technische universität
dortmund

Johannes Weyer, Fabian Adelt, Sebastian Hoffmann

GOVERNANCE OF COMPLEX SYSTEMS

A MULTI-LEVEL MODEL

Soziologisches Arbeitspapier Nr. 42/2015

Herausgeber
Prof. em. Dr. H. Hirsch-Kreinsen
Prof. Dr. J. Weyer
JProf. Dr. M. Wilkesmann

Governance of complex systems
A multi-level model

Johannes Weyer / Fabian Adelt /

Sebastian Hoffmann

Arbeitspapier Nr. 42 (Juni 2015)

ISSN 1612-5355

Herausgeber:

Prof. em. Dr. Hartmut Hirsch-Kreinsen
vormals Lehrstuhl Wirtschafts- und Industriesoziologie
Hartmut.Hirsch-Kreinsen@tu-dortmund.de
http://www.wiso.tu-dortmund.de/wiso/de/forschung/gebiete/fp-hirschkreinsen

Prof. Dr. Johannes Weyer
Fachgebiet Techniksoziologie
johannes.weyer@tu-dortmund.de
http://www.wiso.tu-dortmund.de/wiso/ts

JProf. Dr. Maximiliane Wilkesmann
Vertretung Lehrstuhl Wirtschafts- und Industriesoziologie
Maximiliane.Wilkesmann@tu-dortmund.de
www.wiso.tu-dortmund.de/wiso/is

Wirtschafts- und Sozialwissenschaftliche Fakultät
Technische Universität Dortmund
D-44221 Dortmund

Ansprechpartnerin:

Britta Tusk, e-mail: britta.tusk@tu-dortmund.de

Die Soziologischen Arbeitspapiere erscheinen in loser Folge. Mit ihnen werden Aufsätze (oft als Preprint), sowie Projektberichte und Vorträge publiziert. Die Arbeitspapiere sind daher nicht unbedingt endgültig abgeschlossene wissenschaftliche Beiträge. Sie unterliegen jedoch in jedem Fall einem internen Verfahren der Qualitätskontrolle. Die Reihe hat das Ziel, der Fachöffentlichkeit soziologische Arbeiten aus der Wirtschafts- und Sozialwissenschaftlichen Fakultät der Technischen Universität Dortmund vorzustellen. Anregungen und kritische Kommentare sind nicht nur willkommen, sondern ausdrücklich erwünscht.

Contents

Abstract

Social and political sciences have discussed the issue of governance of complex systems for a long time, but still lack consensus on terms, mechanisms and the performance of different modes of governance. The paper at hand adopts an analytical perspective of governance and develops a general framework of it, rooted in a sociological macro-micro-macro model. It defines the basic mechanisms "control" and "coordination" and depicts "governance" as a specific combination of these basic mechanisms in multi-level socio-technical systems. We claim that successful governance has to solve several problems simultaneously: the governance of singular levels within a multi-level architecture as well as the interplay between them. The heuristic value of this framework will be demonstrated by the sample of modern infrastructure systems (e.g. aviation or energy grids). Here we typically observe a combination of three distinct levels: the coordination in negotiation processes, the regulation of functional subsystems of society, and the operational control of these systems.

Keywords or phrases

governance, control, coordination, complexity, multi-level model

1 Introduction

Modern societies are characterized by an increasing complexity. Non-linear processes in economy, society, ecology, and others are hardly controllable, especially because of their interdependencies. In the 1990s, Helmut Willke already warned that societies run the risk "to lose control of themselves" (1989: 55) and to produce irreversible, self-endangering risks. In so far, it seems reasonable to look for political options of "civilising evolution" (ibid.) and simultaneously for theoretical starting-points regarding the governance of complex systems (cf. Loorbach 2007).

The latter issue has been debated in social sciences as well as in natural sciences for a long time (cf. Duit/Galaz 2008). Many researchers have pointed to the limits of control of complex systems, which are rooted among others in the (partial) intransparencies of processes and self-referential mechanisms.

The sceptical view

Niklas Luhmann has always argued that the concept of control "strongly conflicts with the fact of functional differentiation" (1988: 325). In contrast, Willke developed the concept of decentralised context control (1989: 58), which has recently been translated into "smart governance" (2007), thus pointing to a certain degree of controllability of societal systems in spite of functional differentiation. However, from an action theory perspective, Uwe Schimank (2005) claims an inverse relation of complexity and rationality: The more complex a situation is, the less rational are decisions.

The notion of uncontrollable complex systems can also be found in social studies of technology. In his fourfold scheme, Charles Perrow (1984) has identified a type of high-risk systems, which is characterised by complex interactions and tight coupling. According to his analysis, accidents in these systems are unavoidable, leading him to the conclusion that they should be abandoned.

The optimistic view

On the other hand, we find a cautious optimism in terms of control, mostly combined with the plea for alternative modes of governance, which make use of decentralised self-organization and non-hierarchical coordination (Kooiman et al. 2008). Mixed-mode concepts claim that organizations can operate in different governance modes (hierarchy, self-organization etc.) either by combining these modes or switching between them (Duit/Galaz 2008).

For example, the high-reliability theory has identified a certain type of organization (HROs), which is able to successfully manage complex high-risk systems and to avoid normal accidents (Roberts 1993).

The multi-level model of governance

From our point of view, basic knowledge about the functioning and governance of these socio-technical systems is required in order to answer the question of their governability. Referring to the long-lasting debates and open-ended controversies on governance and control, we firstly will show that a deepened understanding of socio-technical systems' governance is still missing (cf. Section 2).[1] Secondly, we will propose a multi-level model of governance as an analytical framework, which tries to clarify conceptual issues to reconcile different notions of governance, and to finally provide a means to investigate governance issues systematically.

This multi-level model will be developed in two steps:

First, a general framework of governance will be depicted, rooted in a sociological macro-micro-macro model, showing the interplay of structure and action. This general framework defines "control" and "coordination" as basic mechanisms, which can be combined at different levels in various ways. Hence the term "governance" refers to a specific combination of these basic mechanisms in a social or socio-technical system (cf. Section 3).

Second, the heuristic value of this framework will be demonstrated by a sample configuration of governance, namely the case of air traffic control in Europe. When applied to modern infrastructure systems (e.g. aviation, road transportation, energy grids), we typically observe a combination of three distinct levels (cf. Section 4):

1. coordination processes in negotiation systems,
2. regulation of functional societal systems,
3. operational control of these systems.

This model represents a specific combination of the basic mechanisms of control and coordination in a multi-level structure. It proposes that the basic mechanisms not only have to work properly (on each level). Furthermore, mechanisms on different levels have to interact well in order to get the system running and guarantee successful governance. The model thus focuses on the interplay between several mechanisms, trying to bridge the gap between different notions and concepts.

2 State of the art in governance research

In spite of long-lasting debates on "control" and "governance", there is only little consensus in social sciences concerning the meaning and scope of both concepts. There can even be found a certain disillusion about the output of 20

[1] We define systems as follows: Social systems are self-organizing entities, which are constituted by actors' interactions. Socio-technical systems additionally include a variety of non-human agents. Because of non-linear internal process, both types can be regarded as complex systems.

years of governance research, since "important empirical and theoretical questions in this area have not been answered until now" (Grande 2012: 566).

Frequently, the terms "governance" and "control" are used as a synonym (Benz et al. 2007: 18), which partly refers to problems transferring the terms between different languages.[2] Some authors explicitly differentiate between both concepts, demarcating the traditional interventionist control ("Steuerung") of the 1970s, in relation to new modes of governance.

2.1 Notions of governance

Basically, two perspectives on governance can be differentiated: the analytical approach including a neutral notion of governance, and the normative approach which points out substantial changes of societal coordination (Grande 2012: 567).

The analytical approach

Mayntz has defined governance as "the entire spectrum of coexisting modes of collective regulation of societal issues" (2004: 5). From this perspective, governance is a meta-category that comprises different modes of coordination, control and others. Schimank also regards governance as "an analytic perspective" which focuses on "patterns of coping with interdependencies of actors" (2007: 29).

Arthur Benz et al. also use the term "for all forms and mechanisms of coordination between more or less autonomous actors, whose actions are interdependent …" (2007: 9).

The analytical perspective of governance thus subsumes every mode of societal coordination without evaluating these different forms of coping with interdependencies. This neutral approach is capable of seeing a wide variety of governance phenomena but provokes the question if we need a new term – and what is the added value. Concepts as coordination, actor constellation, social network, and others are well-established means to analyse patterns of actor interdependencies as well.

The normative approach

Some authors describe the transition from traditional interventionist control ("Steuerung") to governance as a societal learning process which gave rise to new modes of non-hierarchical coordination, including non-governmental, societal actors (Schultze 2013). Renate Mayntz and Fritz Scharpf (1995) point to growing problems of political control and the increasing capabilities of societal self-control, arguing that negotiation systems in which public and private actors interact in solving societal problems might be a solution (Scharpf 1993).

---

[2] For example, in German, a verb related to the noun "governance" does not exist, and the German verb "steuern" can be translated as "to control", "to steer", "to govern", "to manage", and many more.

They use the term "governance" to demarcate this contemporary mode of coordination of strategically acting actors, e.g. in policy networks, where the state is only one of several co-players (cf. also Kooiman et al. 2008, Duit/Galaz 2008).

The normative approach also rates this development positively as an "expression of modernity" (Haus 2010: 459), because governance results in "an increase of efficiency of the policy outcome" (Schultze 2013: 570, cf. Kooiman et al. 2008: 2f.).

The analytic notion of governance, mentioned afore, has a wide scope; it comprises different forms of societal coordination and refrains from substantial descriptions and normative evaluations. In contrast, the normative approach has a narrow scope, because it reserves the term "governance" for one specific mechanism of coordination, namely the non-hierarchical coordination of public and private actors, which is regarded as a well-suited means of dealing with the issue of complexity. However, claiming the superiority of one singular mode of coordination puts a high burden of proof on researchers devoted to the normative approach.

Furthermore, the question of the added value of the new term arises again, since the policy-network approach is a well-established concept of analysing non-hierarchical coordination.

Since both terms – governance and network – are frequently used interchangeably (Knill/Schäfer 2011), one might suspect they mean the same, raising the question why a new term is needed (Torfing et al. 2012: 13). However, if policy networks serve as an instrument of modern governance, the relation of both concepts still has to be clarified.

Interim conclusion

As the brief outlook of governance research has shown, the result is in some regard disappointing: Basic terms are defined and related to each other variously. Neither of the two approaches has convincingly demonstrated the need for and the added value of the new term.

Nevertheless, from the discussion of these concepts, we can learn that governance theory deals with various *mechanisms* of societal coordination. Furthermore, it might be wise to refrain from normative statements about the superiority of modes and to leave this question to empirical research.

