at least to Max Weber. Indeed, the mode 2 authors themselves accept it as a valid description of Western societies until the onset of the changes they seek to diagnose. Hence, claiming the end of differentiation as a fundamental structuring principle of modern society is a rather bold move. Unfortunately, it comes across more as a postulate than a substantiated analysis explicating and examining the conditions that must be fulfilled to verify the claim. All the examples provided to illustrate the processes of de-differentiation seem to hint at organisational rather than socio-structural transgressions. This has paradoxical analytical implications, as the diagnosis in fact relies on categories it claims are dissolving. It continues to speak about 'science', 'the economy' and 'politics', claiming that the borders between them are dissolving, but without reflecting on the implications of the diagnosis for the analytical consistency of these concepts.

Dissolving boundaries?

There are many indications that science and knowledge production today is organised differently in important respects than, say, 50 or just 20 years ago and interacts in different ways with the surrounding society, including its various publics, as the mode 2 proponents argue forcefully. It seems beyond dispute that scientists and scientific institutions today are exposed to more direct demands to legitimise and justify themselves in the eyes of the public and political decision-makers compared to earlier times. However, in order to make this comparison at all, some degree of continuity is required in the manner in which 'science' is observed. Claiming that the boundaries between 'science' and 'society' are blurring or dissolving does not seem analytically helpful.

Necessary distinctions

My suggestion, following Luhmann, is that such continuity can be found in the understanding of science as a self-referential, communicative subsystem of society (compare Leydesdorff 2007), which is distinct from – but coupled with – other societal subsystems and organisations. Of course, the boundaries between science and the surrounding society depend on perpetually ongoing 'boundary work', but they nonetheless designate socially significant distinctions that should not be overlooked or abandoned for both analytical and normative reasons.[5]

3 The Luhmannian perspective

In order to elaborate this point, I shall briefly expand on the principle of societal differentiation. In its essence, societal differentiation according to Luhmann means that distinct and specialised domains of communication have evolved historically, such as politics, the economy, law, science, religion, education, the mass media etc, which produce mutually exclusive patterns and networks of communication (e.g. Luhmann 1989), just as they produce their own idiosyncratic structures of meaning and motives for action.

Codes and communication media

In Luhmann's formulation, societal subsystems are conceived of as self-referential systems, operating by means of mutually exclusive, binary codes of communication. Scientific communication is guided by the distinction between true/false, economic communication between payment/non-payment, political communication between government/opposition, judicial communication between legal/illegal, to mention just some of the most prominent systems constituting modern society (Luhmann 1989). These distinctions structure communication in their respective domains by selecting between relevant and irrelevant contributions to communication, and they ensure continuity in the operations of the systems. These differentiated communicative systems by definition do not 'overlap' or 'intermingle' as they observe themselves and their respective environments in different ways, but they mutually condition each others' operations in ways that fundamentally shape the dynamics of modern society.

Structural coupling

The distinct modes of communication mean that the systems cannot replace each other (e.g. political communication cannot produce scientific truths, just as scientific communication cannot produce collectively binding decisions etc). They also render systems mutually intransparent (e.g. political communication can achieve only a rudimentary understanding of scientific communication and vice versa). At the same time, the systems are mutually dependent as each system maintains functions that are indispensible for the continued operation of other systems. As such, the systems are simultaneously locked into each other ('structurally coupled' as Luhmann calls it) and autonomous in their operations ('autopoietic' as Luhmann calls it).

In Luhmann's view, this combination of autonomy and interdependence accounts for the proliferation of risks and legitimacy deficits in contemporary societies, exactly because unforeseeable feed-back mechanisms constantly operate in the mutual interactions between these coupled systems (Luhmann 1993).

3.1 Adaptive systems

Inspired by Luhmann, Peter Weingart suggests that it is important to maintain an understanding of science as a particular and distinct mode of communication 'within' and as part of society, which exists alongside other domains of specialised communication (Weingart 2005). Thus understood, the scientific system can be observed as evolving

[5] Although STS scholars have spent the last decades opening up the 'black box' of science and showing how science in manifold ways is interacting with the surrounding society, it seems that there is now a re-emerging interest in also understanding what is particular about science for both analytical and normative reasons. As argued by Pestre in a recent article: "... while STS scholars claim that politics and science are organically intertwined and continuous, scholars also know well how to distinguish them. To say that science and political are organically dependent does not imply that they are identical, that all claims are worth the same, that we are unable to make distinctions" (Pestre 2008: 113, see also Collins and Evans 2002).

over time, gradually modifying the criteria, designating appropriate and inappropriate ways to communicate in the scientific truth-code – often in response to events in the environment of the scientific system. However, the modification of these criteria occurs in the course of the recursive communication in the system as learning or adaptation, and not as a replacement of the true/false distinction with an economic, political or legal logic, as implied in the de-differentiation thesis. In this respect, we can say that science continues to be 'self-referential', as it is hard to conceive of communication claiming to be scientific (and accepted as such, rather than simply ignored), which does not in the final instance recur upon a distinction between true and false, and does so in reference to previous scientific communication.[6]

Decreasing distance

Yet, with a keen eye to the empirical tendencies motivating the mode 2 diagnosis, Weingart suggests that in many areas the social distance between science and other modes of communication is decreasing. Other social activities such as technological innovation and legal regulation increasingly rely on scientific knowledge, which has repercussions for the way knowledge production is organised socially and unfolds over time. However, instead of talking about a general intermingling of 'science' with a rather encompassing image of 'society', we need to be specific in our observations on how the scientific mode of communication is conditioned and itself conditions other modes of communication, rooted in other domains of modern society.

Weingart thus suggests that it is both necessary and important to differentiate between observations of specific interlinked processes of, respectively, 'scientification of politics' and 'politicisation of science'; 'scientification of innovation' and 'commercialisation of science' etc. For instance, when political competition over how to solve pressing social problems is coupled to scientific knowledge at the forefront of research, knowledge production is put under pressure to deliver results fast. This may circumvent the more conventional means of asserting scientific quality, which often works at a slower pace than the political agenda.

Resonance

However, politics still rely on the cognitive authority of science for legitimacy; it cannot manufacture 'truths' itself. The perspective suggested here thus amounts to observing in detail how communication originating within each of these systems *resonates* still more strongly with each other (Weingart 2005: 124) but without losing their domain-specific characteristics.

'Resonance' occurs when communication in one context is observed and has effects in other contexts. The concept of resonance has the advantage of pointing out that interaction effects between different systems may be nonlinear and very difficult to predict. One consequence of this perspective is an assumption that it is still feasible and important to distinguish between the different modes of communication and horizons of meaning within which actors move, even if they need to alternate still more agilely between them, for instance as 'academic entrepreneurs' (see e.g. Vallas and Kleinman 2008).

[6] Even in the most fierce controversies over new technologies, the antagonists usually struggle about what constitutes *adequate* scientific concepts and evidence, and what kind of institutional embedding might render scientists trustworthy, not whether science as such is a relevant resource and scientific reasoning should be abandoned altogether. At the very least, those claiming science to be irrelevant assume a heavy argumentative burden, abandoning one of the strongest sources of cultural authority in modern society. When science is being criticised it is usually for being the 'wrong kind' of science or for being infused with other, e.g. commercial, interests, which is exactly an appeal for upholding the principles of societal differentiation.

3.2 Distinguishing societal differentiation and organisational transformations

As suggested above, the de-differentiation thesis seems to be based on an untenable extrapolation of changes at the organisational level to the level of societal macro-structures. This is unfortunate, as it may limit the ability to conceptualise and observe varieties in these processes more precisely. In the following I will contrast this with a systems theoretical perspective that distinguishes between the communicative subsystems of society described above and the organisations hosting such communication. The mode 2 authors argue that:

"*. . . just as the boundaries between state, market, culture and science are becoming increasingly fuzzy, so too are those between universities, research councils, government research establishments, industrial R&D, even other knowledge institutions*" (Nowotny et al. 2001: 166).

Two levels of social reality

My point is that in order to understand the second kind of fuzziness and reconfigurations, we do not need to assume the first one – rather on the contrary. Varieties of the second – the organisational changes – can be made better sense of if the two levels of social reality are considered as analytically distinct, yet intimately coupled. In fact, the principle of societal differentiation seems to be an implicit, if unrecognised, basis of most organisational theories (Tacke 2001), meaning that our understanding of the dynamics of organisations (implicitly) relies on an understanding of the societal environment as functionally differentiated.

Organisations

In distinction to societal subsystems, organisations are social systems of communication characterised by two features:

1. They have 'members'. This means that they distinguish between and actively regulate who belongs in the organisation and who does not, and they ascribe various 'roles' to these members (that is, they produce behavioural expectations).
2. Organisations operate recursively by making 'decisions'. This means that the identity of an organisation is maintained (or changed) through the continued, recursive references to past decisions as the basis of present decisions (Luhmann 1993: 188–190).

The decisive point here is that unlike the societal subsystems, organisations do not operate with reference to one particular code. Instead they must sequentially (or serially) process a multiplicity of codes.

Organisation and society

The relationship between societal subsystems and organisations is complex, characterised by numerous couplings and mutual feed-back mechanisms. While the societal subsystems rely on organisations, and many organisations constitute their identity around their affiliation to a specific subsystem, no organisations can operate exclusively on the basis of a single communicative code. For instance, a research organisation may see its primary task in the production of new knowledge and contribution to scientific communication. However, to achieve these aims, it needs to ensure adequate funding and staffing, observe the limits of the law and often secure political and possibly public support etc.

In short, while it has a scientific identity, it must also have a capacity to observe and participate in other types of communication. In analytical terms this means that organisations alternate between contributing to the communication of different systemic domains, not that the codes of these different domains fuse or overlap. At any specific point in time, the members of an organisation must decide the appropriate mode of communication, be it scientific, economic, legal, or political etc., and adjust their contributions accordingly.

Therefore, the fact that parliaments these days tend to take a stronger interest in research priorities, and research organisations may feel compelled to modify their priorities accordingly to maintain funding, does not warrant a claim that science and politics are fusing together. It suffices to say that there are stronger resonances between these domains – and that such resonances may occur in unexpected and unplanned manners, which must be studied empirically (e.g. Gläser et al. 2008).

Re-thinking mode 2

The point I wish to emphasise is that analytically it is desirable to distinguish between the communication htat constitues the societal subsystems and organisational communication. The societal systems produce distinct horizons of meaning and organisational communication must alternate between these horizons – possibly at still more rapid intervals. By maintaining this distinction some of the conceptual inconsistencies of the mode 2 framework can be avoided. When considered in these terms, the social processes observed by the mode 2 diagnosis can be interpreted as an expression that

1. the structural couplings between the societal systems are becoming stronger, meaning that the mutual conditioning of their operations are intensified (e.g. the ability to produce economic profit is still more tightly coupled to the ability to produce new knowledge) and
2. that new types of *organisations* are evolving (or old ones changing), which are defined in their identities and self-descriptions as operating at the intersection of a multiplicity of societal subsystems.

In other words, the demand for 'poly-contextual' capacities of many organisations involved with the production, validation and legitimation of new knowledge is increasing, and the manner in which they recruit and circulate their members is changing accordingly. Formulated in these terms, 'social robustness' means that organisations are able to fulfil a multitude of expectations, from a multitude of constituencies, which may be manifested in several codes.

3.3 Public engagement procedures as poly-contextual organisations

Because of the developments described above, some organisations are increasingly forced to pay attention to many different concerns simultaneously, including more unspecific concerns of 'the public' observed in controversies over new technologies. By 'unspecific' I mean here concerns that cannot be neatly categorised as science-based (i.e. pertaining to known physical risks), legal, economic or the like, as appearing from the perspective of scientists, regulators and business operators. This is not a claim that such concerns are void of substance, but the fact that they do not fit neatly within existing, institutionalised frameworks, goes a long way in explaining why they are difficult to handle by conventional means of governance, which are usually geared according to the principles of societal differentiation.

An example of this can be seen in the preparation of the 'GM Nation?' public engagement exercise in the UK (Horlick-Jones et al. 2007, Hansen, *forthcoming*, see also Kurath, *this issue*), where the organisers conducted a series of focus groups in order to formulate the agenda of the debate according to the concerns of 'the public'. This made the organisers observe that

"... *the general public did not demarcate issues and facts into categories of ethics, science, economics etc., as policy makers and professionals tended to ... People approached GM issues through their lived experience (food, my family's health and future, and the cost to me), not experiences of GM as such, or a 'debate.'*"
(Minutes of the GM Nation? Steering Board meeting, December 2002, §6; compare further Marris et al. 2001)

Organised participation

The perspective advanced here suggests that public engagement procedures can therefore be considered as *organisations*, the aim of which it is to relay such concerns into forms that are observable/relevant from the perspective of systemic logics, thus seeking to render the operation of such systems more 'socially robust'. Whatever their particular procedural format as citizens' juries, consensus conferences, planning cells or something else, participatory procedures as organisational systems include (different kinds of) members, towards whom different role expectations are directed. This increasingly entails the inclusion of a new category of members, 'lay people', who are introduced in various ways to deliberate on new technologies and – so it is hoped – to mediate between different systemic perspectives from a 'common sense' perspective (Evans and Plows 2007). Such procedures can be considered organisations that need to make decisions, both on 'internal' procedural issues (selecting participants, distributing roles, setting agendas etc.) and about what to communicate to the surrounding world as outcomes. Except in extreme cases, these outcomes will transcend the viewpoints of the individual participants and be a genuinely organisational product.

Structural logic and local context

The analytical advantage of distinguishing between an 'autopoietic' dynamic of societal subsystems and an organisational level when analysing public engagement processes comparatively is that it can help conceptualise more specifically how similar societal 'mastertrends' may have different local manifestations (Hansen 2006, Hagendijk and Irwin 2006). It directs attention to the fact that,

- on the one hand, there may simultaneously be a general structural logic in play across contemporary societies caused by intensified mutual interaction between science, politics and the economy etc., changing the social expectations directed at knowledge production;
- yet, on the other hand, this will most likely assume different organisational or institutional forms in specific national or sectoral contexts.

In theoretical terms, this means that the general societal differentiation is 'over-layered' by differentiations in time and space, constituting local patterns in the interaction between techno-scientific innovations and other activities in society *at the organisational level*. The specific manner in which patterns of regularities develop in the workings of organisations and institutions – and whether there is in fact convergence in this or not – thus becomes an empirical question.

Exploring the regularities in such patterns comparatively across cases and historically across time will thus facilitate a more nuanced picture of the legitimatory practices accompanying innovation in different contexts, including the role played by public engagement practices.

I shall therefore now turn to the question of how the generalising concepts of the previous sections can be complemented with more specific attention to politico-cultural differences, as something which is 'over-layered' on societal differentiation, in a systematic manner.

4 Introducing cross-national variation in the production of social robustness

Outside STS there is a rich literature examining the role of contextual and institutional determinants of innovation, which can broadly be labelled 'neo-institutional'. This includes, for instance, the National Innovation Systems approach (Nelson 1993, Lundwall 1992), the Varieties of Capitalism approach (Hall and Soskice 2001) and the Triple Helix approach (Etzkowitz and Leydesdorff 2000). These approaches conceptualise and analyse variation in the interplay between a number of societal institutions shaping innovation processes, such as public investment in R&D, labour market relations, educational systems, university-business relations and work organisation in knowledge-intensive firms and sectors, often in cross-national perspectives.

Inquiries in this tradition direct attention to the fact that when scrutinised more closely, deeply ingrained and seemingly lasting differences across different countries, regions and sectors can be observed. The dependent variable in these studies is usually some measure of economic performance, which is related to variables determining the capacity to innovate successfully.

However, most of these approaches devote little attention to the issue at the core of most research on public engagement processes, namely the *legitimatory practices* accompanying innovation. They tend to take for granted that high levels of innovation are desirable per se. It seems clear, however, that the public acceptance of innovations is only indirectly linked to their economic performance.[7]

Having explored in the previous sections how changes in the general conditions of knowledge production in contemporary societies can be conceptualised, how, then, can we go about analysing variation in the legitimatory practices embodied in public engagement procedures in different contexts?

Political culture

Within STS, but linked with the broad neo-institutional tradition, Sheila Jasanoff (2005) has recently suggested reviving the concept of *political culture* to examine varieties in the way biotechnological innovation is appropriated and governed in different national contexts. Inspired by this approach, I shall discuss how political culture might serve as a conceptual tool with which to structure comparative research on public engagement processes. Although originating in a different theoretical tradition, I will suggest that Jasanoff's perspective on political culture can offer a useful addition to the broadly Luhmannian framework adopted here. Both theories rely on a constructivist epistemology in the understanding of how modern societies deal with the different kinds of risks and uncertainties generated by techno-scientific innovations, and they both emphasise contingencies in the mutual interactions between different societal domains. (For a more elaborate discussion of the compatibility between systems theory and culturalist versions of STS, see Fuchs 2004).

According to Jasanoff, political culture ". . . refers to systematic means by which a political community makes binding collective choices" (2005: 21). She argues:
"*Political culture in contemporary knowledge societies includes the tacit, but nonetheless powerful, routines by which collective knowledge is produced and validated. But equally, . . . , political culture includes the moves by which a polity, almost by default, takes some issues or questions out of the domain of politics as usual.*" (ibid.)

This understanding of political culture arguably corresponds to and extends the systems theoretical assumption that political communication proceeds by means of contingent distinctions, which inevitably produces certain blind spots, by providing conceptual tools to specify in more detail how this takes place.

