

1. Introduction: on governance, systems and change

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1.1 INTRODUCTION

Why do we see so few electric cars on our streets today in spite of the overwhelming positive views on them? Why is it so difficult to introduce electronic patient journals in our hospitals or to phase out fossil-based energy sources? How come mobile telephones were developed and expanded so rapidly in the past two decades? How are integrated transport systems transforming commuting in large cities, and who contributes to that change? At a basic level these questions have to do with the way in which science and technology interact with society. It is commonplace today in social sciences literature that science, technology and society are constantly shaping each other in a truly co-constitutive process. However, these questions also have to do with the elements that form the socio-technical and innovation systems as well as with socio-cultural and economic aspects in the intentionality towards (or against) change. This book argues for the need for a better understanding of governance of change in socio-technical systems and innovation systems. It develops a conceptual framework to understand change and studies governance of change in a range of selected case studies that mobilize this framework.¹

The notions ‘socio-technical system’ and ‘innovation system’ refer to the fact that individual technical artefacts or innovations are not operating in isolation. On the contrary, the functioning of technical artefacts and innovations is highly dependent on specific and complex ensembles of elements in which they are embedded. It is not the individual artefact or innovation as such that has an effect, but its interplay with and embedding in other technical and non-technical elements in society and the economy. To approach the issue, we start with a simple illustration of a socio-technical system: the electric car. The technical solutions for electric cars are developing very quickly (batteries, electric engines,

software, and so on), as are the infrastructures for charging batteries and other support services. The development of the electric car system is highly dependent on the opportunities offered by new technical knowledge and consumer demands; by the regulations, soft laws and voluntary standards that frame safety, insurance conditions, and so on for electric cars; and by the societal acceptance and ultimate support to these changes. What we observe over the last decades is a painfully slow process of change towards the electric car system, despite claims of its greatly improved eco-efficiency. This simplified example illustrates the question this book is tackling, namely how the governance of change in socio-technical systems and innovation systems takes place.

It is our humble observation that the way in which the change in socio-technical systems and innovation systems (ST&I systems) is actually governed remains understudied in the social sciences. To be sure, there is a myriad of empirical studies examining the nature of ST&I systems, and the way in which individual artefacts and innovations interact in society and the economy. However, the literature has not come to grips with the intentional nature of the agents' actions that govern the change of these complex systems.¹ During the past decades different disciplines in the social sciences have analysed ST&I systems from very different angles. Scholars in STS (science and technology studies), economics and political science disciplines have been concerned with the complex micro- and macro-level dimensions of the relation between science/technology and society/economics/politics and their mutually shaping interactions. With few exceptions and happy encounters these different disciplinary approaches have run parallel to each other, tending to disregard each other's perspectives.

The various schools of economists have been interested in issues of the role of technical change in economic growth for a long time, at the level of the firm and at the level of national and regional economies. In particular, they have examined the way in which the creation of new knowledge influences the competitiveness of a firm or an economy, and how firms can foster their innovativeness and competitive position in global markets. Sociologists and anthropologists, mostly in the field of science and technology studies (STS), are interested in issues of the co-constitutive relationship between society and science, and in particular in scientific controversies and the critical social contestation of scientific progress. Political scientists for their part are interested in the politics associated with the design of science and innovation policies, the changing role of scientific expertise in advanced democracies, and the implementation, coordination and policy instrumentation of knowledge and innovation policies. These three disciplines in the social sciences

have hardly ever explicitly and systematically addressed questions associated with the governance of change or governance altogether. In existing studies 'governance' is rarely the object of study as such, and if it is, it is typically mentioned in a loose manner, becoming a sort of catch-all notion with virtually no explanatory intention. To be sure, the literature on socio-technical and innovation systems offers several possible (largely implicit) understandings of 'governance', but hardly ever as an upfront object of study. This is probably because 'governance' and 'governance of change' do not have a clear conceptual underpinning, making it difficult to operationalize as an object of study in its own right. Hence, there is a need to take a step further and enable a theoretical and empirical advancement on what the processes of governing change are.

This book thus aims to make three contributions to the literature. First, this book will provide a coherent analytical framework based on conceptual clarification on the notion of governance and socio-technical and innovation systems. Our book will contribute by clarifying these crucial conceptual and analytical aspects of governance and governance of change.

Second, this book aims at providing some stepping stones for theory-building about governance of change. The literature offers many exciting empirical case studies on socio-technical systems' and innovation systems' patterns and dynamics, and also implicitly on the systems' governance. However, the eminently empirical nature of these studies has not lent itself towards taking the crucial step into higher levels of abstraction in the social sciences. This book aims at looking at the regularities associated with the governance of change that emanate both from the empirical cases and from core theoretical concepts of governance. This analytical framework for studying the governance of change – as a step towards theory-building – will be defined around the three lead questions above and will thus be based on three pillars, namely:

- (1) the relation between opportunity structures and capable agents;
- (2) the instrumentation through which intentional definitions of collective solutions are put into practice and
- (3) the sources and hindrances of legitimacy in the process of governing change.