2.2 Modes of governance

Empirical research on governance issues might expect some theoretical hints about how to identify and to distinguish different modes of governance, be they old or new ones. Unfortunately, neither governance nor management research have reached a consensus about (i) the number and the characteristics of different governance modes as well as about (ii) the methods of classification or typologies (Wiesenthal 2000).

Classifications and typologies

Many researchers start with the classic triad of market, hierarchy (or organization) and network (or community), but assume that in practice different mechanisms are mixed "under the rules of the leading principle" (Wiesenthal 2000: 47).

In order to identify these combinations of ideal type mechanisms, Volker Schneider and Johannes Bauer constructed a two-dimensional space with the two axes "mode of coordination" and "mode of property rights", resulting in five different types (2009). Willke's axes are labelled "autonomy" and "coherence", leading to a number of hybrid forms in between the three classic modes (1995: 139). Moreover, Andreas Duit and Victor Galaz (2008: 323) present two axes labelled "exploitation" and "exploration", resulting in four governance types (rigid, robust, flexible, fragile) with various adaptive capacities.

The concepts presented here obviously start with different problem definitions and thus are hardly comparable. The classificatory work mostly results in analytic combinations, which, however, have neither been completely discovered in reality nor yet sufficiently investigated.

Furthermore, except from classifying these new modes and types, it mostly remains unresolved how exactly these combinations work, if, for example, partly contradictory demands of market and hierarchy are mingled. Additionally, empirical research is not provided with indicators that can be operationalized in a way that helps identifying specific types in practice.

New (mixed) modes of governance

New modes of governance have mostly been characterised as mixed types in between decentralised self-organization (market) and centralised control (hierarchy) – sometimes labelled "third way" – or "smart" combinations of these basic principles (Willke 1989: 57, Duit et al. 2010: 366, Hillman et al. 2011).

Management research has identified "mixed scanning" (Etzioni 1967) as a third way between rationalism and incrementalism. Similarly, "transition management for sustainable development" (Loorbach 2007) has been proposed as a third way of governing the transformation of complex systems, which reaches beyond planning and self-organization. Finally, "loose coupling" (in terms of Karl Weick) has been conceived of a means of combining the strengths of central planning and flexible crisis management in high-risk organizations (Grote 2009).

Management research argues that complexity can be managed better if new (mixed) modes of governance are applied, that come about by combining old modes or by switching between them – which points to the importance of organizational culture.

Governance research has also induced a variety of new concepts:

- "Polycentric governance" (Ostrom 2010) asserts that the participation of a great variety of public and private actors may lead to superior solutions;
- "interactive governance" is rather similar, pointing to the interaction of "a plurality of social and political actors with diverging interests" (Torfing et al. 2012: 13), participating in problem solving;
- the same applies to "heterarchical governance", which is kind of a horizontal self-organization, to "network-based governance", and to "co-governance" (Duit/Galaz 2008: 317, 323f.);
- "meta-governance" (Jessop 2011, Loorbach 2007), or "smart governance" (Willke 2007), differs insofar, as it is conceptualized as "the governance of governance" (Torfing et al. 2012: 144) – or in older terms: the cautious moderation of self-organised processes by public agencies in order to ensure that decentralized coordination leads to acceptable results from a common welfare oriented perspective (cf. Mayntz 1993).

Altogether, most concepts presented here resemble the normative approach of non-hierarchical coordination in actor networks (cf. Section 2.1). These new modes of governance are usually presented as abstract, ideal-type concepts, which leaves the question of operationalization and empirical identification unresolved (as well as the one of differentiation from other types).

Interim conclusion

The research overview on modes of governance has shown that there is "something" in between old and new modes that is worth being investigated more thoroughly. At this moment, this "something" can best be described as a combination of different social mechanisms. However, concepts still lack precision, and methods to study this issue empirically are rather rare.

2.3 Measuring governance

As mentioned before, many researchers are in favour of one particular mode of governance because it is supposed to deliver better results than others. In order to assess the performance of different governance modes, we need criteria and indicators to measure their success.

Coping with complexity

First of all, the ability to cope with complexity is a major criterion to measure the performance of governance, which is mostly tested by means of comparative case studies. Once more, we find only limited consensus.

Some researchers argue that decentralized self-organization (bottom-up) is superior to other modes, e.g. central planning (top-down) (Resnick 1995), because "diversity and decentralization increase the capacity of governance systems to handle complex systems" (Duit et al. 2010: 366).

Other researchers point out the context which sometimes may favour central control (as in the case of mass production in stable environments) and decentralized coordination at other times (as in the case of innovation in turbulent environments) (Powell 1990: 393). The speed of change and the predictability of events are also factors that influence the performance of different governance modes, as Duit and Galaz (2008) have shown (cf. Section 2.2).

However, these controversies on capabilities of different modes of governance to cope with complexity have never generated precise indicators that might help to solve the issue.

Indicators of successful governance

In order to evaluate the performance of different governance modes, governance research needs methods and techniques to measure performance, output, and success of governance in a methodologically sound way (Duit/Galaz 2008). Unfortunately, only few hints can be found in the current governance research. Duit et al. complain:

> "We currently have very little systematic knowledge about how different types of real-world governance systems differ in their ability to cope with different types of complex change." (2010: 366)

Schimank refers to the effective "coping with interdependence" as a criterion for successful governance or the "capacity of order" (Ordnungsleistung), to be measured by the "criterion of collective capacity to act" (kollektive Handlungsfähigkeit) (2007: 34f.). Although pointing at the necessity to distinguish between indicators on the system and the actor level, his suggestions remain very abstract, leaving a transfer to empirical research strategies rather difficult. The same applies to Wiesenthal, who lists the efficiency of coordination, the "robustness", "reliability", "continuity", but also "actors' autonomy" and "actors' identity" (Wiesenthal 2000: 60).

Duit and Galaz rate certain types of governance positively (robust type) and other negatively (fragile type), without elaborating their criteria of assessment (Duit/Galaz 2008: 323). The only hint is the ability to balance the contradictory needs of stability and flexibility (Duit et al. 2010: 366) – once more a very abstract statement not suited for empirical operationalization.

A more detailed elaboration of criteria for "measuring goverance" can be found in the book of Jacob Torfing et al. (2012: Chapter 4), who enumerate the following indicators:

- *processes*, above all the implementation of political goals (p. 80f.);
- *outputs* in terms of payoffs and the establishment of regulatory institutions (p. 81f.);
- *outcomes* in terms of goal achievement and legitimacy (p. 82f.);
- *normative* criteria in terms of fair procedures (p. 83f.).

This list might serve as a first step towards measurable indicators that can be used by empirical research, since it points at the need to create different indicators to qualitatively measure processes and other indicators quantitatively. Yet, the actor perspective is missing here.

As long as it cannot be managed to establish measurable indicators, governance research will not be able to demonstrate the efficiency of its research object and to answer the question "if governance really contributes positively to solving regulation problems of modern contemporary societies" (Grande 2012: 577).

Modelling (complex) socio-technical systems

The inability of governance research to name dependent and independent variables and to assess relations between them (Torfing et al. 2012: 78f.) is rooted in an underlying conceptual problem: the missing model of a socio-technical system and its internal mechanisms, resulting in a lacking understanding of the impact of interventions into the system. To quote Edgar Grande:

> "It would be even more important to know, how different elements of governance … *interact*, which internal dynamics and external effects arise, and how this affects the performance capability [of the system]…" (Grande 2012: 578, emphasis in original)

According to Grande, the main gaps are insufficient knowledge about the "mechanisms of action" (Wirkungsmechanismen) and particularly about the "interaction of different mechanisms" (ibid.). However, this knowledge is a prerequisite to answer questions about the performance capabilities of governance regimes or modes (cf. Haus 2010).

One reason for this deficit might be that governance research typically does not evaluate the effects of specific kinds of interventions directly, but the institutional design of actor networks and its presumed (indirect) effects on systems' performance instead (Haus 2010: 459, 470, Grande 2012: 577).

Interim conclusion

The critical review of concepts measuring governance has revealed that basic components to methodologically sound investigate this issue are still missing, namely: a model of the socio-technical system, as well as precisely defined indicators that can be operationalized for empirical research.

However, some hints are valuable, especially the insight that modelling governance has to reflect its multi-level architecture, which contains at least two levels:

Schimank, Wiesenthal, Torfing et al. propose to differentiate the system and the actor level. Grande and Haus on the other hand focus on the negotiation system's level (actor network) and the one of the system being influenced. Hence, on both levels, performance indicators may be (i) goal achievement and payoffs, (ii) the collective capacity to act in face of complexity, and (iii) institutionalization and legitimacy.

2.4 Conclusion

In spite of many unresolved debates and lacking consensus concerning the meaning of central terms, the overview of governance research has demonstrated the importance of a new phenomenon anywhere "in between". Its investigation requires taking a look at mechanisms as well as combining various mechanisms within a multi-level structure. Therefore, it might be wise to refrain from normative statements for now, leaving the question of the best performing combination to empirical research, using precisely defined measurable indicators. We will take all these aspects into account when constructing our multi-level model of governance.

3 A general framework of governance of socio-technical systems

3.1 Governance-Modi

The next section will present basic elements of a framework to analyse socio-technical systems and their governance. The fundamental idea is: Modelling the processes (of decision making, interaction, structuring etc.) inside the levels has to be complemented by modelling the interplay between the different levels.

This allows assessing the impact of external events or efforts in order to influence or control the system.

3.2 Basic model of a socio-technical system

Our starting point is a model of a social or socio-technical system that contains the components (actors), the rules of (inter-)action, and the mechanism of structure formation, which are presented in a formal, theory-based language (Hedström/Swedberg 1996). We refer to the macro-micro-macro-model of James Coleman (1990), the Institutional Analysis and Development (IAD) framework of Elinor Ostrom (2005, 2010), and the model of social explanation (MSE) of Hartmut Esser (1993a). Very similar, all three models include assumptions about the logic of action (Ostrom 2010: 6f., 19ff.), the logic of the situation (p. 12, 22f.), as well as the interrelation of these two levels by means of a macro-micro-macro model (Esser 1993a, Kooiman et al. 2008).