Different political cultures

It is implied in the concept that different political cultures exhibit different, but relatively stable, patterns in terms of which issues are included and excluded from public attention, how decisions are reached, what counts as legitimate kinds of evidence and argumentation etc. 'Culture' is thus the regularities that can be observed if we explore systematically how different actors direct

[7] At least in a number of technological fields, the prospect of economic benefits is not sufficient to ensure public acceptance, as for instance the introduction of genetically modified crops in Europe amply demonstrates.

and mutually adjust their observations of each other in particular, shared contexts, such as for example in a national policy arena.

As Fuchs argues, "'self-similarity' across a more or less demarcated network of distinctions creates a 'culture'" (2004: 19), whereby 'self-similarity' may be the shared focus of interaction of otherwise diverse actors, which emerges when they operate in, for instance, a German rather than in a British policy context. This makes political culture a useful structuring device when seeking to observe and explain variation in the way public engagement is institutionalised and used across different national contexts (compare also Münch and Lahusen 2001). Different expectations are directed at public engagement procedures in different contexts (e.g. Hansen, *forthcoming*), and a politico-cultural perspective assumes that these differences are not incidental but are linked to how the policy arenas are otherwise configured.

Variation

Observing policy arenas in terms of political culture makes comparative inquiries indispensible, as political culture must be understood in a non-essentialistic, relational manner (Jasanoff 2005: 21–23). Political culture is not something that can be observed in and of itself. Rather than an essence, 'political culture' is the product of attempts to identify regularities in the reservoirs of interpretive frames and guidelines for (inter)action, which actors rely on in situations where the contingency of possible actions need to be decreased or eliminated. When it comes to examining public engagement practices, the concept is therefore well-suited as a handle on politico-spatial specifics of science/society interactions.

As such, the generalising aspect of the mode 2 diagnosis and systems theory, which serves to ensure comparability between different cases, can be counterbalanced by a stronger sensitivity to variation in the processes of (perhaps changing) legitimatory practices. In this context, political culture thus designates regularities in the modes of interaction and mutual observation of actors, which is overlayered on the societal differentiation of modern societies. Political culture is more contingent than the socio-structural principle of societal differentiation. This is why the most interesting organisational and institutional variations can be observed exactly at this level, as well as where the question regarding convergence or continued variety can be addressed empirically.

What are we to look for, in order to observe political culture? Jasanoff suggests three dimensions which can guide examinations of the more specific patters of interaction between science and society: representation, participation and deliberation (Jasanoff 2005: 280-287). According to Jasanoff, these dimensions designate analytically relevant features of variation in the ways in which the public engages with science in different contexts.

Representation

'Representation' concerns the framing of issues, by which Jasanoff emphasises that some aspects and consequences of techno-scientific innovation are brought to public attention and made the object of collective reflection and decisions, while others are not. Any political culture exhibits biases in regard to what should be considered important and less important consequences of technological innovations and uncertainties, but the distinctions through which this is observed vary across contexts.

Participation

'Participation' concerns the processes of inclusion and exclusion of different actors as legitimate participants in the arenas of public reflection. It designates that political cultures contain – often implicit – norms and expectations about what kind of actors are important to engage and what roles they are expected and allowed to play in collective decision making. This includes what exactly is to be understood by 'the public' in different polities.

Deliberation

'Deliberation' concerns the manner in which collectively binding decisions are made within the polity, e.g. how expertise and competence are established and exercised, what role is played by science vis-à-vis other modes of communication. Political cultures thus designate – and naturalise – what can be called institutional role-distributions and responsibilities in the way polities make decisions about new technologies.

My suggestion is that these dimensions of political culture can serve as a tool to order observations of local or 'institutional' specifications into how science interacts with politics, the economy and the legal system. These interactions are in principle contingent but often produce relatively stable patterns of expectations over time in particular contexts. Processes and procedures of public engagement designate one particular type of institutionalised locus of such interaction, and as such their operations are inevitably embedded in a political culture.

Repercussions

Just as public engagement processes are shaped by their politico-cultural environment, they may have various kinds of repercussions feeding back into the systems making up this environment. Public engagement procedures generally strive to achieve and maximise their impacts in their societal environment, and impacts constitute important areas of interest when such procedures are evaluated (e.g. Rowe and Frewer 2000). As mentioned earlier, such impacts can be observed as resonance, namely when communication in one context is observed and has impacts in another context (or not).

Public engagement procedures are likely to be both implicitly shaped by, and in some cases consciously tailored to fit the politico-cultural contexts in which they unfold, and their ability to achieve resonance is likely to hinge on their compatibility with the politico-cultural context in which they operate. For instance, 'consensus conferences' are originally tailored to fit the Danish political culture (Klüver 1995), and despite significant international interest it is a matter of dispute as to how well this procedural format can be successfully transplanted into other contexts (e.g. Nielsen et al. 2007, Marris and Joly 1999, Einseidl et al. 2001).

However, this is not to say that we can expect to find a one-to-one static relationship between existing political cultures and the way public engagement and participation is organised and unfolds. This is exactly what must be explored empirically in a comparative fashion. The goal of comparative research on public engagement from the perspective suggested here should therefore be to specify empirically and compare

1. how public engagement processes perform and legitimate the choices they make (for instance on the dimensions suggested by Jasanoff) and
2. how their communication resonates with the centres of societal decision-making.

In this manner we can enhance our understanding of how social robustness is established – or not – *in particular contexts* and how this may be changing over time.

5 Summary and suggestions for empirical research

My initial question concerned how otherwise diverse instances of public engagement procedures can be rendered comparable without unduly ignoring their specific histories and paying due attention to the contexts in which they are naturally embedded. My suggestion is that public engagement procedures – whatever their specific format – can be considered as (temporary or more permanent) organisations established to let 'the public' – in the specific shape it is given by such procedures

– engage with techno-scientific dynamics. In this respect they constitute some of the avenues through which society 'speaks back' to science with the aim of producing social robustness of innovations suggested by the mode 2 diagnosis.

Contesting mode 2

However, I have contested the implications drawn by the mode 2 proponents, who interpret the emergence of such new organisational forums as a sign that the borders between different societal domains are being erased or transgressed. On the contrary, I have argued that the societal subsystems continue to provide important, distinct horizons of meaning and guidance for action in modern society. Therefore, if public engagement processes are to contribute to the establishment of socially robust innovation, they must be able to understand what is particular to each of these domains, as well as how different modes of observing interact in specific contexts. They must develop the ability to operate in a poly-contextual fashion.

If public engagement procedures ignore such structural features of contemporary societies, they are likely to be considered irrelevant in their politico-cultural environment: they will achieve little resonance beyond the procedures themselves. This, I will argue, applies to all public engagement procedures, independently of their specific procedural design. As such, this perspective helps to identify important socio-structural commonalities, which can facilitate a systematic comparison of a range of different procedural designs in a meaningful manner.

Cross-nation differences

An important addition to this criticism, however, is that the specific patterns of interaction between different societal domains may be institutionalised in quite different ways across national or sectoral contexts, and this is exactly what the concept of political culture in Jasanoff's conception seeks to capture in a comparative fashion.

Systems and organisations

One the one hand, the advantage of the approach suggested here compared to other currently influential conceptualisations of changes in science/society interaction lies in the enhanced sensitivity towards the interplay between continuities and changes. This is enabled through the distinction between societal subsystems as relatively stable discursive environments and organisations that may be more easily reconfigured. This provides a more complex set of conceptual tools compared to the dichotomous distinction between a mode 1 and a mode 2-like way of producing knowledge and legitimacy and similar claims about radical transformations in the relationship between science and society.

Persisting boundaries

On the other hand, the systems theoretical approach facilitates conceptualisation and observation of distinct modes of observation affiliated with different societal and institutional contexts, rather than resorting to claims about 'blurring boundaries', which strikes me as unsatisfactory for both analytical and normative reasons. The image of blurring boundaries is at odds with how real world actors make sense of and operate in their respective environments, where boundaries between different modes of communication continue to designate (sometimes contested but nonetheless) important and meaningful distinctions.

Resonance

The concept of resonance therefore plays a key role in conceptualising how these – possibly reconfigured – intersystemic couplings play out. My suggestion is that comparative research can help increase our understanding of the circumstances under which the kind of resonances that promote a social robustness of innovation can be nurtured (or not) through procedures of public engagement in particular contexts. This could be done by examining how they interact with expectations and assumptions embedded in and constitutive of their respective politico-cultural contexts.

In conclusion of this discussion I shall briefly indicate some potential focal points for future research that follow from the theoretical perspective outlined here. If we take a more operational approach to the analytical dimensions of political culture suggested by Jasanoff – representation, participation and deliberation – we can say that they concern issues for which public engagement procedures must provide and justify *organisational* answers. However, the empirical multiplicity of experiences with public engagement processes suggests that there is no standard solution as to how this is done. Therefore, the following questions point towards some of the dimensions where public engagement procedures are likely to vary across politico-cultural contexts, and which may constitute stimulating avenues for comparative research:

Institutional embedding

Where and how are public engagement procedures anchored institutionally? How do their outputs feed into existing decision-making centres?

Procedural design

Which actors are included/excluded from participation and on what grounds? How is interaction organised and how are different roles defined and distributed?

Discursive (or intersystemic) dynamic

What are the communicative resources relied upon (e.g. scientific, political, economic, legal modes of observation etc.) and how do they condition each other?

By asking these kinds of questions in a comparative fashion – as in my suggestion – we might attain a better understanding of the strengths and weaknesses of different procedural designs for public engagement in *different contexts*, rather than assuming that social robustness can be established in a similar fashion everywhere, as is (implicitly) suggested by the mode 2 diagnosis. Similarly, by comparing public engagement processes in their politico-cultural and historical settings, it will also be possible to examine more thoroughly if there is in fact convergence or lingering diversity in the manner in which contemporary societies seek to render techno-scientific innovation legitimate in the eyes of the public.

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Nanotechnology Governance

Accountability and Democracy in New Modes of Regulation and Deliberation

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Abstract

Current discourses in science, technology and innovation policy describe a shift from formal, governmental, or statutory regulation to non-hierarchical, informal, and co-operative self-regulatory approaches. They narrate a turn from government to governance, described as a "governance turn." Governance as a new and popular mode of regulation, deliberation and shared responsibility is often linked to favored attributes of science and technology development, and policy making such as democracy and responsibility. This article analyzes the connection between governance and ideas of accountable and democratic science and technology development in the case of nanosciences and nanotechnologies. For this purpose, soft law measures, self-regulatory initiatives, and public engagement projects in Europe and the U.S. were analyzed using the concept of social robustness (Nowotny et al. 2001).

The study showed that most of the analyzed governance approaches and engagement projects only partially met aspects of social robustness, and that the governance and deliberative turn in science and technology policy has not led, so far, to greater democracy and responsibility in nanoscience and nanotechnology development. As a consequence, the delegation of techno-political decision making to less socially robust governance approaches might lead to a vacuum in science and technology policy and affect not only academic knowledge production but also the innovative force of a society.[1]

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1 "New governance of science"?

The analysis of policy documents in the nanosciences and nanotechnologies (NST)—often subsumed under the term nanotechnology[2]—points to interesting aspects of perceived risks, regulatory need, and the question, which societal actors should become active in regulatory issues and decision-making in science and technology policy?

"*Current legislation covers in principle the potential health, safety and environmental risks in relation to nanomaterials.*" (Commission of the European Communities CEC 2008, 3-4)

"*Public health, environmental and consumer protection require that those involved in the development of nanotechnologies–including researchers, developers, producers, and distributors–address any potential risk, as early as possible.*" (CEC 2004, 22)

"*In a first phase, self-responsibility of industry is of high significance.*" (CH-Bundesrat 2008, 3, 10-11, translation MK)

"*We believe that a constructive and proactive debate should be undertaken now. We recommend that the Government initiate adequately funded public dialogue around the development of nanotechnologies.*" (RS&RAE 2004, xi)

"*Experiments and innovations in public engagement with science have the potential to contribute to a more accountable science and a healthier democracy.*" (Wilsdon 2005, 1)

"*Specific recommendation on how government and industry could improve trust [is] the provision of more information to the public.*" (Macoubrie 2005, 4)

These quotations frame the NST-related techno-political discourse in terms of four principles:

1. Policymakers agree that current legislation mainly covers the potential health, safety and environmental risks of nanomaterials. In general, they do not see an immediate need for additional legislation.
2. NST regulation is mainly framed in terms of governance, meaning non-hierarchical, informal, network-oriented, and cooperative forms of ruling such as soft law[3] and self-regulation. Hereby, the regulatory responsibility is shifted to the actors involved in the research, development, production, retail and disposal process of NST.
3. Public engagement is assigned high significance. However, the question of whether the approach is to be mutual-learning or information-oriented, is an issue (see, for example, the Wilsdon and Macoubrie citations above).
4. A connection is made between governance and democracy that links self-regulation, soft law and public engagement with favorable attributes such as accountability, stewardship, safety, sustainability, acceptance, public trust, democracy and the idea of responsible technology development.

These observations are not new. Since the 1970s, political scientists have observed a shift from hierarchical to more cooperative forms of regulation (Mayntz 1996). They narrate a turn from government to governance (Rhodes 1997)

[2] The term nanotechnology is ambiguously used for all kinds of small molecular research, development, production and futuristic visions (cf. Lösch 2006). The term is also framed as an "empty signifier" (Wullweber, 2008), an "umbrella term" (Rip and Voss 2008), a "folk theory" (Rip, 2006), a "funding strategy" (cf. Kurath and Maasen 2006) or a "lack of reason" (Schummer 2009).

[3] The term "soft law" is used with regard to quasi-legal instruments not having any legally binding force, or whose binding is weaker than that of traditional statutory law—which in contrast to soft law is referred to as "hard law". Originally, the term "soft law" was mainly used for international law, although currently it has been transferred to other branches of domestic law as well, such as voluntary legal schemes by public authorities (cf. Kirton and Treblicock 2004; Nasser 2008). The term "self-regulation" will be used when societal actors are setting standards and monitoring compliance in the interest of public protection, (cf. Boekaerts 2005).

in which governance measures were framed as a substitute for statutory regulation within the context of neoliberalism and questions of effectiveness and efficiency of policy-making (Mayntz, 1996). Recent studies characterize this turn, depending on their analytic frame, as either a governance (Borràs and Conzelmann, 2007, Rose 1996), deliberative (Hagendijk and Irwin 2006, Irwin, 2006, Kearnes and Wynne 2007), or qualitative (Kearnes 2009) turn, or as a shift from a "modernist to postmodernist form of statecraft" (Gottweis and Petersen 2008).

A further framing of those new modes of governance by ideas of accountability, responsible technology development, and an increase in democracy has been described for the field of NST (see Kearnes and Wynne 2007). In this way, soft law, self-regulation, and public engagement have been framed as means for technology development that is—in Nowotny's words—socially robust (Nowotny et al. 2001, 167).

Soft law and self-regulatory approaches

This shift from statutory or "hard law" *federal* regulation (in the cases of the US, Germany, and Switzerland) to "soft law," self-regulatory approaches has been described in science and technology policy studies as a "new governance of science" (cf. Gibbons et al. 1994, Irwin 2006, Barben 2005, Felt et al. 2008, Lengwiler and Simon, 2009, Weingart 2001). Regulation of innovative, uncertain emerging technologies was reinterpreted as a task that no longer concerns traditional governmental institutions, but is instead negotiated at the interfaces between science, politics, industry and civil society (Miller and Rose 2008).

Public understanding of science and upstream engagement

Thinking about public engagement in science and technology-related decision-making processes[4] traditionally has been done in terms of "public understanding of science" (PUS). Relying upon a commonly assumed expert-lay divide, PUS views public engagement mainly in terms of information, education, and dialogue with the public. It assumes that increased information and education of the public leads to increased trust and acceptance of science and technology. However, the PUS concept has been broadly criticized as a "deficit model" and "ill-defined" (cf. Wynne 1995, Irwin and Wynne 1996, Hagendijk 2004, Jasanoff 2005).[5]

In contrast to PUS, a newer conceptualization of public engagement in the early stages of technology development has emerged that is referred to as "upstream engagement" (Wilsdon and Willis 2004).[6] Upstream engagement aims at treating the public as an equal and regarding its knowledge in a mutual-learning-oriented way. This is considered central to emerging science and technology-related decision-making processes, and is framed as a more democratic science-society interaction and way of making science policy (RS&RAE, 2004). Following the RS&RAE (2004) report and a related Nature editorial (Nature 2004), upstream engagement became a fashionable term in science communication. A variety of deliberative and upstream engagement-related projects and communicative activities were initiated and advertised as

[4] On public engagement and its popularization see e.g. (Hagendijk and Irwin 2006, Jasanoff 2005, Wilsdon and Willis 2004, Hagendijk 2005, Abels and Bora 2004).

[5] The focus on NST-related public dialogue varies between the analyzed countries. As an example it is not as intense in the U.S. as it has been in the EU, particularly in Britain and in the U.S., the public understanding of science (PUS) approach is still prevalent, as e.g. the last quotation on page 2 (Macoubrie 2005, 4) showed.

[6] Particularly in Britain, a generic deficit of public trust in science, technology, and political representatives has been broadly recognized (cf. Gaskell et al. 2004, Gaskell et al. 2005, Wynne 2001). Here, public controversies involving nuclear power, GMO, and BSE, have resulted in an early-stage initiation of dialogues, deliberation, and public engagement in the field of NST, with the aim of increasing public confidence (Hagendijk and Irwin 2006).

another democratic turn in the techno-political discourse (Kearnes et al. 2006b, see also Kurath and Gisler 2009).

Questions

This article focuses on the correlation of governance with accountability and democracy in the nanosciences and nanotechnologies. A selection of 14 self-regulatory and soft law schemes in NST, also described as regulatory-oriented governance (Section 3), and six public engagement projects, termed, 'deliberation oriented governance'(Section 4), will be analyzed regarding their social robustness. Among the questions asked are these:

1. Do the analyzed governance schemes and projects show concrete and robust approaches, outcomes, and results, or have they been restricted to declarations of intent only?
2. Have they established robust strategies regarding current policy discourses, the enforceability of their outcomes, and their translation into the political process?
3. Have they addressed the acceptability of their own approaches, methods, and outcomes?
4. Have they considered external social knowledge and how they engaged it?
5. Were they subject to public consultation and established external evaluation, testing, and improvement?

Socially robust knowledge

The concept of social robustness (Nowotny et al. 2001) was originally developed for the analysis of science and academic knowledge production in modern knowledge societies (Weingart 2001, Gibbons et al. 1994, Nowotny et al. 2001). It was based on the emergence of both a new mode of knowledge production and an increased permeability of the societal domains of state and science (Nowotny et al. 2001, 166).

Social robustness also was based on the observation of an intensified contextualization in academic knowledge production: scientists have increasingly been influenced and motivated by external factors such as their contribution to innovation, solving environmental, ethical, and societal problems, and to policy advice. This led to a shift from weakly to strongly contextualized knowledge production (Nowotny et al. 2001, 166). Strong contextualization of a scientific field or research domain leads to high social robustness of the knowledge it is likely to produce. Social robustness has been framed by five criteria (Nowotny et al. 2001, 167):

1. Social robustness is relational, or in other words, contextualized
2. Social robustness describes a process that generates stability
3. Socially robust knowledge is based on its acceptability by individuals, groups and societies
4. Socially robust knowledge is infiltrated and improved by social knowledge
5. Socially robust knowledge is subject to frequent testing, feedback, and improvement, or evaluation

Socially robust regulation

The openness of social robustness well matches the analytical needs of a study of societal processes or activities beyond science and academic knowledge production that include regulation, deliberation, public engagement and governance. Regulatory and deliberative oriented governance approaches could be more socially robust if they consider and include external contexts, generate stability, have been infiltrated and improved by social knowledge, and are subject to frequent testing, feedback, and improvement.

The criteria framing social robustness—contextualization, stability, acceptability, social knowledge and evaluation via feedback, testing and improvement structures (Nowotny et al. 2001, 167)—are open enough for this transition of focus. Their applicability to governance approaches makes social robustness suitable for this study's analysis of accountability and democracy of governance, self-regulatory measures, soft law approaches, and public engagement projects.

A range of governance measures in the NST[7] were chosen for the analysis of these issues within an overarching qualitative comparative analysis of NST-related policy discourses in the US and Europe, including the European Union member states Germany and Britain, and nonmember state Switzerland.[8] Methods consisted of qualitative, semi-structured interviews (Lamneck 1988) with actors involved in science, politics, industry, and civil society organizations, as well as the analysis of relevant policy documents and assessment reports.[9] The analysis of public engagement projects is based on an earlier study conducted in 2007 (see Kurath and Gisler 2009).

2 Criteria for the analysis of social robustness

Analysis of regulatory and deliberation oriented governance schemes and projects, rely upon the following aspects of the concept of social robustness:

Contextualization

Contextualization is an aspect of social robustness that refers to the relation of governance schemes to external contexts. Questions will focus on the ways governance has been embedded in social, cultural, political, and historic contexts, and their relations with current policy and technology discourses, which include environmental, health, and safety (EHS) issues. A particular focus lies on regulation-oriented schemes and whether they are based on standards, which means that the outcome of the schemes is a clearly defined, comprehensible product such as safety data, or whether the schemes have been based on principles, which form less tangible and substantial commitments. Standards-based schemes yield more comprehensible outcomes and substantial contributions to political, regulatory, and technology discourses.

Another specific focus is on the epistemic basis of deliberation-oriented projects. This leads to examining the conceptual framing of public engagement either in terms of upstream engagement (Wilsdon and Willis 2004) through mutual learning and equally engaging citizens in science and technology-related decision-making processes, or a PUS approach in which the main communicative actors persist in framing an expert-lay divide between science and the public.

Stability

Stability refers to the ways in which governance schemes, projects, and their outcomes are translated into political processes, enforceable, and established to one extent or another in related policies.

Acceptability

Acceptability pertains to analysis of whether governance schemes and projects build in steps or measures to consider the societal acceptability of those schemes and projects, and their methods and outcomes.

[7] On the establishment of NST related governance measures, see e.g. (Maasen, 2009, RS&RAE 2004, Wilsdon and Willis 2004, Wilsdon 2005, Kearnes et al. 2006a, Nature 2004, Kearnes and Wynne 2007, Barben et al. 2008, Kearnes and Rip 2009, Lösch et al. 2008, and for a general overview Kaiser et al. 2009).

[8] The aim of this study was a transatlantic comparison. A direct comparison of the US and the European Union's supranational confederation of states might produce epistemological difficulties, as important practices and processes take place on national levels in the EU as well. Therefore, three European states that are leaders in NST, Britain, Germany, and the EU nonmember Switzerland, were included in the analysis and subsumed under "Europe."

[9] Within this study a total of 56 interviews were conducted in the US, Britain, Germany, Switzerland, the EU, and the OECD, and were transcribed and analyzed. They focused on the political discourse, regulatory issues of NST, and the specific perspective of the interviewed actors with regard to their organizational and institutional background. Furthermore, 14 experts were questioned on specific issues.

Social knowledge

Whether governance schemes and projects have established tools to collect, judge, and build in external societal knowledge is analyzed, as well as whether they have been subject to public consultation or only selected actors have been consulted.

How social knowledge was considered is also analyzed. This involves looking at whether communication was oriented toward education/discussion/ dialogue, or two-way communication and mutual learning. Further communicative or decision-making tools such as voting are also examined.

Evaluation

Finally, frequent testing, feedback, and improvement were analyzed, particularly with regard to whether projects and schemes reflected upon their approaches, methods, and outcomes.

3 The robustness of self-regulation and soft law

Fourteen selected supranational, governmental, private, and international NST regulatory-oriented governance schemes were analyzed. They employed voluntary and informal approaches to regulation by public authorities, supranational or international bodies such as the European Commission and the OECD, and self-regulatory activities by manufacturers, industrial associations and civil society organizations such as environmental and consumer groups (cf. the appendix with Table 3, which describes the aims and results of the approaches, and Table 4, which analyses the approaches regarding the criteria of social robustness). Table 1 presents the final rating of the social robustness of the approaches, which are analyzed in more detail below.

3.1 Social robustness rating

This analysis shows that most of the self-regulatory and soft law approaches only partially meet aspects of social robustness and ideas of a robust science and technology development. Only a few produced concrete and measurable outcomes.

Contextualization

Most schemes rated high or medium in their contextualization.

Both supranational EU schemes met certain aspects of social robustness. Both are principle-based, which means they declare the intention or invite member states to follow certain, more or less specified principles or ideals in the promotion, research, and development of NST. Both EU schemes are related to currently debated issues such as safety, sustainability, and ethics in research.

Among the governmental schemes, two are reporting schemes that meet criteria of high social robustness. They are based on standards, which lead to defined outcomes such as safety data on manufactured nanoscale materials and risk-related management systems by manufacturers. The other three governmental schemes are based on principles, which makes them less robust, but they address current relevant issues such as risk and stakeholder engagement.

Among the private schemes, the EDF-DuPont Nano Risk Framework, the VCI guidelines, and the Cenarios certification system received the highest ratings because they are standards-based and address risk. The UK Responsible Nano Code is principle-based and applies to organizations involved in all stages of NST development and use. With an overarching aim of a safe and responsible technology life-cycle, the principles and outcomes of the scheme have not so far been specified and remain rather vague. The Swiss Retail Association's code was rated partially robust for its concretely and comprehensively shaped principles and its relationship with current dialogues concerning transparency in consumer information and product safety.

Among the international OECD schemes, the Working Party on Man-

Table 1: Social robustness-rating of regulatory-oriented governance

	Contextualization	Stability	Acceptability	Social knowledge	Evaluation	Sum
Supranational schemes						
EU Action Plan on Nanosciences and Nanotechnologies 2005	0	0	-1	0	1	0
EU Code of Conduct on responsible Nano Research 2007	0	0	-1	-1	1	-1
Governmental schemes						
UK DEFRA Voluntary Reporting Scheme 2006	1	-1	-1	1	0	0
USA EPA Nanomaterial Stewardship Program 2008	1	-1	-1	1	0	0
German NanoCommission/NanoDialogue 2006	0	-1	-1	0	-1	-3
German Nano-Initiative, Action Plan 2006	0	-1	-1	0	-1	-3
Swiss Federal Action Plan "Synthetic Nanomaterials" 2008	0	-1	-1	0	-1	-3
Private schemes						
EDF-DuPont Nano Risk Framework 2007	1	0	-1	1	0	1
UK Responsible Nano Code 2008	-1	-1	-1	-1	-1	-5
German VCI Guidelines 2008	1	-1	-1	0	-1	-2
German/Swiss Cenarios Certification System 2008	1	0	-1	-1	1	0
Swiss Retail Association Code of Conduct Nanotechnologies 2008	0	0	-1	0	0	-1
International schemes						
OECD Working Party on Manufactured Nanomaterials (WMNM) 2006	1	1	-1	-1	0	0
OECD Working Party on Nanotechnology 2007	-1	-1	-1	-1	-1	-5
1 = meets the criterion 0 = partially meets the criterion -1 = doesn't meet the criterion/no specified aspects in this category						

ufactured Nanomaterials received a slightly higher rating with regard to contextualization, even though it is principle-based, because the member states are engaged in a program to test selected nanomaterials according to a comprehensive framework.

Stability

Most schemes received rather low ratings with regard to their outcomes and their translation into political processes and establishment in related policies.

Only one approach received a rating above 0: the OECD Working Party on Manufactured Nanomaterials, which launched two substantial contributions to which member states could show commitment on a voluntary basis. The committed member states were obliged to contribute to a clearly framed and comprehensible program: the sponsorship program for testing of manufactured nanomaterials and the database on research into safety of manufactured nanomaterials. A steering committee was established to observe the proceedings of the working party's projects and their translation into the member countries' political processes.

Nine of the schemes met certain aspects of stability and received a rating of 0. These include the European Union's schemes (which can apply financial pressure on member states and reviews), the U.S. Nanorisk framework, the Swiss Retailers Association's Code of Conduct (which was launched by committed organizations), and the Cenarios Certification System (with intrinsic obligation on certified firms). However, for these scheme's enforceability is still limited to manufacturers voluntarily implementing a certification system.

Governmental action plans consisting of clearly described and verifiable aims, such as the European Union Action Plan, met certain stability criteria with regard to contents and funding for risk research. However, the epistemic basis of an action plan is primarily a declaration of intent only. If the management of the objectives remains unspecified, as is the case in the German and Swiss Action Plans, those action plans remain noncommittal and less robust.

Acceptability

None of the analyzed schemes built in any measures to consider its own acceptability or that of the knowledge produced within the scheme. A few schemes mentioned contributing to an increase in the public acceptance of NST, but none received a rating exceeding -1.

Social knowledge

Most of the analyzed approaches considered external and social knowledge to some extent.

Governmental reporting schemes received the highest social knowledge ratings. In addition to the consideration of social knowledge of manufacturers and research organizations, which was the epistemic basis and the core element of the UK and U.S. governmental reporting schemes, the schemes also included external knowledge through consultation with selected actors. The schemes were established in close cooperation with related agencies and included public consultation with feedback possibilities for concerned actors and stakeholders prior to launch.

The EDF-DuPont Nano Risk Framework was also subject to public consultation before its launch in June 2007. In April 2008, EDF and DuPont also organized interactive workshops on nanorisk management in Boston and San Francisco. Contributions from any interested party are encouraged on the scheme's website.

In most cases, social knowledge remained confined to actor knowledge. A few action plans and codes of conduct mentioned the initiation of a dialogue with the general public among their aims. However, none of them made additional statements concerning the way this aim should be implemented. In this respect, these schemes were rated as partially socially robust.

In the European governmental initiatives, each of the three action plans considered knowledge of concerned actors and stakeholders prior to or after its launch. While the EU action plan included the aim of organizing dialogues and collecting comments, the German and the Swiss action plan considered knowledge of concerned actors.

The German NanoDialogue was established based on the intrinsic motivation to consider social knowledge. However, in its case social knowledge was limited to actor and concerned stakeholder knowledge. The final report did not specify to what extent knowledge outside the NanoCommission's members was considered (Catenhusen et al. 2008).

In Switzerland, selected actors and stakeholders of various societal domains contributed to a report on which the action plan was developed.

The private German VCI Guidelines and the Swiss Retailers Association regarded dialogue events with selected actors as a basis for the development of their measures. However, actors were involved and how they were to be selected was not specified on the related websites and in the reports.

None of the international schemes reported any consultation of social knowledge external to the member states' representatives. To what extent the representatives themselves consulted social knowledge was not specified either.

Evaluation

The supranational schemes of the European Union take a leading role in evaluation.

In the action plan and the code of conduct for responsible NST research, biannual reporting of the member states was envisaged. While the action plan described an indicator-based report to the council and the parliament, the code of conduct asks for a review of the recommendation and the extent with which it was adopted and applied within the relevant organizations of the member countries. However, due to the voluntary nature of the code it is even less clear to what extent the member states will really participate in the evaluation process. This proposes the question, to what extent this voluntary code can be translated into the political process.

Among the private initiatives, the Swiss Cenarios Certification System forms the most robust evaluation approach. External evaluation of the establishment of the required processes within the firms applying for certification is an intrinsic condition of a certificate system. Such systems best meet the requirements for social robustness.

The EDF-DuPont Nano Risk Framework takes a leading role in this area as well, as continued external and self-evaluation is planned. Because concrete measures beyond publicly open stakeholder workshops and a call for comments on its website have not yet been further specified, EDF-DuPont evaluation is rated as only partially robust. The same rating was given the Swiss Retailers Association Code of Conduct because it requires self-evaluation by regular member reports on the establishment of the code. Furthermore, the OECD Working Party on Manufactured Nanomaterials established a steering committee to evaluate how its work is proceeding.

3.2 Socially robust strategies? A short summary of the analysis

Supranational and governmental schemes

Among the supranational and governmental schemes, the European Commission's Action Plan and the UK and U.S. reporting schemes received the highest social robustness ratings.

The Action Plan's requirement that member states conduct indicator-based external evaluation seems in particular to be highly robust. External knowledge of selected stakeholders was obtained in dialogues and comments, while a certain enforceability might attach to well described financial aims. However, the way in which member states report to the council and the parliament on a regular basis, or whether they actually will report at all, is not clear.

The UK and U.S. voluntary reporting schemes were rated highly contextualized due to their standards and risk-relatedness. They considered social knowledge to a high degree and allowed for self-evaluation, but they did not consider their acceptability. Due to their voluntary character, they were only marginally translated into political processes, which turned out to be their weakest aspects. Only a few of the manufacturing organizations voluntarily took the effort to compose and deliver the necessary data. There were 13 data submissions in the UK,[10] 11 from industry and two from academia; 21 companies submitted reports to the U.S. program (U.S. EPA 2009). An assumed high rate of manufacturers not reporting resulted in criticism of the voluntary data reporting approaches in both countries (see e.g. Bergeson 2007, Bullis 2008, Hanson 2008).

Private schemes

While supranational and governmental schemes were rated between 0 and -3, the private schemes showed greater variability. With an overall rating of +1, the EDF-DuPont Nano Risk Framework was socially robust, while at -5 the UK Responsible Nano Code met no robustness criteria at all. The Nano Risk Framework is standards-based, considers risk, and is strong in contextualization and the consideration of external knowledge. Due to its voluntary approach, the commitment of the launching organizations, and its testing and feedback, the scheme rated medium in stability and consideration of social knowledge.

The Cenarios Certification System was rated second-best. Due to its reliance on standards, consideration of risk, external evaluation and recertification on an annual basis, contextualization and evaluation were rated high. Because evaluation and recertification are built into certification and imply enforceability—at least for the firms applying for or having the certificate—it was rated medium in stability. However, Cenarios does not specify any consideration of social knowledge, nor does it consider its acceptability.

The Swiss Retail Association's code of conduct was rated higher than the two other schemes of private codes or guidelines. This code specified requirements and forces members to adopt the code and conduct evaluation. It intends the establishment of stakeholder dialogue. However, the way in which the results of such dialogue feed forward into the design and content of the code was not specified.

Although the VCI guidelines are clearly specified, they are entirely voluntary and the members are neither under pressure from the Chemical Industries Association to adopt them nor subject to evaluation. However, external knowledge was consulted and considered through stakeholder dialogues.

The UK Responsible Nano Code is the poorest rated private initiative, with low social robustness in each category. The code agreement is principle-based and not binding in any form, not even upon the launching organizations. The principles were rather vaguely shaped, its acceptability is not considered, no social knowledge is consulted, and evaluation is not specified within this code.

International schemes

Among the international schemes, the OECD working parties differed considerably with regard to their social robustness.

The Working Party on Manufactured Nanomaterials (WPMN) is socially robust, particularly because its sponsorship program is based on comprehensible standards and it is sensitive to risk. Further, the WPMN initiated a steering committee that may play a role in

[10] See <www.defra.gov.uk/environment/quality/nanotech/policy.htm> (visited 02.11.09).

the political translation of results and in evaluation.