Figure 1 presents Esser's version of this idea, but Ostrom's version (2010: 6, 8) is rather similar:

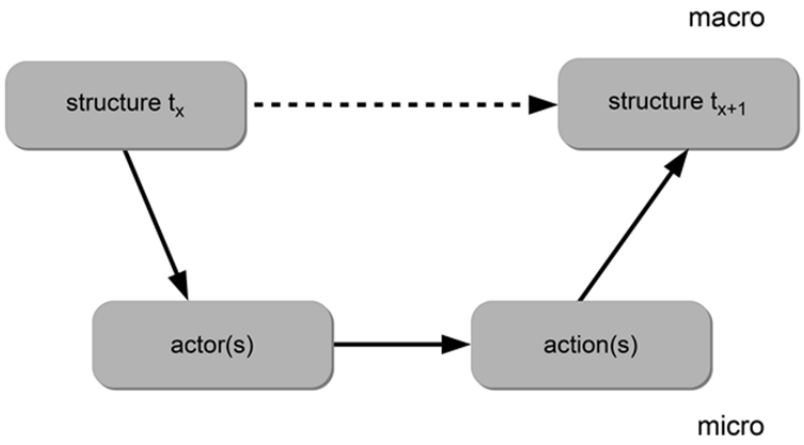

Figure 1: A macro-micro-macro model (Esser 1993a)

The figure starts with the system structure at point in time $t_{x,}$ which is perceived by actors as the situational context which constraints their room for manoeuvre. These actors pursue individual goals and take decisions in a rule-based manner (in Esser's concept, they select the option resulting in the maximum subjectively expected utility). Since a large number of heterogeneous agents act and interact at the micro level, it is difficult to predict which choices they make and how they mutually influence each other.

Finally, in form of the aggregated result of these interactions, a new system structure at point of time t_{x+1} emerges, which is the starting point of the next round. Actors at the micro level are thus constrained by the system, but they also shape and dynamically change the system at the macro level – mostly in a way that is hardly predictable and can only be grasped in form of the unintended result evoked by intentional actions.

This textbook version of a macro-micro-macro model, in which actors act and interact uncoordinatedly and the system structure emerges spontaneously from their interactions, will serve as starting point for more elaborated extensions, applying this model to the study of governance in the next subsections.

3.3 Governance

The overview of governance research in Section 2 has firstly demonstrated that it is a risky strategy (with a high burden of proof) to assign the term "governance" to one specific mode of societal coordination. Secondly, it has highlighted the importance of an analytic perspective that puts emphasis on social mechanisms and such dynamics (cf. also Kalter/Kroneberg 2014). Thirdly, it has clearly shown that pure, textbook forms of either control or coordination can rarely be observed in practice, but a rather large variety of combinations instead (Duit/Galaz 2008: 327, Grande 2012: 582). Fourthly, finally, the outlook has demonstrated the importance of multi-level concepts of governance.

Definition

Hence we propose an analytical definition that allows an open-minded investigation of different pattern as follows:

(DEF-1) The term "governance" depicts a specific combination of the basic mechanisms control and coordination in multi-level socio technical systems.

According to this formal definition, the basic mechanisms can be combined differently, be it horizontally (within levels) or vertically (between those).[3] Yet, in practice, specific combinations of mechanisms (or at least parts of it) are typically set up intentionally as a means of creating or maintaining social order in a functional societal system – even though the emergent result can only partly be related to the creator's intentions.

Levels can be interpreted as any kind of layered structure of or within socio-technical systems, e.g. analytical (micro – meso – macro), territorial (transnational – national – local), or organizational (top management – middle management – operations) ones (cf. Fernández-Ribas 2009).

As presented by the sample in Figure 2, the mechanisms work in a twofold manner: They rule the internal operations of the respective subsystem and they can be used to influence other subsystems, which on their part are guided by an internal mechanism, and – with regard to their openness or closeness – can react differently to external attempts of control or coordination (Luhmann 1990). Of course, feedback loops between levels might also be added, as already suggested in the basic macro-micro-macro model (cf. Section 3.1).

Figure 2 suggests vertical lines to stand for control and horizontal lines to represent coordination; however, the way these mechanisms work in a specific constellation is an open question which can only be resolved empirically.

One can zoom into a specific subsystem and detect more details within the multi-layered internal governance structure. Otherwise, one can zoom out at a higher aggregation level and neglect these details.

Our general framework intends to provide the ground for empirical investigations and refrains from asserting which combination may function in practice and perform best. We merely assume that in practice we will find a number of ideal-type constellations which have proofed their performance through a specific combination of mechanisms.

---

[3] Hillmann et al. (2011: 409) also propose a set of four basic mechanisms, but in an either-or style, which does not look for combinations.

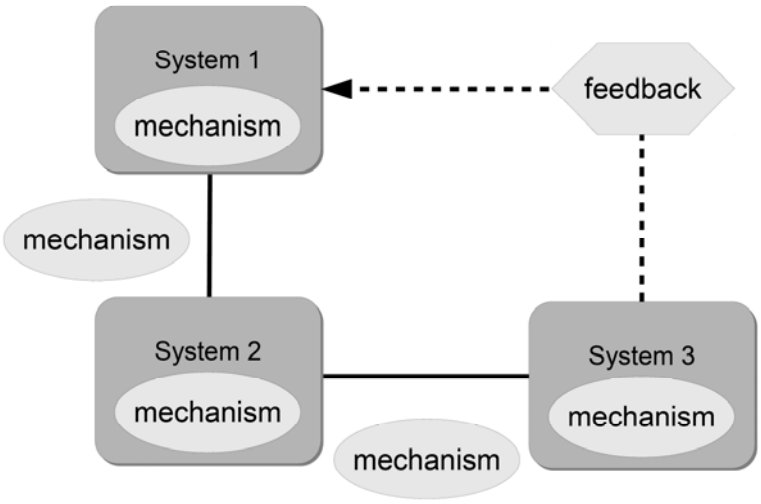

Figure 2: A sample combination of systems and mechanisms

A second assumption is: In practice we will only seldom find a constellation based on merely one single mechanism, and rather observe a variety of mixtures and combinations. This assertion has far-reaching consequences for governance theory, since empirically observed effects can no longer be related to *one singular* mode of governance, but to a specific combination of mechanisms, which derives its strength (or weakness) as well from control as from coordination.

In order to model this concept (see Section 4), we firstly have to define the basic mechanisms more precisely.

3.4 Control ("Steuerung")

Inspite of long-lasting debates on steering and control, especially in German sociology, the term has only seldom been defined. For example, Luhmann defines steering as "minimizing a difference" (1988: 388), namely into a distinct direction. His illustrations ("steering of a car", 326) just like his self-description as "second order cybernetics" (334) show that his notion of steering has been derived from control engineering and that he applies a – surprisingly – intentional notion of control.

Mayntz and Scharpf (1995) are representatives of an intentional concept of steering in terms of a dedicated shaping and reshaping of social systems. Willke takes a middle position, accepting "interventions into autonomous systems" (1989: 133) if the problem of translating "external stimuli into internal information" (134) can be solved.

Definition

Referring to Mayntz, Scharpf and Willke we define control as follows:

(DEF-2) Control shall be the intentional intervention into socio-technical systems, aiming at producing intended effects.

Steering thus is no trivial undertaking, since – as Willke and Luhmann argue – the system to be steered may not be able to process external interventions or even actively resists to them. Our notion of control thus comprises all *attempts* to achieve effects in a socio-technical system, which is not necessarily bound to the successful *realization* of steering intentions in terms of a factual generation of intended effects (cf. Willke 1989: 133f.).[4] System theory puts emphasis on systemic effects of external intervention and thus takes up a sceptical view. In contrast, from an action theoretical perspective, we focus on intentional actions to control systems irrespectively of their success or their – partly unintended – consequences. In this model, every actor – not only the state – may act as controller and simultaneously may become object of control strategies of other actors (Weyer 1997).

To this regard, control always entails the risk of failure – be it complete failure or partial one, e.g. in form of partial implementation of plans or compromises with other actors, who are part of the game as well.

Boundary conditions

In addition to definition (DEF-2), we need two more boundary conditions:

(BC-1) Control is a unidirectional relation between a steering subject and an object-to-be-controlled.

Control typically is exerted by an individual or corporate actor (which is located within a socio-technical system) who *assumes* to have a privileged position that enables her or him to influence or to constrain the (systemic) context of other actors, while conversely being – at least partly – autonomous, i.e. not dependent on these other actors. Control thus supposes an asymmetrical relation between two social systems.

The analytical distinction between steering subject and the object-to-be-controlled (Mayntz/Scharpf 1995: 10) is a central cornerstone of a model of governance (Kooiman et al. 2008: 3, Hillman et al. 2011). It is even reasonable in the case of self-control, when actors play different roles at once: the controller and the object-to-be-controlled.

(BC-2) Control functions via incentives, provided by the steering subject, which shape the situational context of the objects-to-be-controlled and thus leave these objects a leeway to choose between different alternatives.

The second boundary condition refers to the system theoretical concept of system autonomy, which argues that no external power can force a system to change its operations, but can only change situational parameters in a way that

[4] Our notion of control is thus closely related to Schimank's "constellation of influence" (Beeinflussungskonstellation) (2010: 267ff.).

makes reactions on part of the system-to-be-controlled more likely (Luhmann 1990, Willke 1995).

However, this concept is complemented by – and rather fits well to – an action theoretical notion of decision-making, which is rooted in the general model of a socio-technical system (see Section 3.1).

According to this model, strategic actors at the system's micro level pursue goals and take subjectively rational decisions based on their preferences as well as on the given situational constraints. Actors are constrained by the current situation, but not totally determined. They have a certain leeway to make their own choices, which also include the freedom to decide to which extent steering interventions may shape one's own choices.

Furthermore, we assume that incentives may differ according to their strength, ranging from soft measures (e.g. stimuli) to strong measures (e.g. constraints). However, the actors' freedom to comply (or not to comply) to control does both apply in the case of soft and strong control (cf. Kooiman et al. 2008: 8). Actors may decide (differently) on how to cope with these measures. Insofar every attempt to control a socio-technical system entails the risk of failure – at least as long as actors are not put to a strait jacket.

To conclude: Control is a unidirectional interaction between a steering subject and one or several objects to be controlled. However, in most cases, the final objective of control is *not* the individual behaviour, but a desired state of the system (e.g. reducing CO_2-emissions in transportation) – this shall be achieved by a "detour" via the actors' behaviour (e.g. switching to carbon-free modes of transport). Even if control affects the actors, its effects are mostly measured on the system level as aggregated result of the actions and interactions of a large number of actors.

Objectives of control

At latest when assessing the success of control, one has to define its goals, which may be either maintaining system stability (e.g. avoiding traffic jams) or changing the system (e.g. replacing fossils by renewable energies). In the first, case controllers operate by means of negative feedback, trying to damp down fluctuations and to maintain normal operations (or to recover as soon as possible after an incident) (Duit et al. 2010). In the second case, controllers create incentives that shall bring actors to change their individual behaviour, thus producing a dynamic that leads to a systems' transformation in the long run (e.g. in terms of sustainability) (Loorbach 2007). Yet, even in a period of rapid change, the operativeness of the system has to be constantly maintained (Duit/Galaz 2008: 320).