In contrast, the Working Party on Nanotechnology did not demonstrate any social robustness. It specified no evaluation, consideration of social knowledge or program acceptability, translation into the political process, or any contextualization with regard to a concrete product or outcome.

Conclusion

None of the governance measures, soft law and self-regulatory schemes turned out to be socially robust in all aspects. While some schemes showed quite concrete and robust approaches, others are restricted to declarations of intent. Only a few schemes showed robust strategies for consideration of current policy discourses, the enforceability of their outcomes, their translation into the political process, public consultation, and external evaluation, testing and improvement of the scheme. None of the analyzed schemes considered acceptance of its approach, methods, and outcomes.

4 The robustness of deliberation and engagement

"This analysis of public engagement or deliberative-governance projects established in NST draws upon the concepts of participatory technology assessment and upstream engagement." It is based on an earlier study that analyzed six well-documented public engagement projects in selected countries (cf. Kurath and Gisler 2009), which relied upon participant observation (in the Swiss case and the UK Nanodialogue video screening) and a meta-analysis of literature reports and documents (in the other cases).

These public engagement projects included a forum event, the U.S. Nanoscale Informal Science Education (NISE) Network 2005; a citizen jury, the UK Nanojury; dialogues, which include the UK Nanodialogues and the European Union funded Nanologue project; a public event, the UK Bristol Citizen Science project; and a focus group, the Swiss Publifocus project (cf. Bell et al. 2006, Gavelin et al. 2007, Rey 2006, Singh 2007, Stilgoe 2007, Türk et al. 2006), and Table 5, which describes aim and results of the approaches, and Table 6, which analyses the approaches in terms of the criteria of social robustness. Table 2 presents the social robustness ratings of the approaches, which are analyzed in more detail below.

4.1 Social robustness rating

While the social robustness ratings of the self-regulatory and soft law approaches varied from +1 to -5, the ratings of the engagement projects varied even more, between +3 and -5. In principle, most of the engagement projects partially met certain aspects of social robustness and robust science and technology development; few produced a concrete impact.

Contextualization

Only one project—the UK Nanojury—showed high social robustness. Most met some aspects of social robustness, although two projects showed little or no social robustness.

The UK Nanojury was the only project that was conceptually oriented towards a new framing of communicative actors and overcoming the traditional expert-lay person divide. The main focus of its methodological approach is to break traditional expert-lay frames by giving scientists the roles of witness and audience, and citizens that of jurors.

Apart from the Nanojury, the framing of communicative actors as experts versus lay persons was more or less observable in all other engagement projects despite—as in the UK Nanodialogues and the EU Nanologue—commitments to more mutual-learning-oriented framing by upstream engagement.

The UK Nanodialogues, the Swiss Publifocus, and the EU Nanologue were embedded in, and their products were related to, current policy and technology discourses, mostly focusing on potential

Table 2: Social robustness rating of deliberation-oriented governance

	Contextualization	Stability	Acceptability	Social knowledge	Evaluation	Sum
U.S. NISE Network 2005	-1	-1	-1	-1	0	-4
UK Nanojury 2005	1	0	0	1	1	3
UK Nanodialogues 2006	0,5	1	0	0.5	1	3
UK Citizen Science Bristol 2008	-1	-1	-1	-1	-1	-5
Swiss Publifocus Nanotechnology 2006	0	-1	-1	0	0	-2
EU Nanologue 2005-2006	0	-1	-1	0	0	-2
1 = meets the criterion 0 = partially meets the criterion -1 = doesn't meet the criterion/no specified aspects in this category						

risks and societal issues; their contextualization was therefore partial.

Both of the low-rated projects, the U.S. NISE Network and the UK Citizen Science Bristol project, did not consider risk, safety, public health, or environmental issues. They were framed by a traditional PUS-based notion of educating lay citizens, rather than by engaging knowledgeable citizens in engagement-based dialogue processes.

Stability

Stability received rather weak ratings, with few of the public engagement projects specifying concrete outcomes or translation into political processes. Only the UK Nanojury and Nanodialogues showed robust approaches to producing at least some impact. While the UK Nanodialogues produced collaborative impacts on corporations and foreign aid projects, the Nanojury formulated recommendations to scientists and policymakers. However, to what extent these recommendations were taken up within the relevant organizations and institutions remains unclear; they therefore were rated as only partially stable.

Acceptability

Acceptability received even weaker ratings since only two of the projects—the UK Nanojury and Nanodialogues—considered to any extent the acceptability of their approaches, methods, and the issues discussed. While the Nanojury reflected on the acceptability of the dialogue process in its collaboration with related organizations, the Nanodialogues gave the involved citizens discursive space to reflect on their acceptance of the project. However, the acceptability of both projects was not subject to further consultation. Therefore, they were rated as meeting only certain aspects of acceptability.

Social knowledge

How social knowledge was considered in terms of discussion and communication style, the use of further communicative and decision-making tools, and the inclusion of external societal knowledge, generally showed higher ratings.

Here again, the UK Nanojury and Nanodialogues were rated highest for their use of new and experimental modes of engaging social knowledge, allowing two-way communication in pursuit of the explicit goal of mutual learning, and engaging the public "upstream." While the Nanojury worked in close collaboration with organizations related to its target issues and enabled public issues to be taken up within these organizations, the Nanodialogues opened the discussion by letting citizens discuss an issue of their own choice and gave them the opportunity to frame the NST-related issues, themes, and questions to be discussed.

The other dialogue-oriented projects, the Swiss Publifocus and the EU Nanologue, mostly framed the themes, issues, and questions around which they aimed at creating a discussion with the participants themselves. This was even more the case with education-oriented approaches such as the U.S. NISE network events and the UK Bristol Citizen Science project. However, the EU Nanologue project gave at least some attention to social knowledge, with greater focus on dialogues and discussion although its approach did not allow much space for breaking up traditional framings of communicative actors regarding their knowledge background, nor did it encourage much mutual learning. This was even more the case with the Swiss Publifocus project. An information brochure (Cerutti 2006) defining NST and explaining potential products, applications, opportunities and risks was handed out to each participant in advance of the meetings; discussion themes and issues were also given in advance. Its focus group meetings then began with two expert presentations explaining potential risks and ethical issues of NST, and the group discussion was moderated.

Evaluation

Most of the projects used frequent testing, feedback, and improvement. By publishing self-reflective evaluation reports, critically assessing approaches, methods, outcomes, and feed-forward into policy processes the UK Nanojury and the Nanodialogues again achieved the highest ratings. The NISE network, the Swiss Publifocus project, and the EU Nanologue project also published their results. However, they did not reflect on their approaches, methods, processes, and their policy process and current societal discourse outcomes (cf. Flagg 2005, Rey, 2006).[11]

4.2 Deficit or upstream model? A short summary of the analysis

The deficit model

With the exception of the UK Nanojury and Nanodialogues, this analysis shows fairly traditional approaches to public engagement that seem to be influenced by the old deficit model of information and education, rather than exchange and mutual learning. Although the methods and approaches were varied, most looked similar to those used in participative programs of the 1990s like citizen conferences, focus groups, or dialogues, whose translation into the political process had certain limitations (Abels and Bora 2004). These projects only partially met criteria of social robustness and none provided any visible evaluation or reflection on method, concept, general aim, or policy impact at the end of the project.

Upstream engagement

However, the UK Nanojury and Nanodialogues seem to have used new and experimental approaches. Located in the UK, where upstream engagement is widely propagated and disseminated, each reached a +3 rather for social robustness. While the methodological approach of the Nanojury reversed the traditional roles of science and the public, and thus supported mutual learning and two-way communication, the Nanodialogues contributed to significant and innovative uptake of citizen's voices by applying public engagement in new contexts such as funding agencies, corporations and foreign aid projects. Both projects were evaluated by reports that suggested improvements by critically reflecting on aims, approaches, methods, process, policy impact, the concept of upstream engagement in general, and public engagement in a broader context of science-society interactions (Stilgoe 2007, Singh 2007, Doubleday and Welland 2005).

Both projects seem to have reached an impressive level of exchange and mutual learning regarding specific projects

[11] See also <www.nisenet.org/community/groups/forums> and <www.nanologue.net> (visited 15.01.2010).

and contexts. Yet, regarding more general science policy questions and decision making in NST, the translation of public engagement into the political process turned out to be more difficult. Even in experimental and new approaches, traditional contrast structures opposing science and the public in terms of an expert/lay divide are difficult to overcome. The Nanodialogues project in particular, maintained a rather traditional framing of science and the public in its conceptualization of experts (nanoresearchers) and a lay public (randomly selected citizens) (see Kearnes et al. 2006b). A videotape documenting the Nanodialogues, in which the public was almost entirely represented by women (concerned mothers) and science by men (informative teachers), further sustained this construction.[12] Such traditional, and particularly gendered framing of the public as a group of randomly selected citizens or lay persons who are pitted against science, represented mainly by classic scientific experts, might not provide ideal ground for more democratic involvement through reflective exchange and mutual learning, which is a core premise of upstream engagement.

5 Accountability and democracy in science and technology governance

Policy discourses on emerging technologies and new scientific fields point to a shift from government to governance. Governance approaches, whether regulatory or deliberation-oriented, have framed responsibility and democracy as desirable aspects of technology development. Governance of this kind has been postulated as a substitute for federal regulation and as a way to more robust science and technology policy.

[12] The videotape was shown by Prof. Phil Macnaghten at the conference "The risk governance of nanotechnology: recommendations for managing a global issue" on 6th - 7th July 2006 hosted by Swiss Re in Rüschlikon Switzerland.

5.1 Summary of the analysis

Looking at 14 regulatory-oriented and 6 deliberation-oriented governance approaches and projects in NST, this article analyzes the reported increase of social robustness in science and technology policy. None of the 20 governance approaches and projects that were analyzed entirely met all the criteria of social robustness. Only eight had ratings of 0 or greater. Of the 14 soft law and self-regulatory approaches, only one had a social robustness score greater than 0, while five were rated 0. By comparison, two of the 6 engagement projects had social robustness scores of 3, while the rest were rated below 0.

Contextualization

Most of the regulatory and deliberation-oriented governance approaches were well embedded and contextualized in current technology and policy debates, and focused on issues such as potential risks, and environmental and societal issues in NST. Contexts and methods providing engagement played a major role. Even if PUS-based, the highest rated engagement projects used experimental approaches of two-way communication to engage the communicative actors, whether or not expert/lay person framing predominated, in an upstream-engagement-oriented way.

Stability

Stability, which encompasses the ways schemes feed forward into political processes, was nearly the weakest aspect of social robustness. Only one regulatory-oriented and one deliberation-oriented governance scheme established a measure of policymaking and contributed to concrete, measurable outcome. These soft law or self-regulatory approaches are to a certain extent enforceable: they can direct pressure for commitment upon member states or manufacturers. The sponsorship program for testing manufactured nanoscale materials of the OECD Working Party on Manufactured Nanomaterials, requires a binding commitment on the part of member states to fund and oversee a testing program of selected nanoscale materials, while the UK Nanodialogues contributed new insight to policy discourse in funding agencies, corporations, and foreign aid projects.

Acceptability

None of the regulatory, and only two of the deliberation-oriented schemes reflected on acceptability; it proved the weakest of the five aspects. The UK Nanojury and the Nanodialogues partially met acceptability criteria by affording participating actors a formative role in discussion.

Social knowledge

Most of the governance schemes considered the social knowledge of at least selected actors. Only a few were open to fully public consultation. The regulatory-oriented projects that received the highest scores—the UK and U.S. governmental reporting schemes and the U.S. private Nanorisk Framework—built in tools, methods, and measures to collect and consult social knowledge beyond that of only selected actors. Among the engagement projects, the question primarily focuses not on *whether* public consultation happened, but rather on the *way* social knowledge was considered. However, only two of the six engagement projects received ratings higher than 0. The UK Nanojury and Nanodialogues established equality-oriented engagement that made possible mutual learning and dialogue. The others oriented accounting for social knowledge around education or the provision of acceptance.

Evaluation

Most of the 20 analyzed schemes used frequent testing and at least self-evaluation to assist improvement. Regulatory schemes with external evaluation, testing, and improvement processes collected feedback on websites, held stakeholder consultations and public events, or had built-in external evaluation mechanisms such as certification systems. The supranational EU schemes also performed well. Among the deliberation-oriented governance measures, evaluation mostly focused on results rather than methods, on approaches, and on critical reflection upon the projects. The UK Nanojury and Nanodialogues, projects with a reflective final report that critically assessed their epistemic basis, approach, methods, and results, performed the best.

5.2 Social robustness

This study shows that only 8 of the 20 analyzed governance schemes met at least some of the social robustness criteria in a concrete, solid way (that is, had ratings equal to or greater than 0). Most turned out to be weak in most aspects of social robustness. Some gave the impression of being confined to declarations of intent, of holding to traditional information and education-oriented engagement based on the old, and widely criticized divide between experts and lay citizens.

For the soft law and self-regulatory initiatives, the lack of robustness arises particularly from their instability with regard to integration into the political process, their lack of consideration of their acceptability, and a deficit of concrete results and enforceable outcomes. They considered little societal knowledge outside that of the proximal actors, organizations, and institutions, and were rarely subject to external evaluation, testing, and improvement.

Regarding the deliberative approaches, several did not go beyond consensus formation or measuring public opinion. Apart from innovative and experimental approaches such as the UK Nanojury and the Nanodialogues, which provide a substantial level of exchange and mutual learning, most projects used fairly traditional methodological approaches that reflect the conceptual framing of the old deficit-model of public understanding of science and related education ideas.

In particular, the notion of a boundary separating science and the public into two societal actors on either side of an expert/lay divide, and the focus on old contrast structures that further set a unified science and an illiterate public in opposition persist in most of the projects. In addition to this major obstacle to reflective exchange, mutual learning, and more democratic public involvement, the translation of public engagement into the political process and science and technology policy, appears difficult and unclear in most of the analyzed cases. These findings contest the idea that deliberative governance projects and public upstream engagement in NST exemplify a paradigm shift in techno-political discourse and will lead toward the more democratic development of technology that is advocated by proponents of the upstream engagement approach (Wilsdon and Willis, 2004). In fact, governance projects still appear to limit public engagement to values, and social and ethical matters, rather than to expose expertise to scrutiny (Hagendijk and Irwin 2006, 175-176).

5.3 Conclusion

In the governance turn, self-regulation and public engagement have often been framed as substitutes for governmental regulation. In governmental regulation, political responsibility is institutionally based, while in the logics of governance, political responsibility is distributed and deliberated among a variety of actors in different societal domains. As conceived in the governance turn, regulation takes place in a sphere that is, in contrast to governmental regulation, situated outside of democratic control mechanisms. In the case of science and technology governance, techno-political competence is delegated to societal actors who act outside of democratic, legitimized bodies. In NST potential implications are still uncertain. Currently, genuine regulatory and policy issues have been rationalized in terms of governance, which includes ideas such as "good practice," "responsible behavior," and "acceptance building" in self-regulatory approaches and public engagement projects. This could lead to a decentralization and distribution of political and regulatory responsibility. It is no longer locally bound or identifiable, which as a consequence leads to a depoliticization of regulation (Offe 2008, 71).

As the social robustness analysis of regulatory and deliberation-oriented governance approach shows, the governance turn might not contribute to the intended increase in responsible and democratic science and technology policies. This might be due to the intrinsic weakness by means of political stability, concrete and enforceable outcomes and impacts, and the absence of consideration of social knowledge or at least considering it as an equal, in a mutual-learning-oriented way.

Particularly in NST, in which uncertainty with regard to potentially hazardous implications is predominant, the establishment of politically unstable and socially less robust governance measures appears problematic. This is particularly the case regarding the protection of society and the environment from potential hazards. Therefore, the delegation of techno-political decision-making by political representatives to a variety of societal actors through socially less robust, self-regulatory soft law approaches and engagement projects, might lead to a vacuum in science and technology policy. Such a vacuum might not only impact academic knowledge production in related research fields, but also limit the innovative force of a society.