Modelling control

The macro-micro-macro model, depicted in Section 3.1, will help us to model the mechanism of control more precisely, as Figure 3 shows.

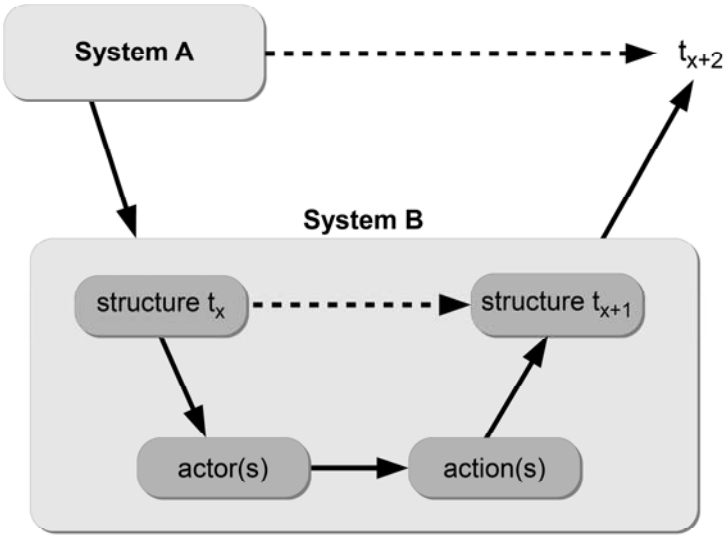

Figure 3: Model of control

In this sense, control is an attempt of external actors (in system A, e.g. climate policy), to purposely influence the state and the processes of system B (e.g. aviation). In an action theoretical perspective, control is mostly exerted *indirectly* by changing the situational parameters of system B at point of time t_x, which are part of the actors decision-making and thus enabling the controller to achieve the presumed outcome at point of time t_{x+1} via this "detour". However, it is hard to predict (and even more difficult to control), whether system B produces the desired outcome or rather unintended effects.

Of course it is possible to zoom into system A in order to see the internal macro-micro-macro processes more detailed and to achieve a better understanding of how the decision to control system B has emerged (see Figure 4).

Finally, different feedbacks are conceivable, for example when the output of system B at point of time t_{x+3} (e.g. delays in aviation) triggers decision-making in system A at point of time t_{x+4} (e.g. climate or transportation policy).

Even without any (purposeful) control activities and only "normal" operations, different systems mutually influence each other, shaping the other systems' context. However, dedicated control activities enforce this mechanism and can thus be used to purposefully change things.

This model presents control as a purposeful shaping of other systems from an external point of view, which even applies if the controller (e.g. a politician) is also part of the controlled system (e.g. a car driver) and thus plays different roles. However, given the desire to exert influence, one has to put oneself into an external reflexive position.

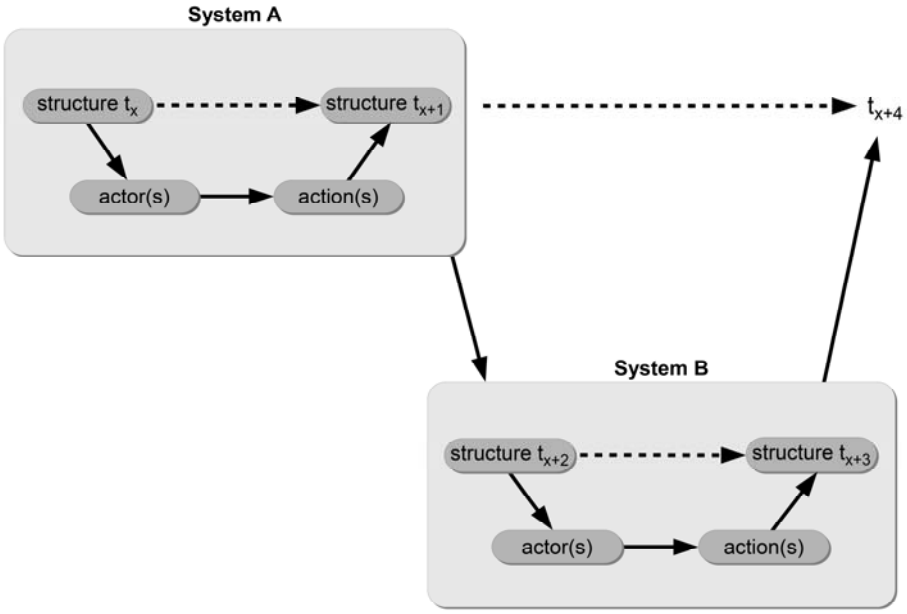

Figure 4: Control in a multi-level configuration

3.5 Coordination

In contrast to control, coordination is decentralized and multidirectional. A multitude of actors participate in negotiation and coordination processes. All participants are – more or less – equally-ranked steering subjects (cf. Habermas 1970), who try to mutually influence each other, none of them being in a privileged position to control other actors unidirectionally (cf. Mayntz 1993, Willke 1995). This notion of coordination is rather close to the above mentioned concept of "interactive governance" (Torfing et al. 2012, Kooiman et al. 2008).

Hence we define coordination as follows:

(DEF-3) Coordination shall be the mutual adjustment of heterogeneous actors aiming at collectively solving problems in a way that is acceptable to all parties involved.

The most common way to accomplish this task, is to take into account the others' perspectives while interacting, which goes along with Max Weber's definition of social action as "actor's behaviour [that] is meaningfully oriented to that of others" (1968: 23, cf. also Schimank 2010: 38ff.).

We further distinguish different types of coordination:

- *spontaneous coordination*, as in the Weberian example of two bicyclists who approach each other and manage to coordinate their actions.
- *reflexive coordination* as in the case of actors in policy or innovation networks who are partly motivated by reaching a consensus, i.e. a common problem solution.[5]

[5] Spontaneous coordination thus resembles Schimank's (2010)„constellation of observation" (Beobachtungskonstellation, p. 226ff.), while reflexive coordination resembles the „constellation of negotiation" (Verhandlungskonstellation, p. 305ff.).

The first case typically covers a short period of time and the actors involved pursue individual goals only. Furthermore, they mostly react to a given situation in an automatic-spontaneous mode (Kroneberg 2014), and optimize their outcomes locally, not taking into account external effects.

The second kind is rather long-range, covering all kinds of strategic action that take into account the presumed actions and reactions of (several) fellow actors in a rationally calculating mode (Habermas 1970, Kroneberg 2014). Common goals and external effects may become more important, and optimization is attained rather indirectly. The most important feature of this type of coordination is its reflexive capability, i.e. the ability to anticipate the following steps in a rationally calculating manner and to take into account what other actors might be doing next.

Modelling coordination

The mechanism of coordination can be modelled as an adjusted version of the basic macro-micro-macro model. Spontaneous coordination is to be depicted as a sequence of decision-making processes, linked to each other in a short period of time, as illustrated in Figure 5.

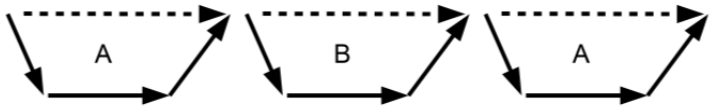

Figure 5: Spontaneous coordination

Actor B acts in a situation that has been shaped by actor A's conduct and vice versa. Both actors reciprocally adapt to each other, because everyone is pursuing one's own goals individually, though dependent on the other's cooperation.

The second type, reflexive coordination, is more complicated, since actors not only take into account the current structure of the system at point in time $t_{x,}$ when defining the situation. They also consider the existence of co-actors, asses their past (inter-)actions, try to anticipate their future actions (and presumed reactions to own actions), and consequently reflexively bear in mind these facts, too.

Referring to Esser's multi-level model (1993b: 113) and previous attempts of Robin Fink and Johannes Weyer (2014) to apply this model to hybrid interactions of humans and machines, we propose the illustration presented in Figure 6.

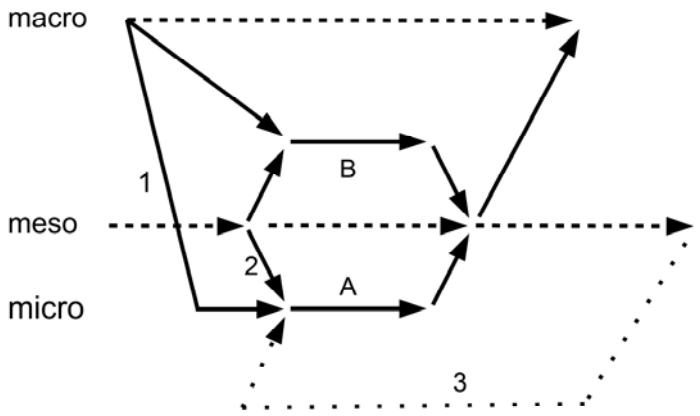

Figure 6: Reflexive coordination

As in the basic model, actor A perceives and interprets the current situation (arrow 1), but additionally s/he is particularly sensitive to actor B's conduct and results from past interactions (arrow 2) and takes both factors – as well as anticipated events in the future (arrow 3) – into consideration. Since actor B is behaving alike simultaneously, a meso structure in between the macro and micro level emerges which influences the actors' choices as well. Hence, each actor not only takes into account the situational parameters (arrow 1), but also the prevailing state of the interaction system at the meso level (arrow 2).

The two models of spontaneous and reflexive coordination differ to that regard that spontaneous coordination typically is more sequential and does not reflect long-term aspects, while reflexive coordination is more simultaneous and reflects the existence of an interaction system at the meso level as well as the outcome of the next and second-next step.

3.6 Relating control and coordination

Despite *the analytical* distinction between "control" and "coordination", the interrelatedness of both concepts is obvious, since in many cases coordination is no end in itself, but serves as a means of control. This would be the case when different parties agree (via coordination) to take measures to influence a system (via control). We will come back to this point in Section 4, where we will present exemplary combinations of coordination and control.

Surprisingly, even the *formal* differences between the control and the coordination mechanism partly seem to dissolve. Control has been defined as attempt to influence a system's behaviour from an external point of view, which includes changing primarily situational parameters of the object-to-be-controlled, namely the actors.

However, coordination works similarly. Several actors try to mutually influence one another by changing situational parameters. Indeed, the actors are part of the same system and exchange resources reciprocally, guided by common objectives and the mutual acceptance of equal standing.

In model-building purpose, control and coordination can therefore formally be constructed as two extreme points of one basic mechanism, namely the intentional shaping of fellow actors' boundary conditions, in order to achieve one's own goals. The remaining difference between the two concepts is the actor's strength to reciprocally define their situations and thus to influence their behaviour, so to speak the degree of asymmetry in terms of power and resources.