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7 Appendix (tables)

Table 3: Description, aim and results of self-regulatory and soft law approaches

Supranational schemes	
European Union (EU), European Commission Action Plan on Nanosciences and Nanotechnologies 2005	Commitment of commission and call to member states for promotion research and development, infrastructure, education, technology transfer, societal dimension, public health, safety and international collaboration in NST. Commitment for concrete actions by the commission such as funding and research focus in 6^{th} framework program. Aim: Integrated and responsible NST strategy for Europe, institutional level of NST discussions. Results: Implementation report and political responses of EU Council and European Parliament.
EU European Commission Code of Conduct on Responsible Nano Research 2007	Voluntary code and recommendation to member states to support public comprehensibility, sustainable, precautionary, inclusive, excellent, innovative, accountable economic, social and environmental development of NST. Aim: to ensure that NST research is undertaken in safe, ethical and effective framework. Results: Conference, EU Commission recommendation and EU Council conclusion.
Governmental schemes	
UK Department for Environment, Food and Rural Affairs (DEFRA) Voluntary Reporting Scheme for Engineered Nanoscale Materials 2006	Voluntary data reporting scheme for industry and research organizations. Aim: government receives information relevant to understanding the potential risks posed by free engineered nanoscale materials. Results: 13 Data submissions according to guideline, annual scheme's progress update reports.
U.S. Environmental Protection Agency (EPA) Nanomaterial Stewardship Program 2008	Voluntary data reporting scheme for manufacturers and processors. Aim: Support agency assembles existing data and information on existing chemical NM; identify and encourage use of risk management practices in developing and commercializing NM; and encourage the development of test data needed, collaborative process with invited stakeholders. Results: Concept paper, TSCA Inventory Status on Nanoscale Substances, 21 data submissions, according to supporting statement and reporting form, public meeting.
German Federal Parliament (Bundestag) NanoCommission/NanoDialogue 2006	Stakeholder commission as central national dialogue committee of the German Government and various interest groups. Stakeholder consisted of representatives from science, industry environmental and consumer organizations, trade unions, government departments and agencies. Aim: analysis of opportunities and risks of NM, under precautionary and sustainable innovations approach. Results: assessment criteria, and basic principles for „responsible" use.
German Federal Government (Bundesregierung) Nano-Initiative, Action Plan 2006	Innovation initiative and action plan of several federal ministries (of education and research (BMBF), work and social issues (BMAS), for the Environment, Nature Conservation and Nuclear Safety (BMU), of Food, Agriculture and Consumer Protection (BMELV), of Defense (BMVg), of Health (BMG), of Economy and Technology (BMWi)). Aim: Technology transfer, political conditions, collaboration among agencies, public dialogue, analysis of environmental and health risks, leading innovations, research-, support- and agency initiatives. Results: Research focus, funding of leading innovations

to be continued

Swiss Federal Government Action Plan "Synthetic Nanomaterials" 2008	Action plan for risk assessment and management of synthetic nanomaterials, based on basic report: "Risk Assessment and Risk Management of Synthetic Nanomaterials" of the Federal Office of Public Health (FOPH) and the Federal Office for the Environment (FOEN). Aim: a responsible development of nanotechnology, a regulatory framework and public dialogue on its opportunities and risks. Results: National research program on opportunities and risks of nanoscale materials, precautionary framework (Vorsorgeraster) for industrial recognicion of NST specific risks, development of safety framework for NST-related products together with representatives from science, industry, environmental and consumer organizations.
Private schemes	
U.S. Environmental Defense Fund (EDF) – DuPont Nano Risk Framework (NRF) 2007	Standards-based risk management framework scheme for manufacturers Aim: Comprehensive process to evaluate and address potential risks of nanoscale materials for organizations, Results: Scheme consisting six detailed steps for guidance in key questions and risk management practice, commitment to governmental programs (EPA) of applying organizations.
UK Royal Society – Insight Investment – NT Industry Association – NT Knowledge Transfer Network Responsible Nano Code 2008	Principle based code of conduct for organizations involved in the research, production, retail and disposal of products using nanotechnologies. Aim: responsible NST approach throughout the product life-circle. Results: written code with 7 general principles, update and background information.
German Chemical Industries Association (VCI) Guidelines Manuals for a Responsible Handling of Nanoscale Materials 2008	Guideline manuals consisting of core principles such as precaution, product responsibility and workplace safety. Aim: Support for manufacturers and customers for responsible use of nanomaterials, harmonization and use in OECD process. Results: Manuals consisting of checklists, safety sheets, strategy documents, safety research, standardization, stakeholder workshop and risk management guidelines.
German TUV Süd – Swiss Innovation Society Cenarios Certification System 2008	Certifiable risk management and monitoring-system for nanotechnologies. Aim: recognize risks, provide safety, identify, analyze and rate of potential opportunities and risks of NST. Results: certificate for applying firms, annual evaluation and recertification.
Swiss Retail Association Code of Conduct Nanotechnologies 2008	Principle based code on information exchange between manufacturers, suppliers, customer information, risk management and cooperation. Aim: To face increasing importance of nanotechnology in consumer products. Consumer information, transparency between producers, suppliers, retailers and consumers. Results: Factsheet, declaration document for suppliers.
International schemes	
Organization for Economic Co-operation and Development (OECD) Working Party on Manufactured Nanomaterials (MNM) 2006	International cooperation in addressing human health and environmental safety aspects of manufactured nanomaterials. Aim: Safety of manufactured nanomaterials, international cooperation on databases, testing, definition and implementation. Results: sponsorship program for testing of MNM, database on research into safety of MNM, workshops and events.
OECD Working Party on Nanotechnology 2007	International cooperation and consultation on scientific, technical and innovation related questions on responsible nanotechnology development, coordinated analysis in safety issues. Aim: advise upon emerging policy issues of science, technology and innovation related to the responsible development of nanotechnology. Results: review of nanotechnology developments based on indicators and statistics
NT=Nanotechnology, NM=nanoscale materials, MNM=manufactured nanomaterials	

Table 4: Analysis of self-regulatory and soft law approaches regarding the criteria of social robustness

	contextualization	stability	acceptability	social knowledge	evaluation
Supranational schemes					
EU Action Plan on Nanosciences and Nanotechnologies 2005	Principle-based, R&D, risk and social issues related	Declaration of intent, partly enforceably by financial pressure on member states	Not specified	Indirect by dialogues and comments	Bi-annual report to council and parliament based on indicators
EU Code of Conduct on responsible Nano Research 2007	Principle-based, research-related	Invitation to member states, voluntary, but partly enforceable by bi-annual reviews	Not specified	Not specified	Bi-annual review recommendation and extent of adoption and applicance
Governmental schemes					
UK DEFRA Voluntary Reporting Scheme for Engineered Nanoscale Materials 2006	Standards-based, risk-related	Voluntary call, non-enforceable	Not specified	Subject to public consultation	Annual self-evaluatory review
U.S. EPA Nanomaterial Stewardship Program 2008	Standards-based, risk-related	Voluntary call, non-enforceable	Not specified	Subject to public consultation	Self-evaluation
German NanoCommission/NanoDialogue 2006	Principle-based, risk- & dialogue-related	Recommendation, voluntary principles non enforceable	Not specified	Knowledge of involved actors	Not specified
German Nano-Initiative, Action Plan 2006	Principle-based, R&D & risk-related	Declaration of intent, non enforceable	Not specified	Indirect by involved actors	Not specified
Swiss Action Plan Synthetic Nanomaterials 2008	Principle-based, risk-related	Declaration of intent, non enforceable	Not specified	Consultation of selected actors	Not specified
Private schemes					
U.S. Nano Risk Framework 2007	Standards-based, risk-related	Voluntary agreement, partly enforceable on launching organization	Not specified	Public consultation, international	Continued self-and external evaluation planned
UK Responsible Nano Code 2008	Principle-based, organization-related	Voluntary agreement, non enforceable	Not specified	Not specified	Not specified
German VCI Guidelines 2008	Standards-based, risk-related	Voluntary agreement, non enforceable	Not specified	Discussion with actors	Not specified
German/Swiss Cenarios Certification System 2008	Standards-based, risk-related	Enforceable for certified firms	Not specified	Not specified	Annual evaluation and re-certification
Swiss Retail Association Code of Conduct Nanotechnologies 2008	Principle-based, dialogue-related	Voluntary agreement, members required to report	Not specified	Stakeholder dialogue	Self-evaluation by member reports
International schemes					
OECD Working Party on Manufactured Nanomaterials 2006	Standards-based, risk-related	Commitment of member states to sponsorship program and database	Not specified	Not specified	Not specified, evaluation possible by steering committee
OECD Working Party on Nanotechnology 2007	Principle-based, R&D innovation-related	Not specified	Not specified	Not specified	Not specified

Table 5: Description, aim and results of public engagement projects

U.S. Science Museums Nanoscale Informal Science Education (NISE Network) 2005	A series of forum events lasting 2-3 hours, involved presentations by scientific experts and small group discussions, attended by 30-50 participants (mainly science museum visitors), organized by a nationwide collaboration of five science museums, universities, research institutions, artists. Aim: engage the public in the emerging NST field. Results: Forum event discussions.
UK Greenpeace - The Guardian - Interdisciplinary Research Collaboration (IRC) in Nanotechnology, University of Cambridge - Policy, Ethics and Life Sciences Research Centre (PEALS), Newcastle University Nanojury 2005	Two-way citizens' jury, traditional method enriched with multi-stakeholder oversight: of science advisory panel, and built-in control mechanism allowing jurors address topic of their choice before turning to NST. Aim: non-specialist perspective on NST science policy and environmental and public health issues, recommendations by jurors for nanotechnology's future development in UK. Results: promise of response from Department for Business, Enterprise and Regulatory Reform.
UK Think Tank DEMOS - Lancaster University Nanodialogues 2006	Four small-scale experiments in upstream public engagement, inquiry, dialogue, workshop, focus group, experience, experimental approach and a mix of adapted dialogue methods such as people's inquiry (three deliberative workshops with east London residents and input from scientists, environmental agency staff, policymakers, and other stakeholders); deliberative dialogue involving scientists, research-council staff, and members of the public; a workshop involving policymakers, politicians, and representatives from two communities; and a series of focus groups discussing scenarios developed by DEMOS and a commercial manufacturer. Aim: public engagement in decision making of research direction. Results: Set of recommendations and presentation to DEFRA and research councils.
UK University of Bristol Citizen Science Bristol 2008	Science-communicaton, activities consisting of chat show-style debates, website resources, online games, and teachers' materials. Aim: engaging young people (mostly students) in discussions about the role of science and technology in society. Results: Vote on areas of NST research to be founded and the degree of NST regulation.
TA Swiss – Federal Office of Public Health (FOPH) – Federal Office for the Environment (FOEN)- Zurich University of Applied Sciences Publifocus Nanotechnology, Health and the Environment 2006	Focus group meetings with randomly selected citizens/members of the public in 4 lingual regions of Switzerland, one with concerned actors. Use of traditional method of focus group meetings citizens discussed a topic set by organizers, participants received a brochure defining NST in advance, and meetings were introduced by expert presentations from a toxicologist and an ethicist. Aim: Finding out about public acceptance, opinions and questions on nanotechnology and public view on potential social and economic implications. Results: Final report for public and parliament.
EU 6^{th} framework programme: German Wupppertal Institute – Swiss Federal Laboratories for Materials Testing and Research (EMPA) – UK Forum for the Future and pan-European Triple Innova Nanologue 2005-2006	Research project with dialogue part, using methods of public consultation and stakeholder-dialogues involving business, science, and civil society organizations. Aim: help establish common understanding on social, ethical and legal aspects of nanotechnology applications and facilitate Europe-wide dialogue among science, business and civil society about benefits and potential impacts. Results: web-based tool (the NanoMeter), scenario report, presentations, and articles.

Table 6: Analysis of public engagement projects regarding the criteria of social robustness

	contextualization	stability	acceptability	social knowledge	evaluation
U.S. NISE Network 2005	PUS-based, research, development and trade-related, expert/ layperson framing	Not specified	Not specified	Education-oriented, expert teaching, expert-lay citizens discussion	Not specified, reports on public opinion and communication
UK Nanojury 2005	Engagement-based, risk-, and societal issues-related, equally-oriented framing of communicative actors	Recommendations to scientists, policy-makers, journalists	Methodological acceptability of participants	Mutual-learning-oriented, two-way communication,	Report, articles, meta reflection on project, design, methods
UK Nanodialogues 2006	Engagement-based, risk-, research-, policy- and societal issues-related, slight orientation to expert/ layperson framing	Impact in corporations, foreign aid, research councils	Methodological acceptability of participants	Mutual-learning-oriented, discussion, dialogue	Reports from each experiment, articles, pamphlet, meta-reflection on project, design, methods
UK Citizen Science Bristol 2008	PUS-based, research and development-related, expert/ layperson framing	Not specified	Not specified	Education-oriented, discussion, vote	Not specified
Swiss Publifocus Nanotechnology 2006	Engagement-based, risk-related, expert/layperson- framing	Not specified	Not specified	Dialogue-oriented, discussion, teaching, vote	Report, no meta-reflection on project, design, methods
EU Nanologue 2005-2006	Engagement-based, risk-related, expert/layperson- framing	Not specified	Not specified	Dialogue-oriented, discussion	Report, no meta-reflection on project, design, methods
Public engagement projects	contextualization	stability	acceptability	consideration of social knowledge	evaluation
U.S. NISE Network 2005	PUS-based, research, development and trade-related, expert/ layperson framing	Not specified	Not specified	Education-oriented, expert teaching, expert-lay citizens discussion	Not specified, reports on public opinion and communication
UK Nanojury 2005	Engagement-based, risk-, and societal issues-related, equally-oriented framing of communicative actors	Recommendations to scientists, policy-makers, journalists	Methodological acceptability of participants	Mutual-learning-oriented, two-way communication,	Report, articles, meta reflection on project, design, methods
UK Nanodialogues 2006	Engagement-based, risk-, research-, policy- and societal issues-related, slight orientation to expert/layperson framing	Impact in corporations, foreign aid, research councils	Methodological acceptability of participants	Mutual-learning-oriented, discussion, dialogue	Reports from each experiment, articles, pamphlet, meta-reflection on project, design, methods
UK Citizen Science Bristol 2008	PUS-based, research and development-related, expert/ layperson framing	Not specified	Not specified	Education-oriented, discussion, vote	Not specified
Swiss Publifocus Nanotechnology 2006	Engagement-based, risk-related, expert/layperson- framing	Not specified	Not specified	Dialogue-oriented, discussion, teaching, vote	Report, no meta-reflection on project, design, methods
EU Nanologue 2005-2006	Engagement-based, risk-related, expert/layperson- framing	Not specified	Not specified	Dialogue-oriented, discussion	Report, no meta-reflection on project, design, methods

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Technology Adoption in Small-Scale Agriculture: The Case of Cameroon and Ghana

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Abstract

This study explores one of the most important questions for alleviating poverty in sub-Saharan Africa, why are advancements in agricultural technology not taking root in this region? Using data from deep interviews of 42 small-scale farmers in Ghana and Cameroon, a conceptual analysis of drivers and factors of agricultural technology adoption in this region is made and represented as causal loop diagrams. Interviews also provide a basis for weighting factors that farmers consider before adopting a new technology. These weights are then used to run a system dynamics model with a hypothetical population of 10.000 farmers to see the effects of different drivers of technology adoption on the adoption rate and number of adopters over a 25 year period. Results show that most farmers have a bet-hedging strategy as they try to minimize risks of production failures. While certain factors like scale of production, long-term considerations, the history of success of past technologies, and the endorsement of technologies by opinion leaders may be important, many other factors do influence decisions to adopt new technologies. This limits any silver bullet strategy towards solving the problem of limited diffusion of agricultural technologies in this region. Addressing such a problem therefore calls for a much more holistic approach.

1 Introduction

Small-scale farming forms the backbone of agricultural production in sub-Saharan Africa. Historically, productivity of small-scale farming systems has been plagued by a number of structural and policy issues that have led to slow increases in yields and even stagnation in some parts and for some crops. The absence of technology, limited access to or the use of inappropriate technology are among some of the factors blamed for food deficiency in many parts of the developing world (von Braun et al. 2007; McCalla 1999). It seems to be taken for granted that with the right technology in place (better seeds, fertilizers, tools, techniques, and others), agricultural production will routinely be increased and challenges of food security overcome in areas with some physical and social limitations to food production. Such assumptions are based on the expectation that if there is a solution to a problem, then it is rational that people who know of the existence of such a solution, have access to it, and are facing problems for which the solution is appropriate will use it to find a way out of their problem (Beckford 2002).

International agencies, national governments, regional authorities and local concerned groups do attempt at different scales to make agriculture more productive and profitable by introducing technologies to meet or reduce some of the constraints of farm production. These constraints include soil erosion, depleted soil nutrients, low quality of seeds, over-grazing, the use of rudimentary farming tools and techniques, among others. The outcome of these efforts has largely been modest (Ahmed 2004). Some of the basic technologies have not yet reached many of the farmers of this region, especially those of small-scale production (Gallup et al. 2000). Where outside extension agents have introduced new technologies, initial adoption rates have been low and the low adoption rates have largely failed to spread spontaneously beyond the communities into which such introduction is made (Moser et al. 2006). In areas where some of these technologies exist, the adoption rate has been very low and hence their spread has been limited and their intended benefits unachieved (Lado 1998).

Improving agricultural productivity in the developing world in general and sub-Saharan Africa in particular has become an urgent need, dictated by population growth, uncertainty in global food markets, changing consumption patterns of food commodities, as well as the desire to meet important milestones in food and nutrition in the region such as those of the millennium development goals. There is the desire of achieving this improvement in productivity while facing up to the contemporary challenges of global environmental change: global warming, land degradation, water pollution and scarcity, and biodiversity loss (World Bank 2007; McCalla 2001; Blackman 1999). Properly tailored incentives and policies will be needed to ensure that future efforts to increase agricultural productivity do not compromise environmental integrity, public health, and the ability for future generations not to be over-burned by our present day actions (Tilman et al. 2002). Access to and the use of appropriate technologies may be one of the tools needed to meet these production challenges in sub-Saharan Africa (McCalla 2001).

2 Study Objectives

While technology is constantly being developed at almost all levels of the food production, distribution and retail chains, the need to provide small-scale agriculturalists (especially in developing countries confronted with problems of food deficiency) with basic appropriate technology needed to improve their production capacity seems to be overwhelmingly supported (World Bank 2007; Pinstrup-Andersen et al. 1998; McCalla 1999). Understanding the factors that influence the adoption or non-adoption of technologies at the production end of small-scale agriculture can therefore have important implications in the planning of technology-related projects for meeting the challenges of food production for this category of producers.

This study aims to explore some of the insights of the process of decision-making by some of the most important but vulnerable group of agricultural producers in the world - small-scale farmers in Sub-Saharan Africa (World Bank 2007). Using tools of systems dynamics (causal loop diagrams (CLD)[1] and quantitative modeling) the study seeks to understand the process of decision-making from a more holistic perspective. Insights into the process of decision-making may provide clues to the long-standing question of why technology-related assistance has in many cases failed to take root in this part of the developing world (Ahmed 2004).

3 The baseline model and its shortcomings

Technology adoption has been investigated by a number of diffusion of innovation theories. The most influential has been by Rogers (1995) who framed the adoption of innovation as a life-cycle made of five categories of adopters: innovators (brave people ready to take risks and try out new things), early adopters (opinion leaders who are ready to try out new things but exercise a bit more caution than the innovators), early majority (people who are careful but ready to accept change more quickly than the average), late majority (skeptical people who will use new ideas or products only when the majority is using it), and laggards (traditional and conservative people, slow to change and critical towards new ideas, will only accept or use them if the new ideas have become mainstream or even tradition) (see Figure 2).

This theory (like the Bass diffusion model (Bass, 1969)) sees technology spread as the outcome of two main factors: innovation which refers to the desire of people to try out new technologies, and imitation which refers to the influence of those that have tried out a technology in drawing in others who have not yet tried this technology to trying and using it. The innovation adoption curve developed by Rogers (1995) therefore seems to suggest that trying to quickly and massively convince the bulk of people of a new idea or product is useless. It takes time for innovation to diffuse through a society and it makes better sense to start with convincing innovators and early adopters first before expecting other groups of adopters to follow suit.

3.1 Interaction between Actual and Potential Adopters: the Bass Diffusion Model

A well tested theory of the diffusion of technology is the Bass diffusion model (Bass 1969). This model sees the adoption of new products as an interaction between a population of would-be users (potential adopters) and the population currently using the product (actual adopters). Mathematically, the Bass diffusion model is represented as:

Equation 1:

$$N_t = N_{t+1} + p(m - N_{t-1}) + q\frac{N_{t-1}}{m}(m - N_{t-1})$$

Where N_t is the number of adopters at time t; m is the market potential (potential adopters) or the total number of people who may eventually use the product; p is the coefficient of innovation (external influence) or the probability that someone who is not yet using the product will begin using it because of advertisement; q is the coefficient of imitation (internal influence) or

[1] A characteristic causal-loop (influence or cause-effect) diagram is used to define positive and negative causal links (or influences). Positive (+) and negative (-) polarities are used to define the nature of influence from one factor to another. A has a positive influence or effect on B if A adds to B, or if a change in A results in a change in B in the same direction. In the same light, A has a negative influence or effect on B if A subtracts from B, or if a change in A results in a change in B in the opposite direction.

the probability that someone who is not yet using the product will start using it because of "word-of-mouth" or person-to-person communication.

It is generally assumed that the timing of the first time purchases is somewhat distributed over the general population (meaning the role of the innovators and early adopters is very important in determining the speed of the adoption process and hence the time the innovation adoption cycle will run). Hence the diffusion rate at time t is generally expressed as (Sultan et al. 1990):

Equation 2:

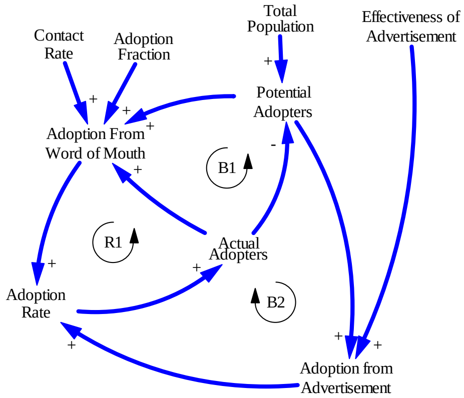
$$\frac{dN(t)}{dt} = g(t)[N^* - N(t)]$$

Where *dN(t)/dt* is the rate of diffusion at time t, $N(t)$ is the cumulative number of adopters at time t, *N** is the total number of potential adopters in the population, and g(t) the probability of adoption for individuals who have not yet adopted.

3.2 Test-runs with the baseline model

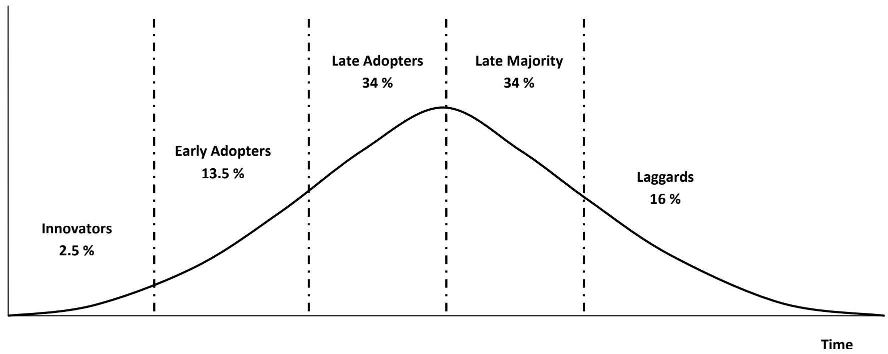
The baseline model of technology adoption assumes no constraints of purchasing power, willingness to pay, access to information, and access to the new technology. The main factors driving adoption are the roles of advertisement and the word-of-mouth. These factors are illustrated in the causal loop diagram of the baseline conceptual model of technology diffusion (Figure 2). It is basically the translation of the Bass model into stocks, flows and feedback loops carried out by Sterman (2000). The role of advertisement and word-of-mouth in influencing adoption rate is determined by the effectiveness of advertisement and contact rate respectively (loop R1). The degree to which these two factors will determine adoption rate is however limited by the population of potential adopters (loop B1 and B2)

Figure 2: A causal loop diagram of the baseline model of technology adoption that takes into account the roles of advertisement and spread by word-of-mouth



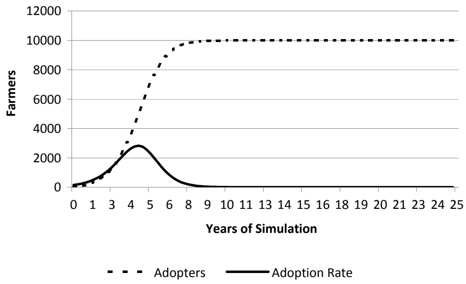
Using a hypothetical farming population of 10.000 (constituting the population of potential adopters), the initial model is run for 25 years with Euler's integration method. The model replicates the role of the influence of internal (word-of-mouth), and external (ad-

Figure 1: Rogers' adoption/innovation cycle showing the distribution of different categories of adopters of a new technology over time.



vertisement) factors on the diffusion of new technologies are based on Equation 1 (Figure 3).

Figure 3: The traditional logistic curve of the adoption rate of a new technology



The conceptual models represented as causal loop diagrams (CLDs, see Figure 6-13 in Chapter 4) and the weights attributed to these factors in influencing technology adoption (Table 1) are used to further develop the baseline model that characterizes the system of decision-making in the case studies.

3.3 The Importance of Internal and External Influences

Different studies have established different levels of importance on the role of internal and external factors (q = the coefficient of imitation, and p = the coefficient of innovation respectively in the Bass diffusion formula above) in influencing the process of innovation adoption. Mansfield (1961) sees the role of internal influence (personal communication through word-of-mouth, personal recommendations, and experiences of others using and being successful with an innovation) more important in determining the rate of diffusion of innovation. Hence $g(t)=qF(t)$, where $qF(t)$ is the coefficient of person-to-person (internal or word-of-mouth) influence - a function of the number of previous adopters which increase with time.

Fourt and Woodlock (1960) on the other hand, believe that the roles of external influences (advertisement, mass media, and other forms of outreach that enable potential users to be influenced by imitation to adopt an innovation) are more important in driving the diffusion process. The model $g(t)=p$ is suggested to explain the singular role of external factors in influencing the technology diffusion process. Here, p signifies the coefficient of external influence (i.e. the role of mass media and other forms of advertisement).

Diffusion of technological change over a population of potential adopters is often characterized by two well-known facts (Cabe 1991): the length of time required by the diffusion is often significant and the time often varies considerably among innovations. Moreover, threshold effects are also important, where drastic changes can happen when a threshold is passed. One example of such a technology spread within the agricultural sector is drip irrigation (Fichelson *et al.* 1989).

4 Methods to improve the baseline model

4.1 Additional factors

Several factors have been advanced as determinants of the adoption and diffusion of technology among small-scale farmers in developing countries. Earlier research established the importance of access to financial resources for investment and size of farm holdings (Feder 1980; Feder *et al.* 1985; Sunding et al. 2001; Lee 2005). More recently, research has also identified the role of learning in the diffusion of pineapple production technology in Ghana (Conley et al. 2003), and the role of social networks on hybrid seed adoption in India (Matuschke et al. 2009). In developing conceptual models for individual determinants of technology adoption and diffusion in the case studies, farmers are asked to identify factors that would make them adopt a new technology introduced through normal channels of technology introduction in the communities (using field agents of technology production companies, agricultural extension workers, farmers' social networks). Through further discussions, drivers of these factors are identified and presented as cause-effect relationships in causal loop diagrams of individual sub-systems.

4.2 Interviews with farmers

The study develops a theoretical understanding of the system of decision-making with regards to agricultural technology adoption through a review of literature and field observations. A total of 42 small-scale farmers were questioned in open interviews: 12 in the Western High Plateau Region of Cameroon and 30 in the Asebu Kwamankese District of the Central Region of Ghana. The farmers were asked questions with reference to technology adoption between 1990 and 2009. These questions were related to the adoption of improved seeds, inorganic fertilizers, pesticides, and farm tractors (technologies that have been introduced in these communities over the last 19 years).

Farmers were selected based on a number of factors. Leaders of local community groups helped identify respondents who must have resided in their respective communities for over 15 years during which time they must have been practicing farming. They must be practicing farming at a small-scale. The term “small-scale” used in this study is in line with the definition given by Beckford (2002) which describes such farming as being labor-intensive and characterized by a high degree of fragmentation, low resource base, and mixed cropping. For the purpose of this study, the definition further restricted interviewees to individuals with farm holdings of less than two hectares dedicated mainly to the production of food crops. Even though the study intended to uphold a balanced gender representation, women proved to be more co-operative and available for interviews than men and hence we had more women respondents (24) than men (18). Respondents were aged between 35 - 65 years and included people who owned their own farms as well as those who were renting farm plots. Results of the interviews were used to develop a general conceptual framework of the system of decision-making concerning agricultural technology adoption in these regions.

Using an example of the new maize seeds that were introduced in both study regions in the early 1990s, farmers are brought in to discuss the importance of different factors to their motivations for adopting or not adopting these seeds. These were seeds developed by PANNAR, a South African seed producing company based in the KwaZulu-Natal Midlands. They were high yielding maize seeds that began entering markets in Central and West Africa in the early 1990s. An initial enthusiasm for high yielding cultivars prompted a great deal of trials by many small-scale farmers. This enthusiasm quickly died less than five years later due to a number of reasons. Small-scale farmers who produce primarily to feed their households complained that the maize produce from these seeds did not have the taste of maize they have been familiar with. Farmers also complained that the produce was difficult to manage – the cobs grew longer than the ears, exposing the maize grains to elements of weather. As a result, the maize grains became soaked by rain soon after maturation and rotted or molded on the farms before they could be harvested. Lastly, farmers observed that replanting PANNAR maize from previous harvests as they had been doing with traditional varieties did not produce good harvests. They had to continuously buy new seeds from the seed distributors every planting season. For households who cultivated mainly for consumption, they needed to be able to raise money for these purchases which was not without problem for many.

4.3 Factors identified by interviewees

Farmers identify eight main factors as being important when they make the decision on either to adopt or not to adopt a technology (Figure 4). These factors are:

1. *Ability to pay* which refers to farmers' capability of paying for and owning or using the newly introduced technology. This depends on farmers' level of income, access to credit, and other sources of financing for agricultural activities.
2. *Vulnerability* refers to the susceptibility of farmers to adverse conditions that may result from using a new technology or from deviating from their usual agricultural practice. This susceptibility may reduce the farmers' ability to turn out the produce they have been relying on for their sustenance. There is therefore some threat of production failure (*risk)* involved in adopting a new technology.
3. *Scale of production* refers here to farmers' range of production possibility. One can distinguish between the physical range of this possibility which will be how much land the farmer actually has and can bring to production and the range in terms of diversity, meaning the number of different production associations the farmer practices at any given time. Each of these possibilities is taken to refer to farmers' scale of production in this study wherever applicable.
4. *Adaptability to local conditions* refers to the ability of new technology to be used with minimal disruptions in the formalized system of functioning of local agriculture. It includes the ability for new technology to be flexible and adjustable enough to facilitate its integration into the local agricultural system.
5. *Long-term considerations* refer to the assessment made by farmers of how sustainable this technology can be. It is a consideration of the dependability of a new technology.
6. *Suspicion towards new technologies* is born from a history of failed attempts at introducing viable innovations in small-scale agriculture in the study areas. It refers to a misgiving about the true intentions of the new technology.
7. *Endorsement by opinion leaders* refers to the backing or approval or the new technology given by people who matter in the communities and lives of small-scale farmers.
8. *Access to information* refers to the ease of having information on the new technology under consideration. Information here refers to knowledge about the existence of a technology, knowledge of what the technology can or cannot do, its limitations, and so on. Information in can be tainted or biased when small-scale farmers receive it (even from

Figure 4: Percentage of farmers advancing different considerations for adopting improved maize seeds in Ghana and Cameroon (N=12 in Cameroon and N=30 in Ghana)

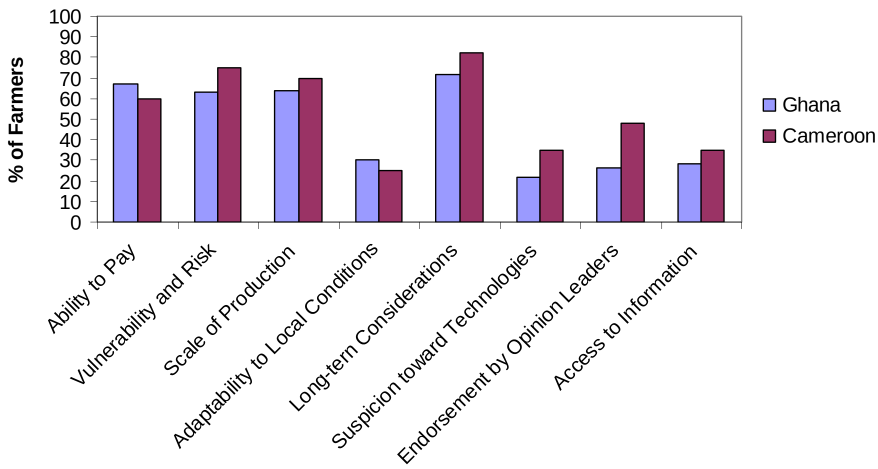


Table 1: Summary of the Qualification of Different Factors of Agricultural Technology Adoption Derived from Interviews

Factor	% Ghana	% Cameroon	% used in the Model
Access to information	25 {Low}	30 {Low}	30 {0.30}
Endorsement by opinion leaders	24 {Low}	49 {Average}	49 {0.49}
Scale of production	63 {Average}	69 {Average}	69 {0.69}
Ability to pay	68 {Average}	60 {Average}	68 {0.68}
Adaptability of technology to local conditions	28 {Low}	24 {Low}	28 {0.24}
Vulnerability and risk	63 {Average}	76 {High}	76 {0.76}
Suspicion towards new technologies	20 {Low}	34 {Low}	34 {0.34}
Long-term considerations	72 {Average}	83 {High}	83 {0.83}

Factors are qualified as low <40%, average 40-75%, and high >75% (columns 2 and 3). They are used in converting the conceptual model into the quantitative model. The higher percentage for each factor from either Cameroon or Ghana is used as a weight for the influence of the factor in determining rates of adoption in the model (last column with weights represented in curly brackets where the maximum is 1 and the minimum 0).

their trusted sources – agricultural extension workers and other opinion leaders) for a variety of reasons.

Four of these factors stood out as important factors considered by farmers when they make decisions to adopt a new technology. These are: farmers' ability to pay for the new technology, their assessment of the degree of vulnerability and risk associated with adopting the new technology, farmers' scale of production, and long-term considerations. Less prominent factors were the adaptability of the new technology to local conditions, suspicion of the technology, endorsement by opinion leaders, and access to information. The percentages of farmers who identified different factors as important are represented in Table 1.

4.4 The refined model of systems dynamics

Other factors that affect the adoption of new technologies (besides advertisement and word-or-mouth) are incorporated into the conceptual baseline model to give a more integrated system that illustrates the system of decision-making among small-scale farmers (Figure 5). In the baseline model of the diffusion of new technologies (shown in bold in Figure 5), individual sub-systems (which comprise other factors identified by farmers as being important in considering the adoption of new technologies) are in boxes and are connected to the baseline model (in bold) with dotted lines. These boxed variables are different from the non-boxed variables in that they are the outcome of cause-effect relationships of smaller sub-systems. The absence of polarity (+ or – signs) in the arrows that link them to the baseline model (in bold) indicates that they can have both a positive and negative influence on the Adoption Rate and Adoption from Word-of-mouth in the baseline model.

R1 represents the reinforcing effect of the adoption of the technology from word-of-mouth and from advertisement. This reinforcing loop give rise to the rising limb of the traditional logistic growth curve of technology diffusion (see the adopters curve in Figure 3; and also Morecroft 2007; Sterman 2000; and Bass 1969). R1 therefore represents the potential of an unlimited growth in an infinite number of potential adopters.