In a formal model, we consequently can implement only one mechanism and cover the scale between 'pure' control and 'pure' coordination by adjusting the parameters 'power', 'external/internal', and 'reflexiveness'.

4 Modelling multi-level governance

In the next step, we will be putting all the pieces together, integrating them into a multi-level model of governance. Air traffic control (ATC) in Europe will serve as an example to briefly demonstrate its analytic value.

4.1 "Regelungsstruktur" and "Leistungsstruktur"

In order to achieve this integration task, we refer to Mayntz and Scharpf (1995: 16), who investigated functional societal systems as education, transportation, health, etc. in a governance perspective, and proposed the analytical distinction between

- the "control structure" (Regelungsstruktur), where different actors coordinate themselves in multi-lateral negotiation systems including public and private actors,
- and the "performance structure" (Leistungsstruktur) of these functional societal systems.

Successful governance thus has to solve two problems simultaneously (Lütz 1995: 171f.):

- the definition of control goals with the aid of *coordination* in a negotiation system
- and the implementation of these control goals via *regulating* the functional system in order to change its status.

However, referring to Kooiman et al., the "governability of a societal system" depends on the "system-to-be-governed", the "governing system", "and the relation between the two" (2008: 3f.) – which means that three components are required instead of only two.

The missing third level

Going beyond Mayntz and Scharpf, we insert a third level to grasp the *operational* processes within the functional systems, which on their part produce a governance problem as well (GOV-3). The members of a negotiation system (GOV-1) mostly do not directly affect the actors' behaviour in functional sys-

tems through regulation, but typically set up regulations and specialized, intermediate institutions (GOV-2), which for their part provide the framework for operational control of the systems-to-be-governed (GOV-3).

Figure 7 presents a sample multi-level model of governance of socio-technical infrastructure systems as in the case of air traffic control (ATC) in Europe.

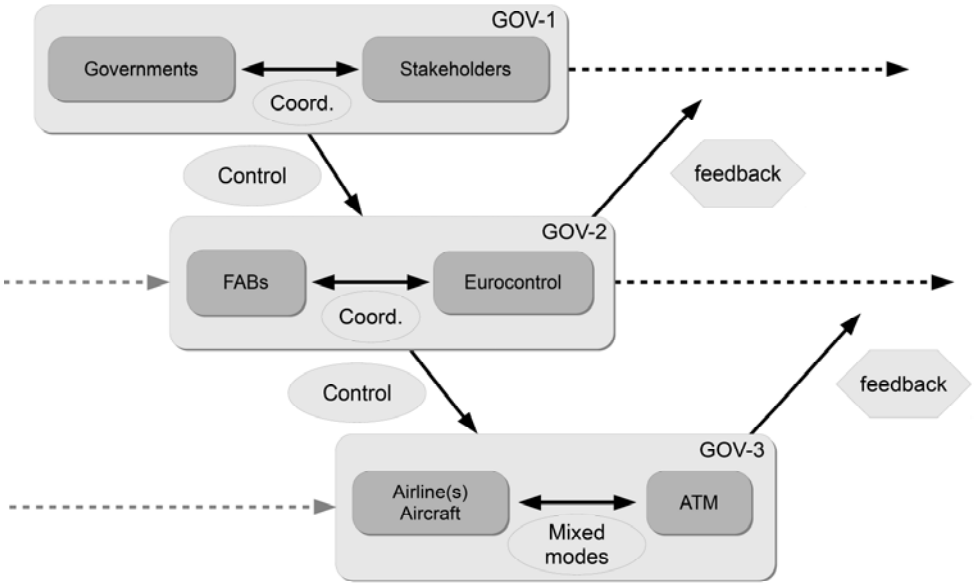

Figure 7: A sample multi-level model of governance of socio-technical systems

4.2 Air traffic control in Europe

At the first level, we find actors negotiating policies, e.g. national governments, industrial and other societal stakeholders (GOV-1). Since the late 1990s, the issues at stake had been a fragmented air space in Europe, lacking buffers to handle the predicted growing air traffic in future decades, and also increasing environmental and safety concerns (Button/Neiva 2013). The goals set for future aviation in Europe were to increase capacities and cost-efficiency and simultaneously to reduce CO_2 emissions – above all via of harmonizing standards and practices.

After a long lasting process, these actors reached a consensus in 2004 to set up a new regulatory regime named "Single European Sky", and to redesign institutions such as Eurocontrol, which has been allocated to act as central authority for coordination of ATC in Europe (GOV-2) (Baumgartner/Finger 2014). One major step towards reorganising European airspace shall be the merger of 41 national ATC sectors into nine Functional Airspace Blocks (FAB) (Mölders 2014). Since this concerted problem solution has been implemented via legal regulation, the arrow between the levels GOV-1 and GOV-2 is labelled "control", indicating an attempt to steer European airspace regulation into the desired direction of a unified airspace with common standards throughout the continent.

However, many actors with partly divergent interests such as national governments, (mostly national) air-navigation service providers, (mostly national) manufacturers of ATC equipment, trade unions, the military and others are part of the – still ongoing – negotiations at the second level (GOV-2). The issue at stake is how precisely to implement the new regulation and how to transform European air traffic management, e.g. by redesigning airspace blocks. These negotiations currently have led to a "gridlock" (Baumgartner/Finger 2014).

Although not fully completed, this new regulatory regime already sets the frame for future operational practices in aviation (GOV-3), since the centralization of rules and regulations goes hand-in-hand with an increasing decentralization of operations, relying on new technologies such as ADS-B or TCAS and the capabilities of self-coordination on part of the actors (Weyer 2006).

For example, the tasks of conflict-detection and separation (in case of another aircraft approaching) have been assigned to pilots, who have much more freedom to plan their routes in order to avoid conflicts and reduce delays (so-called "free-flight") (Hughes/Mecham 2004). The role distribution between ATC, airlines, airports and cockpit crews has changed considerably, shifting from central control by ATC to decentralized coordination of aviation actors, only monitored by ATC.

Nevertheless, close to airports, pilots have to comply with strict rules of central control, and ATC can intervene, e.g. in order to reduce noise or emissions by charging high-noise aircraft (soft control) or banning them (strong control), thus creating incentives for behavioural changes.

To conclude: At the operational level (GOV-3) we typically observe a patchwork of control and coordination mechanisms, indicated in Figure 7 as "mixed modes".

The multi-level model also contains feedback loops, for example from operations to regulation or from regulation to politics. Data about increasing delays in aviation (as in the 1990s) served as an input to politics and triggered deliberations about new measures and programs (as in the case of "Single European Sky").

4.3 Multi-level governance of infrastructure systems

The multi-level model, as depicted in Figure 7, presents a typical constellation that can be found in the governance of modern infrastructure systems such as aviation, road transportation, or energy grids. It implements the idea of a nested, Russian-doll like combination of the mechanisms "control" and "coordination" at different levels, as debated in Sections 2.2 and 3.2. We can see several interconnected macro-micro-macro relations, since the output of "higher" levels serves as input for "lower" levels, while feedback runs inversely.

The same applies to processes within levels. Every system involved has its internal mechanism (be it coordination or control),[6] which can be deciphered zooming in and modelled as macro-micro-macro relation (cf. Section 3). Mechanisms also guide exchanges with the external environment, i.e. other social systems at the same or other levels.

As Figure 7 indicates, horizontal exchange at the respective level is typically performed in the mode of coordination, while vertical exchange between levels embodies control. But these details may differ from case to case and have to be investigated by empirical research.

To sum it up: Governance of modern infrastructure systems typically consists of a combination of three distinct levels:

1. coordination processes in negotiation systems (GOV-1),
2. regulation of functional societal systems (GOV-2),
3. operational control of the systems (GOV-3).

We assert that one has to take into account the interplay of all these levels in order to understand the dynamics of complex systems and to tackle the problem of their governability.

Of course, various other combinations of mechanisms and levels, as visualized in Figure 7, are possible.[7] Which combinations work in practice and which ideal types of combinations can be derived, is only to be identified via empirical research.

The strong assertion of our proposition is: In order to get the socio-technical system running, both the basic mechanisms (on each level) and the interaction between levels have to function properly. Successful governance has to solve all three problems (coordination, regulation, and control) simultaneously.

4.4 Measuring governance

As mentioned before, governance research is in need of indicators that are suited for assessing system performance and for comparing the actual outcomes with the intended ones. The overview in Section 2.3 has shown that performance indicators may be i) goal achievement and payoffs, ii) the collective capacity to act in face of complexity, and iii) institutionalization and legitimacy. Additionally, indicators are needed for the system level as well as for the actor one.

To proceed, we have to assume that it is possible to measure the output of a socio-technical system in different dimensions. However, there are no general-purpose indicators, but the usefulness of different measures depends on the following distinctions.

---

[6] For reasons of clarity these internal mechanisms have been omitted in Figure 7.

[7] It cannot be excluded that some cases will require adding even more levels.

Control vs. coordination

Successful control can be measured by a target-performance comparison, which is based on the expectations of the controller as well as on performance data, e.g. concerning the number of delays in aviation. If the goal is to avoid mid-air collisions, control has been successful if no such event occurs. Simple quantitative indexes may be sufficient to indicate this.

Successful coordination can only be measured via qualitative analysis of policy processes and outcomes: If different actor groups agree on a common problem solution and on concerted measures, e.g. to change the aviation system, coordination can be regarded as successful.

Levels of governance

Consequently, successful governance depends on the regarded level. It could either be the succeeding coordination of public and private actors resulting in a consensus (GOV-1), or the successful implementation of a regulatory regime (GOV-2). Furthermore, it could also be the achievement of a desired system performance with regard to economic and/or ecological dimensions (GOV-3).

This distinction directs our attention again to the interrelatedness of levels. We assume that coordination at level GOV-1 is a necessary precondition of successful governance but no end in itself, since successful control of level GOV-3 is usually the final objective. Vice versa, control at level GOV-3 only makes sense if it is guided by a consented vision (e.g. reducing pollutions caused by aviation) at level GOV-1.

Objectives of governance

As mentioned in Section 3.3, control may be directed towards two main objectives, which have to be measured differently:

- If stability is the primary objective (e.g. safe and punctual air transport), an indicator that measures system stability is needed. Since no such indicator has been available yet, we developed an index combining overall performance with the degree of fluctuations and applied it in (Adelt et al. 2014).
- However, if system change is the primary objective (e.g. transformation of European airspace), there is the necessity of a measure that identifies the emergence of a new regime that has the potential to challenge and finally replace the old one. Frank Geels and Johan Schot have proposed to define a market share of five percent of new technologies as one rough indicator (Geels/Schot 2007: 405).

System and actor

Although we assume that successful governance has to be measured primarily at the system level (e.g. the number of delays in aviation), actors matter as well.