However, the population is always a limiting factor to the number of potential adopters, hence the flattening top of the curve of *adopters* (Figure 3). In the small-scale farming system of sub-Saharan Africa, the effectiveness of advertisement, adoption from word-of-mouth, and the adoption rate also have limitations (shown in the boxes accompanied by dotted arrows) which determine the eventual speed of technological adoption and shape of the adoption rate curve.

5 The Role of Other Factors from Conceptual Analysis

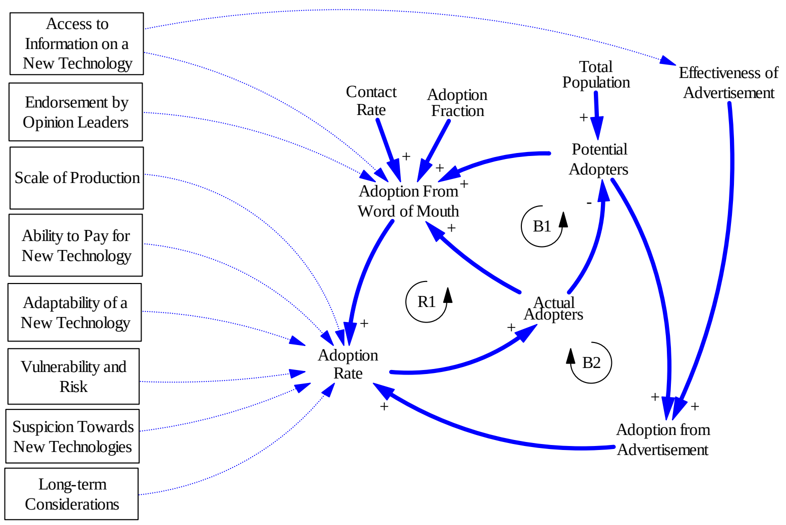
We discuss here the results of both interviews and quantitative modeling of the decision-making process of agricultural technology adoption among small-scale farmers in the case studies. The results of interviews are represented as causal loop diagrams which represent feedback processes of individual factors of decision-making in agricultural technology adoption. These can be illustrated in a three-stage model of drivers of factors that determine adoption, the factors that determine adoption, and the decision to adopt the new technology (Figure 6). The decision to adopt a new technology is determined by a number of factors which are themselves the outcome of several drivers. The main factors of adoption in the baseline model (advertisement and spread by word-of-mouth) are omitted. It must be noted that some factors of technological adoption in one system become drivers of factors in other sub-systems.

Given that the baseline model takes the role of advertisement and word-of-mouth in the spread adoption of technology for granted, the role of other factors in determining the process and speed of technology spread are discussed. Results of the quantitative modeling are an application of the understanding of the decision-making process to a hypothetical population of farmers to see the effects of individual factors on the rate of adoption of a new technology.

5.1 Access to Information

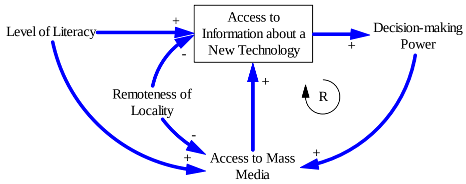
Farmers need knowledge about the benefits of a pice of technology to be able to make decisions on whether or not to adopt it (Beckford 2002). In many parts of sub-Saharan Africa, the availability of this knowledge to farmers may be constrained by a number of challenges: the remoteness of an area may limit the availability of information on a piece of technology; and limited economic resources may mean that farmers or farming communities may not have access to information through certain forms of mass media like television, print media, internet, and others. In many cases, the literacy rates

Figure 5: A more integrated CLD illustration of the system of decision-making



are low and potential users may not be able to access needed information even if it is available (Figure 7). This form of knowledge about a piece of technology which allows potential users to be able to make decisions on whether to adopt it is termed by Abdulai et al. (2005) as "*schooling*". Some of the common means through which information is brought to small-scale farmers in developing countries is through farmers' cooperatives and common initiative groups, rural development field staff, churches, farmers' representatives, and extension staff of the Ministry of Agriculture.

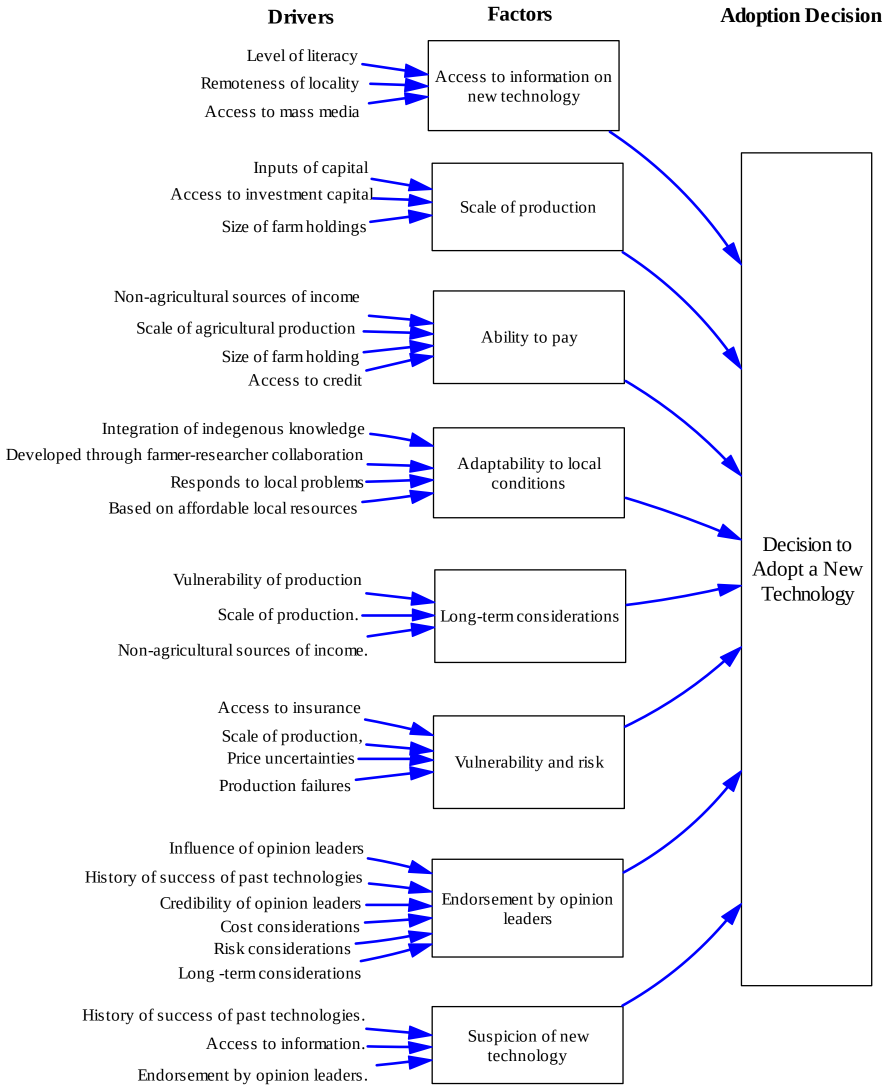
Figure 7: CLD of drivers of access to information on a new technology on its adoption



5.2 Scale of Production

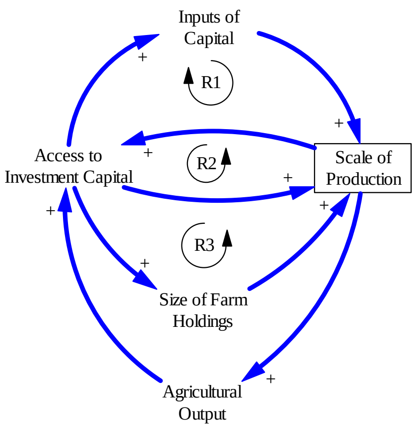
In sub-Saharan Africa where agriculture employs more than 60 percent of workforce, and contributes to more than 35 percent of the gross domestic product, small scale farming con-

Figure 6: A three-stage model of the adoption of a new technology based on studies of the adoption of maize seeds in the case study



tributes more than 80 percent of total agricultural outputs (FAOSTAT 2009; Gallup et al. 2000). Small-scale agriculture here is characterized by small farm holdings, low capital inputs, low outputs, and vulnerability to production failures, price shocks, and loss of income. The low outputs implies a limited ability to raise investment capital through savings, while the vulnerability of farmers prevents them from taking production risks that may otherwise be profitable. The small and fragmented nature of their farm-holdings also prevents them from investing in and using technologies (especially machinery) that may save labor and increase output and productivity (Figure 8). By increasing access to capital, a number of reinforcing processes (R1, R2, and R3 in Figure 4) are set in motion, that can lead to a sustained increase in the scale of production in different ways.

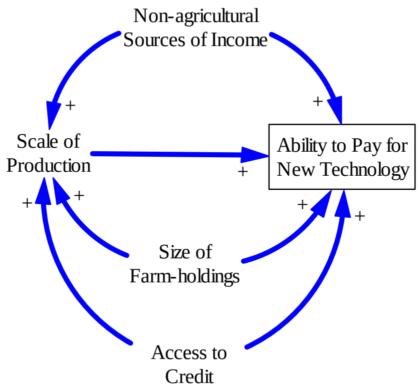
Figure 8: CLD of drivers of scale of production in the adoption of a new technology



5.3 Ability to Pay

Most of the small-scale farmers in sub-Saharan Africa are subsistent producers with small farm holdings ranging from 0.5 hectare to about 4 hectares, and producing food mainly for their household with little surplus for sales in local community markets (UNDP 2007). Although all farmers interviewed may like to invest in new technologies that may save labor and increase productivity, they can neither raise the necessary capital to do so through meager savings, or be approved for bank loans which they have no adequate collateral. Their limited farm-sizes and limited access to credit imposes a small-scale of production which sustains a state of inability to pay for new technology (Figure 9; also see Abdulai et al. 2005). In many parts of the continent, farming has therefore remained underdeveloped, labor intensive, and producing comparatively low yields per capita for almost all of the major cereals and oil crops (FAOSTAT 2009; UNDP 2007). It is reported that in cases where farmers may have land but lack the financial means to develop it for agriculture, they tend to lease it out and even sell some of the little inputs they have to the few non-financially constrained farmers who can buy (Ahmed 2004).

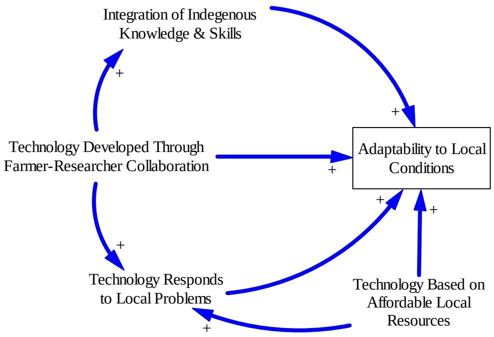
Figure 9: CLD of drivers of ability to pay for a new technology in the adoption of that technology



5.4 Adaptability of New Technologies to Local Conditions

The adaptation of new technologies to reflect farming practices and traditions of a community requires recognition of existing indigenous know-how, skills and technologies (Norton et al. 2003; Lado 1998). When new technology is adapted to local conditions, it builds on such existing skills and technological capacities as well as maximising use of local resources (Figure 10). This gives farmers the opportunity of experiencing a less steep learning curve as they attempt to familiarize themselves with the new technology. It also reduces the level of dependence of farmers on external sources of inputs, spare parts, and other resources that are associated with the use of this technology. Lastly, locally adapted technology should strive towards solving vitel problems (Figure 10). This calls for a revision of the paradigm of science being developed by experts at international or national levels, and then disseminated for use by farmers at local scale (Tilman et al. 2002).

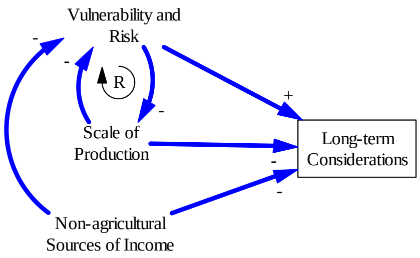
Figure 10: CLD of drivers of the adaptability of new technologies to local conditions



5.5 Long-term Consideration

Farmers interviewed were unanimous in the belief, that they take into account the long-term effects of their actions when they make decisions regarding the adoption or non-adoption of new technology. Farmers' vulnerability to risk (discussed abovebelow) is an important factor when assessing the long-term implications of adopting new technology. Farmers who are more vulnerable to risks prefer taking less risk and so will tend to be the late adopters of laggards in Roger's innovation adoption cycle (Figure 11). The scale of production is also an important consideration. The smaller the scale of production, the more risk averse the farmer is (Figure 11). This is because a decision that leads to bad harvests will have a larger negative impact on small scale farmers than on large scale farmers. The last important factor taken into long-term consideration is the amount of income made by the farmer from other sources (non-agricultural income). When non-agricultural activities provide more income to farming households, they can afford to try out new technologies, safe in the knowledge that if such technologies should fail, they may not be entirely out of income or livelihood.

Figure 11: CLD of drivers of long-term considerations on the adoption of new technologies



5.6 Vulnerability and Risk

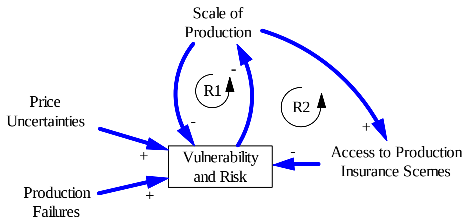
Most farming in sub-Saharan Africa (especially small and middle-scale farming) is not covered by any form of insurance against production failures. Farmers are therefore fully responsible for every one of their decisions, which may mean a total loss of food, income, and livelihood in times of poor harvest. They therefore tend to be more risk-averse and will question the level of their exposure to risk more, before deciding on the adoption or rejection of new technology (Feder et al. 1985). To estimate the extent to which new technology may expose them to production risks, farmers would generally ask the following questions:

1. Would the adoption a new piece of technology make them dependent on another subsidiary of this technology which they may not be able to afford?
2. Is the new technology going to substantially change their production system in such a way that they may have to undergo a major adaptation process to cope with the change?
3. Will they be able to continue with production as before if this technology ceases to be available?

4. How easy is the process of procurement, and how reliable is the source of the new technology?

These questions and others make small-scale farmers in the developing world, and sub-Saharan Africa in particular, generally more conservative and less enthusiastic in adopting new technologies (Beckford 2002). When asked if farmers may be willing to receive a new piece of technology, of which payments can be made after they sell their produce, they seem to be less enthusiastic, arguing that the prices of farm produce are not stable. If such prices fall (given that they are usually quite volatile) they may be left with a burden of debt that may strain their livelihoods in the future (Figure 12). It seems by increasing the scale of production, and giving farmers access to some form of insurance against production failures, their vulnerability to risks would be reduced. This means increasing the reinforcing effect of the loop R 1 and R2 in Figure 12.

Figure 12: CLD of drivers of vulnerability and risk on the adoption of a new technology



5.7 Role of Opinion Leaders

In the rural communities, which are homes to the small-scale farmers studied, the traditional rulers, educated elites, church leaders, and others still play the role of opinion leaders in their communities. These are generally people with access to the media, and have a better understanding of media content. They are therefore regarded as the group that can understand the benefits and dangers of innovations though their greater awareness and experience. The role that they play in the process of technology diffusion is therefore greater than just being risk-takers and innovators in the Rogers' cycle of technology/innovation growth. Their decisions on the adoption of new technology are usually determined by cost, risk and long-term considerations, and the effectiveness of their position is determined especially by the history of the successes or failures of previous technologies which they supported (Figure 13). The communities view them as leaders who can assess, understand, explain and diffuse the content and understanding of new technologies to others. Their endorsement or non-endorsement of an innovation is taken seriously by the farmers, and can influence the effectiveness of the diffusion of the information through word-of-mouth and even of advertisements (see Figure 5).

5.8 Suspicion Towards New Technologies

In certain parts of the region, past innovations in agriculture brought distress to farmers and have sown seeds of suspicion towards new technologies. Some of these innovations include the structural adjustment programs in sub-Saharan Africa, and the introduction of genetically modified strains of cotton from Monsanto in India (McGregor 2005; Shiva et al. 2000). In such cases, new technologies or other forms of innovations in agriculture are viewed with distrust and farmers would prefer to adopt a wait-and-see attitude towards them. This could be especially pronounced when information about these new technologies is insufficient to enable farmers and opinion leaders to make a judgment with regards to the different considerations that would suit the farming community (Figure 14).

5.9 Interim conclusion

The covariates discussed above do not function in isolation. Instead, they form part of a more complex decision-making process in the lives and communities of small-scale farmers (Beckford 2002; Wigley 1988). The decision to adopt any specific new technology at

Figure 13: CLD of drivers of the endorsement of a new technology by opinion leaders in the adoption of that technology

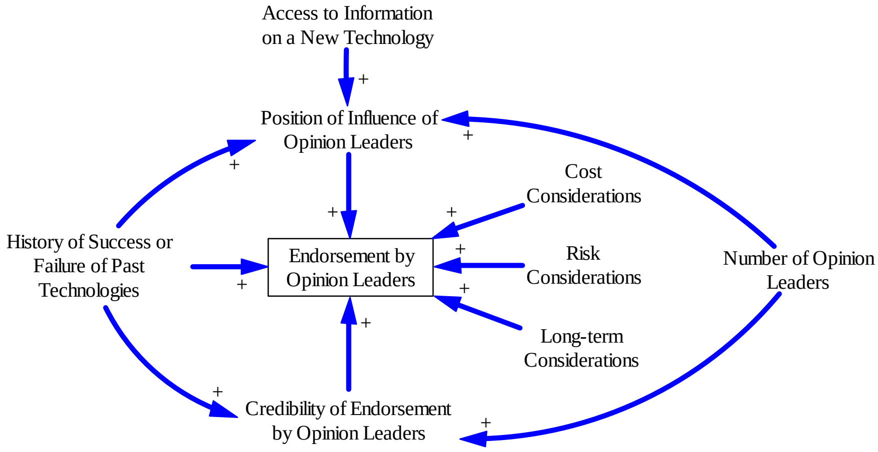
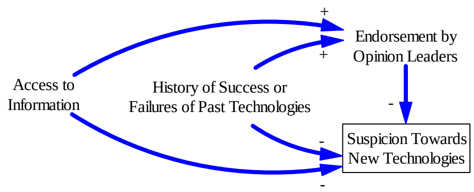


Figure 14: CLD of drivers of suspicion of a new technology in its adoption



any given time is unique, dependent on the outcome of the analysis of these factors at that particular time and place. Hence farmers may take the decision to adopt new technology today based on the circumstances of the time, but the same technology at a different time or place with a different state of covariates may be rejected. The adoption of each new technology therefore has to find a perfect balance of the combination of individual covariates that suit the circumstances.