Even if the global goals at the system level have been achieved, actors may nevertheless be dissatisfied because changing their behaviour into the desired direction they did not reach their individual targets. In the long run, this may impede or even hamper effective system control.

Required indicators to measure individual performance can be constructed by the use of a target-performance comparison of each actor involved. One can zoom in at every layer of the multi-level model in order to examine micro indices in more detail.

Interim conclusion

To conclude: All indicators proposed above are in accordance with the concepts of Schimank, Torfing et al., and others, discussed in Section 2.3. They provide a way of constructing indexes which are able to measure the performance of different social mechanisms at different levels of the nested governance structure.

5 Conclusion and outlook

This paper has developed an analytical perspective of governance that refrains from biased statements about the superiority of certain modes of governance. Instead, it provides an abstract framework that depicts governance as a specific combination of the basic mechanisms of control and coordination in multi-level socio-technical systems. Which combinations work in practice and perform well (or even better than others) can only be investigated by empirical research and a comparison of different cases.

However, this requires not only to collect empirical data and to present singular cases in virtue of storytelling. Instead, those empirical data have to be put into a multi-level model of governance in order to make them comparable and to decipher the mechanisms responsible for empirically observable variation.

Hence, our multi-level model of governance does not answer the opening question whether complex socio-technical systems can still be governed. Instead, this model provides a framework and heuristic to investigate the issue of governability in a methodologically sound way.

We assume that modelling socio-technical systems as well as modelling their governance may contribute to progress in governance research and may help solving seemingly endless debates on governance issues (cf. Kalter/Kroneberg 2014). Modelling is only applied in some parts of sociological theory (Esser 1993a, Schimank 2010), and more prominent in agent-based modelling and simulation (ABMS) of social systems (Gilbert 2007, Van Dam et al. 2013). However, both strands of research never got in touch with each other and - surprisingly, as discussed in Section 2 - never dealt with governance issues. The paper at hand tries to fill this gap by making the first step of developing a model of governance of socio-technical systems.

5.1 Limitations

One limitation of our paper is the missing empirical test of the multi-level model of governance. Here we can refer to the short case study on air traffic control in Section 4.2 and another one on discontinuation of the regime of automobility, which – although not presented here – also seems to fit the model at first sight (Weyer et al. 2015).

Parts of the model have been tested in (Adelt et al. 2014) where we implemented the operational part (GOV-3) of the functional system road transportation and tested different modes of governance at the hands of computer simulation.

5.2 Outlook

Future research will probably concentrate on certain parts of the multi-level model of governance and neglect others, either by zooming out or by modelling the interplay between only two levels. Nevertheless, the long-term objective of research should be a comprehensive model of governance that can be applied to different societal sectors. Since the number of actors, interactions, factors, constellations, etc. will be high, agent-based modelling and simulation may become an indispensable tool for governance research.

6 References

Adelt, Fabian/Johannes Weyer/Robin D. Fink, 2014: Governance of complex systems. Results of a sociological simulation experiment. In: Ergonomics (Special Issue „Beyond human-centered automation") 57: 434-448, http://www.tandfonline.com/doi/full/10.1080/00140139.2013.877598.

Baumgartner, Marc/Matthias Finger, 2014: The Single European Sky gridlock: A difficult 10 year reform process. In: Utilities Policy 31: 289-301.

Benz, Arthur et al., 2007: Einleitung. In: dies. (Hg.), Handbuch Governance. Theoretische Grundlagen und empirische Anwendungsfelder. Wiesbaden: VS Verlag, 9-25.

Button, Kenneth/Rui Neiva, 2013: Single European Sky and the functional airspace blocks: Will they improve economic efficiency? In: Journal of Air Transport Management 33: 73-80.

Coleman, James S., 1990: Foundations of Social Theory. Cambridge/Mass.: Harvard University Press.

Duit, Andreas/Victor Galaz, 2008: Governance and complexity—emerging issues for governance theory. In: Governance 21 (3): 311-335.

Duit, Andreas et al., 2010: Governance, complexity, and resilience. In: Global environmental change 20 (3): 363-368.

Esser, Hartmut, 1993a: The Rationality of Everyday Behavior: A Rational Choice Reconstruction of the Theory of Action by Alfred Schutz. In: Rationality and So-ciety 5: 7-31.

---, 1993b: Soziologie. Allgemeine Grundlagen. Frankfurt/M.: Campus.

Etzioni, Amitai, 1967: Mixed Scanning: A "Third" Approach to Decision-Making. In: Public Administration Review 27 (5): 385-392, www2.gwu.edu/~ccps/etzioni/A49.pdf.

Fernández-Ribas, Andrea, 2009: Public support to private innovation in multi-level governance systems: An empirical investigation. In: Science and Public Policy 36: 457-467, http://spp.oxfordjournals.org/content/36/6/457.abstract.

Fink, Robin D./Johannes Weyer, 2014: Interaction of human actors and non-human agents. A sociological simulation model of hybrid systems. In: Science, Technol-ogy & Innovation Studies 10: 31-46, http://www.sti-studies.de/ojs/index.php/sti/article/view/131/127.

Geels, Frank W./Johan Schot, 2007: Typology of sociotechnical transition pathways. In: Research Policy 36: 399-417.

Gilbert, Nigel, 2007: Computational social science: Agent-based social simulation. http://epubs.surrey.ac.uk/cress/44.

Grande, Edgar, 2012: Governance-Forschung in der Governance-Falle?–Eine kritische Bestandsaufnahme. In: Politische Vierteljahresschrift 53 (4): 565-592.

Grote, Gudela, 2009: Management of Uncertainty. Theory and Application in the Design of Systems and Organizations. Berlin: Springer.

Habermas, Jürgen, 1970: Technology and Science as Ideology. Student Protest, Science, and Politics. In: idem (Hg.), Toward a Rational Society. Boston/Mass.: Beacon Press, 81-122.

Haus, Michael, 2010: Governance-Theorien und Governance-Probleme: diesseits und jenseits des Steuerungsparadigmas. In: Politische Vierteljahresschrift 51: 457-479.

Hedström, Peter/Richard Swedberg, 1996: Social Mechanisms. In: Acta Sociologica 39: 281-308.

Hillman, Karl et al., 2011: Fostering sustainable technologies: a framework for analysing the governance of innovation systems. In: Science and Public Policy 38: 403-415, http://spp.oxfordjournals.org/content/38/5/403.abstract.

Hughes, David/Michael Mecham, 2004: 'Free-Flight' Experiments. In: Aviation Week & Space Technology June 7, 2004: 48-50.

Jessop, Bob, 2011: Metagovernance. In: Mark Bevir (Hg.), The SAGE Handbook of Governance. London: Sage, 106-123.

Kalter, Frank/Clemens Kroneberg, 2014: Between Mechanism Talk And Mechanism Cult: New Emphases in Explanatory Sociology And Empirical Research. In: Kölner Zeitschrift für Soziologie und Sozialpsychologie 66: 91-115.

Knill, Christoph/Ansgar Schäfer, 2011: Policy-Netzwerke. In: Johannes Weyer (Hg.), Soziale Netzwerke. Konzepte und Methoden der sozialwissenschaftlichen Netzwerkforschung (2. Aufl.). München: Oldenbourg, 189-218.

Kooiman, Jan et al., 2008: Interactive governance and governability: an introduction. In: Journal of Transdisciplinary environmental studies 7: 1-11.

Kroneberg, Clemens, 2014: Frames, Scripts, and Variable Rationality: An Integrative Theory of Action. In: Gianluca Manzo (Hg.), Analytical Sociology: Norms, Actions, and Networks. Hoboken, NJ: Wiley, 97-123.

Loorbach, Derk, 2007: Transition Management. New mode of governance for sustainable development. Utrecht: International Books.

Luhmann, Niklas, 1988: Die Wirtschaft der Gesellschaft. Frankfurt/M.: Suhrkamp.

---, 1990: Die Wissenschaft der Gesellschaft. Frankfurt/M.: Suhrkamp.

Lütz, Susanne, 1995: Politische Steuerung und Selbstregelung korporativer Akteure. In: dies. (Hg.), Gesellschaftliche Selbstregelung und politische Steuerung. Frank-furt/M.: Campus, 169-196.

Mayntz, Renate, 1993: Modernization and the logic of interorganizational networks. In: Knowledge and Policy 6: 3-16.

---, 2004: Governance Theory als fortentwickelte Steuerungstheorie?, MPIfG Working Paper http://www.mpifg.de/pu/workpap/wp04-1/wp04-1.html.

Mayntz, Renate/Fritz W. Scharpf, 1995: Steuerung und Selbstorganisation in staatsnahen Sektoren. In: dies. (Hg.), Gesellschaftliche Selbstregelung und politische Steuerung. Frankfurt/M.: Campus, 9-38.

Mölders, Marc, 2014: Sustainability as a Change Agent? Lessons From the European Airspace Regulation. In: Environment and Natural Resources Research 4 (4): 130-141, http://dx.doi.org/10.5539/enrr.v4n4p130.

Ostrom, Elinor, 2005: Understanding institutional diversity. Princeton NJ: Princeton University Press.

---, 2010: Beyond markets and states: polycentric governance of complex economic systems. In: The American economic review 100: 641-672.

Perrow, Charles, 1984: Normal Accidents: Living with High-Risk Technologies. New York: Basic Books.

Powell, Walter W., 1990: Neither Market nor Hierarchy: Network Forms of Organization. In: Research in Organizational Behavior 12: 295-336.

Resnick, Michael, 1995: Turtles, Termites, and Traffic Jams. Explorations in Massively Parallel Microworlds (Complex Adaptive Systems). Cambridge/Mass.: MIT Press.

Roberts, Karlene A. (Hg.), 1993: New Challenges to Understanding Organisations. New York: Macmillan.

Scharpf, Fritz W., 1993: Positive und negative Koordination in Verhandlungssystemen. In: Adrienne Héritier (Hg.), Policy-Analyse. Kritik und Neuorientierung (Sonderheft 24 der Politischen Vierteljahresschrift). Opladen: Westdeutscher Verlag, 57-83.

Schimank, Uwe, 2005: Die Entscheidungsgesellschaft. Komplexität und Rationalität der Moderne. Wiesbaden: VS Verlag.

---, 2007: Elementare Mechanismen. In: Arthur Benz et al. (Hg.), Handbuch Governance. Theoretische Grundlagen und empirische Anwendungsfelder. Wiesbaden: VS Verlag, 29-45.

---, 2010: Handeln und Strukturen. Einführung in eine akteurtheoretische Soziologie (4. Aufl.). München: Juventa.