The socio-economic realities of sub-Saharan Africa and other parts of the tropical developing world gives small-scale farming a unique character which unlike large-scale farming (especially in the developed world), is influenced by factors more important than the market (Wigley 1988). However, their problems can be summarized into two main categories over which they have little or no control: natural constraints to production, and a limited socio-economic power to change their production status or their level in the agricultural production value chain. This explains why flexibility and adaptability in decision-making is often a necessary approach to permit farmers to cope with the habitually changing economic and physical conditions (Davis-Morrison et al. 1997). The production decisions (including decisions of adopting or not adopting new technologies) of small-scale farmers are therefore much more complex and cannot be evaluated on the same scale of rationality as those of farmers in the developed world.

6 Results of Simulations

When different weights are attributed to factors identified by farmers as being important in driving their adoption or non-adoption of a new technology and included in the baseline model of technology adoption, three groups of factors emerge (Table 2). These groups are derived on the basis of how heavily they decrease the adoption rates of new technologies among small-scale farmers in the case studies.

6.1 Factors that heavily decrease adoption rates

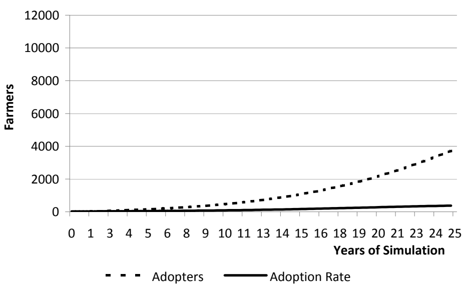
Long-term considerations stand out as the most important factors that may decrease the desire to adopt new technology (Figure 15). With a generally small

Table 2: The effect of different factors in decreasing the rate of adoption of a new technology

Factor	Adopters in Year 15	Adopters in Year 25	Effect on Adoption Rates
Long-term considerations	1071	3814	***Heavily decrease adoption rates***
Vulnerability and risk	1620	5645	
Scale of production	2541	7668	
Adaptability of technology to local conditions	3444	8291	***Decrease adoption rates***
Ability to pay	4332	8940	
Endorsement by opinion leaders	8482	9976	***Have minor effects on adoption rates***
Suspicion towards new technologies	8487	9979	
Access to information	9917	9999	

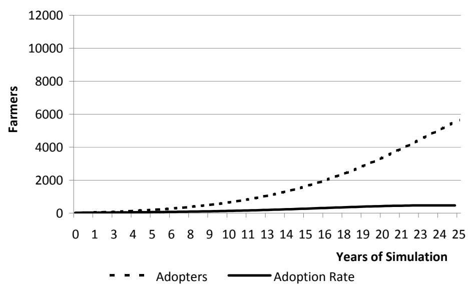
scale of production, limited financial means, and low credit opportunities, farmers would tend to consider long-term implications in their decisions to adopt new technology. Including long-term considerations in the model gives rise to a delayed start of adoption which eventually is sustained at a rate lower than that resulting from the effect of vulnerability. It seems most of the potential adopters may adopt a wait-and-see attitude to the new technology, but once they are sure that its long-term credentials are good, the adoption process may then accelerate.

Figure 15: The effect of long-term considerations on the adoption rates of new technology. Long-term considerations heavily decrease the rate of adoption.



The level of vulnerability and risk is determined by farmers' scale of production, price uncertainties, the frequency and number of production failures and especially farmers' access to insurance against production failures (Figure 6 and 12). When farmers are exposed to a high vulnerability and risk (76%), the result is an adoption rate that starts late and grows steadily (Figure 16). The number of adopters correspondingly remains very low for a long time before increasing.

Figure 16: The effect of vulnerability and risk on the adoption rates of new technology. Concern over greater vulnerability and risk from adopting new technology heavily decreases its rate of adoption.

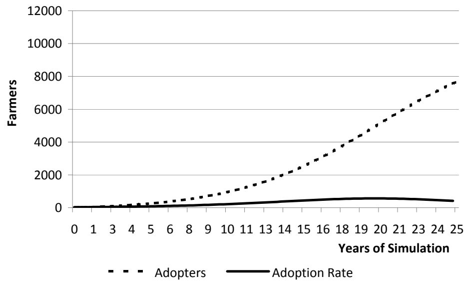


While long-term considerations, vulnerability and risk may be important factors that may decrease the adoption of any new technology, their importance in this case must be seen in the light of the example of technology being studied. The maize seeds being introduced were affordable – farmers with small production scales and limited incomes could buy as little as half a kilogram and try it out in a small portion of their farms. Therefore financial burden and production scale were no longer an issue. Information on the existence and benefits of the new seeds was spread by agricultural extension workers (present in most local communities), hence knowledge of the product in question increased. It had to take time (several seasons of cultivation) for the farmers to assess whether the maize seeds were adapted to the local conditions. Given that the seeds were actively being promoted by agricultural extension workers (who are opinion leaders in the small-scale farming world of both case studies and whom the farmers expect to know what is good for agriculture) the importance of suspicion towards the new technology and effect of endorsement by opinion leaders in decreasing the adoption rate declined. The adoption of other technologies that influence the lives of small-scale farmers through different channels, which are promoted in different ways, may have different acquisition costs (much higher or much lower) and may therefore be heavily influenced by different factors.

6.2 Factors that decrease adoption rate

Farmers' scale of production is a factor which decreases the adoption rate of new technology. It leads to a late start of adoption with a rate which peaks about 20 years into the simulation period (Figure 17). Given that about 80% of farming in the case studies are small-scale farmers and the backbone of national food security in developing countries is the small scale farmer (Khor 2006), the influence of scale on technology adoption is very important. Scale of production is not as important in decreasing adoption rates as long-term considerations and vulnerability partly because of the production under study (maize seeds) can be bought in quantities small enough to be tested on small patches of farmland.

Figure 17: The effect of scale of production in decreasing the adoption rates of new technology. When the scale of production is small, farmers tend to be less inclined to adopting new technology.



The ability to pay decreases the adoption rates of new technology among small-scale farmers in the case studies (Figure 18). This means that the greater the affordability of a pice of technology, the greater the tendency for famers to adopt the technology. As discussed earlier, some farmers may not like to take loans to purchase new technology. They prefer investing for such technologies with their own income. The rate of adoption, when the ability to pay is average, peaks in about 16 years into the simulation period (Figure 18). Most technology has to be bought and therefore entail the availability and accessibility of money to small-scale farmers. Most small-scale farmers in developing countries however have low purchasing power and limited access to credit facilities which make them unable to afford many of the types of technology that are introduced. In the case of the maize seeds farmers could not rely on continually paying for new seeds every planting season. It however seems that the ability to pay is not as important a factor as long-term considerations and farmers' vulnerability and risk of production failures. This may partly be explained by the fact that the maize seeds that are used as a case study is comparatively affordable (at least in the short-term). Hence farmers can at least afford them on retail basis for trial. The outcome may be different if the new technology were a more expensive piece of machinery or other technology.

The adaptability of the new technology to local conditions leads to a decrease in rates of adoption of almost the same magnitude as scale of production and ability to pay (Figure 19). Adaptability here could be in terms of the system of farming, method of storage, manner of storage, preparation, etc. In the case of the maize seeds, they were ill-adapted to their environment in terms of not being harvestable and storable in ways farmers were familiar with. They were also ill-adapted in terms of their taste (see Section 4.2).

Figure 18: The effect of the ability to pay for new technology in decreasing the adoption rate of that technology. The ability for farmers to pay for new technology decreases their adoption rate of the technology.

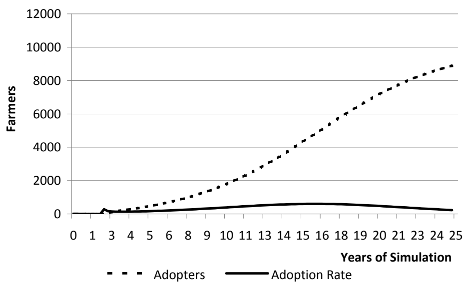
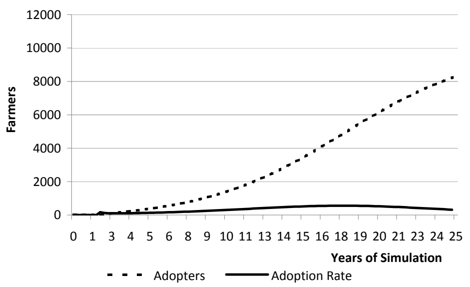


Figure 19: The effect of adaptability of new technology to local conditions in decreasing its adoption rate. When a technology is not adapted to local conditions, it decreases the adoption rate of the technology.



6.3 Factors with only minor impact on adoption rates

While present, other factors seem to play a less important role. They include access to information, suspicion of new technologies, and the effect of endorsement by opinion leaders.

Access to information is seen to play a minimal role in decreasing the adoption rate. The peak of the adoption rates is easily attained in about 5 years and about 9.000 adopters in a total population of 10.000 potential adopters is reached by the 7^{th} year (Figure 20). In terms of the maize seeds under study, information on the seeds was spread by agricultural extension workers whose operations reach some of the most remote areas of the case study. Knowledge about what the new technology intended to accomplish had been disseminated through people whom the farmers apparently trust to deliver correct news and information on innovations. Farmers therefore had the necessary knowledge to guide their decisions on whether to adopt or not to adopt the technology. Access to information therefore had a minimal impact on the adoption rates of the technology in questions. The absence of information may seed doubts in farmers minds as to what exactly the new technology may stand to benefit them, thereby reducing adoption rates. In the same light, access to sufficient information may also reveal weak points about a new technology and reduce its adoption rates. The information disseminated to farmers in the case of the maize seeds for example was more focused on the higher yields per hectare. Farmers were to discover problems with taste, storage and seed preservation later. Figure 20 should therefore be understood within the context of the case study in question.

Suspicion towards the new technology is seen to be a minor factor in decreasing adoption rates. As discussed earlier, the maize seeds under consideration benefited from positive "public relations" through agricultural extension workers who are seen as trusted and

Figure 20: The effect of access to information in decreasing the adoption rate of new technology. Access to information is seen to have a minor impact in decreasing adoption rates.

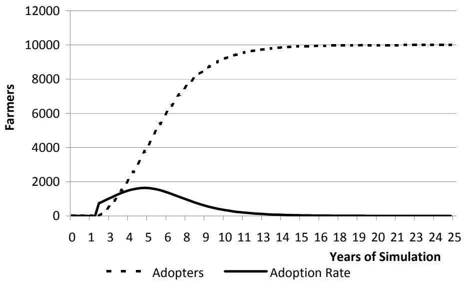
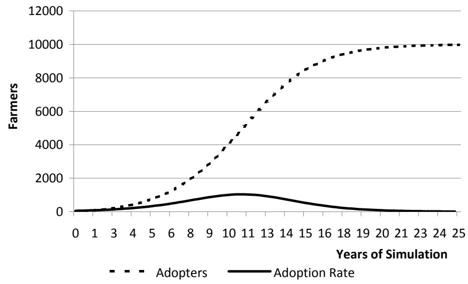
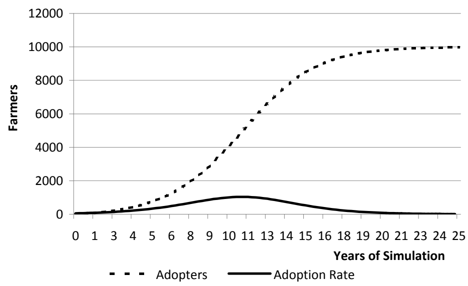


Figure 21: Effect of suspicion of new technology in decreasing its adoption rate. Suspicion of a new piece of technology has only limited impact in decreasing its adoption rate.



knowledgeable agents of agricultural change in rural areas of the case studies. Being agricultural opinion leaders in their own right, the endorsement of the technology by agricultural extension workers co-opted other opinion leaders (village elders, leaders of agricultural common initiative groups and cooperatives, and others) into their ranks. This decreased the role that endorsement by opinion leaders would have played in decreasing adoption rates of the maize seeds. Like the effect of suspicion towards new technologies, of the endorsement by opinion leaders generates a peak adoption rate by the 12^{th} year and a total of about 9.000 adopters in a potential population of 10.000 by the 15^{th} year (Figure 21 and 22). The close resemblance of the adoption rates resulting from the effects of endorsement by opinion leaders and the suspicion of new technology results from the relationship between the two factors. When opinion leaders endorse a technology, suspicion farmers may have over this technology is allayed. The two factors are therefore closely coupled.

Figure 22: The effect of endorsement of new technology by opinion leaders in decreasing its adoption rate. The endorsement of new technology by opinion leaders has only a minor impact in decreasing adoption rates of the new technology.



7 Policy Implications

The transfer of technology to encourage development of Africa's agriculture is seen as an essential ingredient in attaining sustainable rural development in the continent, raising many of the agriculture-dependent population out of poverty, and contributing to global food security (World Bank 2007; Pinstrup-Andersen *et al.* 1998; McCalla 1999). The challenges for policy makers are many and stem from the social and economic realities of alot of sub-Saharan Africa's rural landscape. Besides low levels of literacy, limited access to information, and low purchasing power, these areas have fewer agricultural support services than they had 25 years ago, and have tended to distrust some of the advice and innovations being proposed by decision makers in the sector (Blackman 1999; Ahmed 2004; World Bank 2007). To meet these challenges agricultural development policy may have to streamline their efforts to:

- Improve basic education which raises the level of literacy and improves farmers' ability to access needed information (Figure 7). Access to information then empowers farmers in that they are able to make informed choices offered by new technologies.
- Improve agriculture-related infrastructure (farm-to-market roads, and other communications infrastructure) which can enable farmers to have affordable access to farm technology, agricultural inputs and markets for their products. This enhances mobility of people and products and can affect the adoption of technology in a number of ways: information on new technology can easily reach areas remote from cities at lower costs if mobility were limited; mobility of farmers to structures and services that can be useful in meeting their production needs is increased, e.g. financial structures for investment capital (Figure 3 and 4).
- Provide basic protection and minimum standards for agriculturalists (especially small-scale farmers) with a low capacity to compete with large-scale subsidized agriculture from many parts of the developed world. This can reduce the vulnerability of small-scale farmers to production risks and empower them to venture into increasing their scales of production (Figure 6). Small-scale farmers would be more willing to try new technology, knowing that they have some protection in the event of a production failure resulting from the new technology.
- Recognize the importance of indigenous skills and technology and integrate their beneficial traits into new technology solutions at local level. Adapting new technologies to local level realities may involve the development of technology that is based on affordable local resources, responds to local problems, and is developed through farmer-researcher collaboration (Figure 5). Small-scale agriculture should be part of the beneficiaries of the resulting new technology and innovations that may result from this effort.

To attain the above objectives, the process of technology transfer may require an integrated approach which brings together all sectors related to agricultural development rather than offer a piecemeal solution to the introduction of technology in improving agricultural production. This is because, while technologies may be important in promoting the development of agriculture in sub-Saharan Africa and other parts of the developing world, it has not been very successful so far in achieving this change (Ahmed 2004). In few areas where they have succeeded on the continent, efforts have been made to adapt such technologies to new settings (Norton et al. 2003). Sound decision-making with regards to appropriate technology that can meet some of the sustainability challenges faced by agriculture in sub-Saharan Africa, has to therefore be a bottoms-up approach where technology that enhances decision-making for small-scale farmers is derived through an active interaction between scientists and farmers at a basic level (Tilman *et al.* 2002). Therefore participatory research and collaborative initiatives among relevant stakeholders at the local level, should serve as a forerunner to the introduction of new technologies within the small-scale agricultural sector in order to stimulate better policy outcomes.

8 Conclusion

When the baseline factors, used in many models of diffusion of innovation (the role of advertisement and spread of technology by word-of-mouth), are applied to small-scale farmers in the Sub-Saharan Africa, the result is the traditional logistic S-shaped curve of growth of adopters which is the same as with the spread of other technology in different sectors around the world. However, there are some important factors which need to be considered to get a more complete picture of the drivers of innovation diffusion among this group of producers. These include: the role of opinion leaders, long-term considerations, the vulnerability of farmers to production risks, farmers' scale of production, the history of success of past technologies, and others. These covariates contribute in different ways and to different degrees in shaping the speed and magnitude of the diffusion process. They are the outcome of the socio-economic and political framework within which small-scale agriculture in this region operates. They therefore constitute important considerations to be taken into account when designing policies of innovation-based agricultural development in the region.

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