Schneider, Volker/Johannes M. Bauer, 2009: Von der Governance- zur Komplexitätstheorie. Entwicklungen der Theorie gesellschaftlicher Ordnung In: Johannes Weyer/Ingo Schulz-Schaeffer (Hg.), Management komplexer

Systeme. Konzepte für die Bewältigung von Intransparenz, Unsicherheit und Chaos. München: Oldenbourg, 31-53.

Schultze, Rainer-Olaf, 2013: Governance – ein neues Regime? In: Zeitschrift für Parlamentsfragen (44): 659-674.

Torfing, Jacob et al., 2012: Interactive governance. Advancing the paradigm. Oxford: Oxford University Press.

Van Dam, Koen H./Igor Nikolic/Zofia Lukszo (Hg.), 2013: Agent-based modelling of socio-technical systems. Dordrecht: Springer.

Weber, Max, 1968: Economy and Society. An Outline of Interpretive Sociology (edited by Guenther Roth and Claus Wittich). Berkeley, CA: Univ of California Press.

Weyer, Johannes, 1997: Weder Ordnung noch Chaos. Die Theorie sozialer Netzwerke zwischen Institutionalismus und Selbstorganisationstheorie. In: Johannes Weyer et al. (Hg.), Technik, die Gesellschaft schafft. Soziale Netzwerke als Ort der Technikgenese. Berlin: edition sigma, 53-99.

---, 2006: Modes of Governance of Hybrid Systems. The Mid-Air Collision at Ueberlingen and the Impact of Smart Technology. In: Science, Technology & Innova-tion Studies 2: 127-149, http://www.sti-studies.de.

Weyer, Johannes/Sebastian Hoffmann/Jessica Longen, 2015: Achieving sustainable mobility. The discontinuation of socio-technical regimes. In: Research Policy (submitted).

Wiesenthal, Helmut, 2000: Markt, Organisation und Gemeinschaft als „zweitbeste "Verfahren sozialer Koordination. In: Raymund Werle/Uwe Schimank (Hg.), Ge-sellschaftliche Komplexität und kollektive Handlungsfähigkeit. Frankfurt/M.: Campus, 44-73.

Willke, Helmut, 1989: Systemtheorie entwickelter Gesellschaften. Dynamik und Riskanz moderner gesellschaftlicher Selbstorganisation. Weinheim: Juventa.

---, 1995: Systemtheorie III: Steuerungstheorie. Grundzüge einer Theorie der Steuerung komplexer Sozialsysteme. Stuttgart: Gustav Fischer.

---, 2007: Smart Governance. Governing the Global Knowledge Society. Frankfurt/M.: Campus.

amework. In: M.W. Bauer et al. (Hg.), *Dismantling Public Policy: Preferences, Strategies, and Effects*. Oxford: Oxford University Press, 30-51.

Beck, Ulrich, 1986: *Risikogesellschaft. Auf dem Weg in eine andere Moderne.* Frankfurt/M.: Suhrkamp.

Benz, Arthur, 2004: Einleitung: Governance - Modebegriff oder nützliches sozialwissenschaftliches Konzept? In: ders. (Hg.), *Governance - Regieren in komplexen Regelsystemen. Eine Einführung.* Wiesbaden: VS Verlag, 11-28.

Benz, Arthur et al., 2007: Einleitung. In: (Hg.), *Handbuch Governance. Theoretische Grundlagen und empirische Anwendungsfelder.* Wiesbaden: VS Verlag, 9-25.

Brooks, Rodney, 2002: *Menschmaschinen. Wie uns die Zukunftstechnologien neu erschaffen.* Frankfurt/M.: Campus.

Esser, Hartmut, 1999: *Soziologie. Spezielle Grundlagen, Bd. 1: Situationslogik und Handeln.* Frankfurt/M.: Campus.

Etzioni, Amitai, 1967: Mixed Scanning: A "Third" Approach to Decision-Making. In: *Public Administration Review* 27 (5): 385-392, http://dspace.wrlc.org/bitstream/1961/378/1/A49.pdf.

Franz, Oliver, 2012: *Koordination in komplexen Systemen - eine Simulationsstudie (Masterarbeit).* TU Dortmund, Fachgebiet Techniksoziologie.

Grote, Gudela, 2009: Die Grenzen der Kontrollierbarkeit komplexer Systeme. In: Johannes Weyer/Ingo Schulz-Schaeffer (Hg.), *Management komplexer Systeme. Konzepte für die Bewältigung von Intransparenz, Unsicherheit und Chaos*. München: Oldenbourg, 149-168.

Hoffmann, Sebastian, 2013: *Konzepte zur Beendigung sozio-technischer Systeme - eine Literaturstudie (Masterarbeit).* Dortmund: TU Dortmund, Fachgebiet Techniksoziologie.

Kneer, Georg/Uwe Schimank/Rainer Greshoff (Hg.), 2003: *Die Transintentionalität des Sozialen. Eine vergleichende Betrachtung klassischer und moderner Sozialtheorien.* Wiesbaden: Westdeutscher Verlag.

Knill, Christoph/Ansgar Schäfer, 2011: Policy-Netzwerke. In: Johannes Weyer (Hg.), *Soziale Netzwerke. Konzepte und Methoden der sozialwissenschaftlichen Netzwerkforschung (2. Aufl.)*. München: Oldenbourg, 189-218.

Kooiman, Jan, 1999: Social-political governance. In: *Public Management an International Journal of Research and Theory* 1 (1): 67-92.

Kühl, Stefan, 1995: *Wenn die Affen den Zoo regieren. Die Tücken der flachen Hierarchien.* Frankfurt/M.: Campus.

Langlois, Richard N./Paul L. Robertson, 1992: Networks and innovation in a modular system: Lessons from the microcomputer and stereo component industries. In: *Research Policy* 21: 297-313.

Langner, Benedict/Markus Schwenke, 2011: *Der einheitliche europäische Luftraum: Single European Sky. Stand und Ausblick.* Freiburg: Centrum für Europäische Politik (CEP).

LaPorte, Todd R./Paula M. Consolini, 1991: Working in Practice But Not in Theory: Theoretical Challenges of "High Reliability Organizations". In: *Journal of Public Administration Research and Theory* 1: 19-47.

Loorbach, Dirk, 2007: *Transition Management. New mode of governance for sustainable development.* Utrecht: International Books.

Luhmann, Niklas, 1988: *Die Wirtschaft der Gesellschaft.* Frankfurt/M.: Suhrkamp.

---, 1997: *Die Gesellschaft der Gesellschaft.* Frankfurt/M.: Suhrkamp.

Lütz, Susanne, 1995: Politische Steuerung und Selbstregelung korporativer Akteure. In: dies. (Hg.), *Gesellschaftliche Selbstregelung und politische Steuerung.* Frankfurt/M.: Campus, 169-196.

Mayntz, Renate, 1987: Politische Steuerung und gesellschaftliche Steuerungsprobleme - Anmerkungen zu einem theoretischen Paradigma. In: Thomas Ellwein et al. (Hg.), *Jahrbuch zur Staats- und Verwaltungswissenschaft.* Baden-Baden: Nomos, 89-110.

---, 1988: Funktionelle Teilsysteme in der Theorie sozialer Differenzierung. In: Renate Mayntz et al. (Hg.), *Differenzierung und Verselbständigung. Zur Entwicklung gesellschaftlicher Teilsysteme.* Frankfurt/M.: Campus, 11-44.

---, 1993: Policy-Netzwerke und die Logik von Verhandlungssystemen. In: Adrienne Héritier (Hg.), *Policy-Analyse. Kritik und Neuorientierung (Sonderheft 24 der Politischen Vierteljahresschrift).* Opladen: Westdeutscher Verlag, 39-56.

---, 2004: *Governance Theory als fortentwickelte Steuerungstheorie?*, MPIfG Working Paper http://www.mpifg.de/pu/workpap/wp04-1/wp04-1.html.

Mayntz, Renate/Fritz W. Scharpf (Hg.), 1995a: *Gesellschaftliche Selbstregelung und politische Steuerung.* Frankfurt/M.: Campus.

---, 1995b: Steuerung und Selbstorganisation in staatsnahen Sektoren. In: dies. (Hg.), *Gesellschaftliche Selbstregelung und politische Steuerung.* Frankfurt/M.: Campus, 9-38.

Mölders, Marc, 2012: *Der Himmel über Europa Eine Fallstudie zur Genese des „Single European Sky".* Dortmund: TU Dortmund, Fachgebiet Techniksoziologie.

Nonaka, Ikurijo/Hirotaka Takeuchi, 1997: *Die Organisation des Wissens - wie japanische Unternehmen eine brachliegende Ressource nutzbar machen.* Frankfurt/M.: Campus.

Perrow, Charles, 1987: *Normale Katastrophen. Die unvermeidbaren Risiken der Großtechnik.* Frankfurt/M.: Campus.

Powell, Walter W., 1990: Neither Market nor Hierarchy: Network Forms of Organization. In: *Research in Organizational Behavior* 12: 295-336.

Resnick, Michael, 1995: *Turtles, Termites, and Traffic Jams. Explorations in Massively Parallel Microworlds (Complex Adaptive Systems).* Cambridge/Mass.: MIT Press.

Rifkin, Jeremy, 2010: *Die emphatische Zivilisation. Wege zu einem globalen Bewusstsein.* Frankfurt/M.: Campus.

Roberts, Karlene A. (Hg.), 1993: *New Challenges to Understanding Organisations.* New York: Macmillan.

Scharpf, Fritz W., 1988: Verhandlungssysteme, Verteilungskonflikte und Pathologien der politischen Steuerung. In: Manfred G. Schmidt (Hg.), *Staatstätigkeit. International und historische vergleichende Analyse (PVS-Sonderheft 19)*. Opladen: Westdeutscher Verlag, 61-87.

---, 1993: Positive und negative Koordination in Verhandlungssystemen. In: Adrienne Héritier (Hg.), *Policy-Analyse. Kritik und Neuorientierung (Sonderheft 24 der Politischen Vierteljahresschrift)*. Opladen: Westdeutscher Verlag, 57-83.

Schimank, Uwe, 2005: *Die Entscheidungsgesellschaft. Komplexität und Rationalität der Moderne*. Wiesbaden: VS Verlag.

---, 2007: Elementare Mechanismen. In: Arthur Benz et al. (Hg.), *Handbuch Governance. Theoretische Grundlagen und empirische Anwendungsfelder*. Wiesbaden: VS Verlag, 29-45.

---, 2009: Wichtigkeit, Komplexität und Rationalität von Entscheidungen. In: Johannes Weyer/Ingo Schulz-Schaeffer (Hg.), *Management komplexer Systeme. Konzepte für die Bewältigung von Intransparenz, Unsicherheit und Chaos*. München: Oldenbourg, 55-71.

---, 2010: *Handeln und Strukturen. Einführung in eine akteurtheoretische Soziologie (4. Aufl.)*. München: Juventa.

Schneider, Volker/Johannes M. Bauer, 2007: Governance: Prospects of Complexity Theory in Revisiting System Theory. In: *65th Annual National Conference of the Midwestern Political Science Association. Chicago, IL, April 12-15, 2007*.

---, 2009: Von der Governance- zur Komplexitätstheorie. Entwicklungen der Theorie gesellschaftlicher Ordnung In: Johannes Weyer/Ingo Schulz-Schaeffer (Hg.), *Management komplexer Systeme. Konzepte für die Bewältigung von Intransparenz, Unsicherheit und Chaos*. München: Oldenbourg, 31-53.

Simonis, Georg, 1995: Ausdifferenzierung der Technologiepolitik - vom hierarchischen zum interaktiven Staat. In: Georg Simonis/Renate Martinsen (Hg.), *Paradigmenwechsel in der Technologiepolitik*. Opladen: Leske + Budrich, 381-404.

Surowiecki, James, 2005: *The Wisdom of Crowds*. New York: Anchor Books.

Taubert, Niels C., 2008: Balancing Requirements of Decision and Action: Decision-Making and Implementation in Free/Open Source Software Projects. In: *Science, Technology & Innovation Studies* 4: 69-88, http://www.sti-studies.de.

Weyer, Johannes, 1993: System und Akteur. Zum Nutzen zweier soziologischer Paradigmen bei der Erklärung erfolgreichen Scheiterns. In: *Kölner Zeitschrift für Soziologie und Sozialpsychologie* 45: 1-22.

---, 2008: Mixed Governance - Das Zusammenspiel von menschlichen Entscheidern und autonomer Technik im Luftverkehr der Zukunft. In: Ingo Matuschek (Hg.), *Luft-Schichten. Arbeit, Organisation und Technik im Luftverkehr*. Berlin: edition sigma, 188-208.

---, 2011a: Einleitung: Netzwerke in der mobilen Echtzeitgesellschaft. In: ders. (Hg.), *Soziale Netzwerke. Konzepte und Methoden der sozialwissenschaftlichen Netzwerkforschung (2. Aufl.)*. München: Oldenbourg, 3-38.

---, 2011b: Zum Stand der Netzwerkforschung in den Sozialwissenschaften. In: ders. (Hg.), *Soziale Netzwerke. Konzepte und Methoden der sozialwissenschaftlichen Netzwerkforschung (2. Aufl.)*. München: Oldenbourg, 39-69.

Weyer, Johannes/Gudela Grote, 2012: Die Grenzen der Beherrschbarkeit technischer Systeme. In: Fritz Böhle/Sigrid Busch (Hg.), *Management von Ungewissheit*. Bielefeld: Transcript, 189-212.

Weyer, Johannes et al., 1997: *Technik, die Gesellschaft schafft. Soziale Netzwerke als Ort der Technikgenese*. Berlin: edition sigma.

Wiesenthal, Helmut, 2000: Markt, Organisation und Gemeinschaft als „zweitbeste "Verfahren sozialer Koordination. In: Raymund Werle/Uwe Schimank (Hg.), *Gesellschaftliche Komplexität und kollektive Handlungsfähigkeit*. Frankfurt/M.: Campus, 44-73.

Willke, Helmut, 1987: *Systemtheorie. Eine Einführung in die Grundprobleme (2. Aufl.)*. Stuttgart: Gustav Fischer.

---, 1989: *Systemtheorie entwickelter Gesellschaften. Dynamik und Riskanz moderner gesellschaftlicher Selbstorganisation.* Weinheim: Juventa.
---, 1995: *Systemtheorie III: Steuerungstheorie. Grundzüge einer Theorie der Steuerung komplexer Sozialsysteme.* Stuttgart: Gustav Fischer.
---, 2007: *Smart Governance. Governing the Global Knowledge Society.* Frankfurt/M.: Campus.
Wooldridge, Michael, 2001: *Introduction to Multiagent Systems.* Hoboken, NJ: John Wiley & Sons.

Bereits erschienene Soziologische Arbeitspapiere

1/2003 Hartmut Hirsch-Kreinsen, David Jacobsen, Staffan Laestadius, Keith Smith
Low-Tech Industries and the Knowledge Economy: State of the Art and Research Challenges (August 2003)

2/2004 Hartmut Hirsch-Kreinsen
"Low-Technology": Ein innovationspolitisch vergessener Sektor (Februar 2004)

3/2004 Johannes Weyer
Innovationen fördern – aber wie? Zur Rolle des Staates in der Innovationspolitik (März 2004)

4/2004 Konstanze Senge
Der Fall Wal-Mart: Institutionelle Grenzen ökonomischer Globalisierung (Juli 2004)

5/2004 Tabea Bromberg
New Forms of Company Co-operation and Effects on Industrial Relations (Juli 2004)

6/2004 Gerd Bender
Innovation in Low-tech – Considerations based on a few case studies in eleven European countries (September 2004)

7/2004 Johannes Weyer
Creating Order in Hybrid Systems. Reflexions on the Interaction of Man and Smart Machines (Oktober 2004)

8/2004 Hartmut Hirsch-Kreinsen
Koordination und Rationalität (Oktober 2004)

9/2005 Jörg Abel
Vom Kollektiv zum Individuum? Zum Verhältnis von Selbstvertretung und kollektiver Interessenvertretung in Neue Medien-Unternehmen (Juli 2005)

10/2005 Johannes Weyer
Die Raumfahrtpolitik des Bundesforschungsministeriums (Oktober 2005)

11/2005 Horst Steg
Transnationalisierung nationaler Innovationssysteme (Dezember 2005)

12/2006 Tobias Haertel
UsersAward: Ein Beitrag zur optimalen Gestaltung von Mensch-Maschine-Systemen in der Logistik (Februar 2006)

13/2006 Doris Blutner, Stephan Cramer, Tobias Haertel
Der Mensch in der Logistik: Planer, Operateur und Problemlöser (März 2006)

14/2006 Johannes Weyer
Die Zukunft des Autos – das Auto der Zukunft. Wird der Computer den Menschen ersetzen? (März 2006)

15/2006 Simone Reineke
Boundary Spanner als Promotoren des Wissensmanagementprozesses (Juli 2006)

16/2006 Johannes Weyer
Die Kooperation menschlicher Akteure und nicht-menschlicher Agenten. Ansatzpunkte einer Soziologie hybrider Systeme (Juli 2006)

17/2006 Jörg Abel/Sebastian Campagna/Hartmut Hirsch-Kreinsen (Hg.)
Skalierbare Organisation - Überlegungen zum Ausgleich von Auftragsschwankungen (August 2006)

18/2007 Tabea Bromberg
Engineering-Dienstleistungen in der Automobilindustrie: Verbreitung, Kooperationsformen und arbeitspolitische Konsequenzen (Mai 2007)

19/2007 Hartmut Hirsch-Kreinsen
Lohnarbeit (September 2007)

20/2008 Katrin Hahn
Der Lissabon-Prozess: Das Innovationskonzept und die Auswirkungen auf die Politikgestaltung (März 2008)

21/2008 Anja J. Lorenz/ Johannes Weyer (Hg.)
Fahrerassistenzsysteme und intelligente Verkehrssteuerung. Soziologische Analysen hoch automatisierter Verkehrssysteme (Juni 2008)

22/2008 Hartmut Hirsch-Kreinsen
Innovationspolitik: Die Hightech-Obsession (August 2008)

23/2008 Hartmut Hirsch-Kreinsen
Multinationale Unternehmen (September 2008)

24/2009 Jörg Abel/ Hartmut Hirsch-Kreinsen/ Peter Ittermann
Einfacharbeit in der Industrie. Status quo und Entwicklungsperspektiven (Mai 2009)

25/2009 Robin D. Fink
Attributionsprozesse in hybriden Systemen. Experimentelle Untersuchung des Zusammenspiels von Mensch und autonomer Technik (Juli 2009)

26/2009 Hartmut Hirsch-Kreinsen
Innovative Arbeitspolitik im Maschinenbau? (September 2009)

27/2010 Hartmut Hirsch-Kreinsen
Technological Innovation and Finance (Oktober 2010)

28/2010 Robin D. Fink, Tobias Liboschik
Bots - Nicht-menschliche Mitglieder der Wikipedia-Gemeinschaft (Dezember 2010)

29/2011 Jörg Abel, Peter Ittermann, Hartmut Hirsch-Kreinsen
Einfacharbeit in der Ernährungsindustrie (Februar 2011)

30/2012 Jörg Abel, Peter Ittermann, Hartmut Hirsch-Kreinsen
Einfacharbeit in der Gummi- und Kunststoffindustrie (Januar 2012)

31/2012 Peter Ittermann, Jörg Abel, Hartmut Hirsch-Kreinsen
Einfacharbeit in der Metallbearbeitung (Februar 2012)

32/2013 Lehrstuhl Wirtschafts- und Industriesoziologie, Lehrstuhl Arbeits- und Produktionssysteme
Wandel von Industriearbeit. Herausforderungen und Folgen neuer Produktionssysteme in der Industrie (März 2013)

33/2013 Fabian Lücke, Johannes Weyer, Robin D. Fink
Steuerung komplexer Systeme. Ergebnisse einer soziologischen Simulationsstudie (April 2013)

34/2013 Marco Hellmann, Sarah Rempe, Jan Schlüter
Die Katastrophe der Deepwater Horizon (Oktober 2013)

35/2013 Johannes Weyer
Experimentelle Soziologie. Der Beitrag der Computersimulation zur Weiter entwicklung der soziologischen Theorie (Oktober 2013)

36/2013 Johannes Weyer, Fabian Adelt, Robin D. Fink
Steuerung komplexer Systeme. Ein Mehrebenen-Modell von Governance (Oktober 2013)

37/2013 Hartmut Hirsch-Kreinsen
A sample multi-level model of governance of socio-technical systems
(November 2013)

38/2014 Hartmut Hirsch-Kreinsen
Wandel von Prosuktionsarbeit – „Industrie 4.0"
(Januar 2014)

39/2014 Hartmut Hirsch-Kreinsen, Katrin Hahn
Financialization of Innovation – the Case of the German Industrial Innovation System
(August 2014)

40/2014 Katrin Hahn
Innovationsfinanzierung im Spannungsfeld von Risiko und Unsicherheit: Bremsen die gegenwärtigen Finanzmarktbedingungen unternehmerische Innovationen?
(Oktober 2014)

41/2015 Daniel Ruppel
Hindernisse und Herausforderungen bei der Implementierung von Ganzheitlichen Produktionssystemen
(Januar 2015)