These three pillars will structure the theoretical considerations regarding the governance of change in more general and abstract terms and will also determine and structure the collection of empirical analysis of a set of very diverse cases.

Third, the book will bridge the gap between disciplinary fields. It aims at conducting a ‘double movement’ by bringing the governance approach (which is largely based on the discipline of political science) into the different social science studies on science and technology; and vice versa, bringing the ST&I system approaches into governance studies. This double movement is necessary not only in view of redressing a remarkable blind spot in the social sciences, but most importantly in view of identifying unexplored synergies in terms of the theory-building efforts mentioned above. The empirical area of ST&I systems is very rich and varied, given the broad nature of science and technology and its multiple forms of interaction in society and the economy. Studying how change is governed in these ST&I systems can provide very useful and rich empirical evidence that will help us to better understand the context in which governance operates in our advanced societies. By doing so, the book will contribute to an important mission of social studies of science, technology and innovation – underpinning empirical analyses of systems’ change with a theory of governance of change – and at the same time it will further advance the understanding and conceptualization of governance with broader implications for governance studies more generally.

The remainder of this chapter discusses the existing approaches to socio-technical or innovation systems in various strands of social science literature (see section 1.2). This discussion brings to the fore the commonalities, and above all, their differences in the various literature strands in terms of explanatory variables and axiomatic assumptions, particularly those that refer implicitly (or occasionally explicitly) to governance. We reveal the different bases of these theories according to whether they see ST&I systems as being anchored essentially in an economic and market context or a socio-cultural context, and which emphasis they put on the role of agency and the role of institutions. These differences have clear implications on the way the scholars have implicitly addressed issues associated with the governance of change in the systems. Hence, characterizing these approaches is important because while spelling out their alternative views on the systems’ dynamics and change processes, the review will unveil the different implicit takes on the question of the governance of change.

After this literature discussion, we develop a working definition of ST&I systems (see section 1.3) and discuss the concept of governance of change (see section 1.4). When doing so, we realize that the notion of governance has been used with different meanings and connotations. While we do not need to analyse these different conceptualizations, as broad and valuable work already exists, we build on this work and

present a workable definition in the context of ST&I systems, understanding ‘governance of change’ as the mechanisms by which societal and state actors intentionally interact and coordinate (see our full definition in section 1.4).

These three steps, discussing antecedents in different strands of literature, defining ST&I systems and then defining governance of change in ST&I systems, serve to demonstrate the need and prepare the ground for our own conceptualization of governance of change that we develop in Chapter 2 of this book. Once this is done, this introductory chapter presents the various case studies presented in the second part of the book.

1.2 SYSTEM, CHANGE AND GOVERNANCE: APPROACHES IN THE LITERATURE

During the past decades many social scientists have analysed the complex processes of science, technology and innovation in their wider context, as phenomena that are intrinsically social, economic and political. In spite of the widespread recognition that these processes are multi-dimensional, the bulk of this literature remains solidly anchored within their own disciplines. In a way, economists, STS scholars, sociologists and political scientists have, each of them on their own terms, developed ‘systemic’ approaches in their efforts to understand the changes and dynamics of socio-technical and innovation processes. Yet, they have done so in different ways. Reviewing this diversity will allow us to take a further step in developing some theoretical pillars about the governance of change in ST&I systems.

Within the field of economics, the notion of ‘system’ was coined by evolutionary and institutional economists in a direct challenge to the lineal process view of technical change suggested by neo-classical economists since the 1950s, which assumed a more or less natural and direct relation between the levels of private or public research investments and levels of innovative performance. Founded on notions of bounded rationality and asymmetric information, the evolutionary economists re-examined the role of technical change in economic growth theory, assigning it a central role, and dismantled the ‘linear’ view (Nelson and Winter, 1982; Dosi, Freeman et al., 1988). Overall, this literature introduced the ideas of evolutionary biology into economics, focusing on variation, selection and retention in the process of technological trajectories and the context conditions under which these processes evolve.

The notion of 'national' or 'regional' innovation systems emerged in the attempt to explain cross-national differences in innovative performance (Lundvall, 1992; Nelson 1993; Braczyk et al., 1998). This was followed by a more knowledge and technology oriented approach under the terms 'technological systems' (Carlsson, 1997) and a more sector related variant with 'sectoral systems of innovation' (Malerba, 2004; Jacobsson and Bergek, 2004). There are some differences, however, regarding the 'narrow' or 'broad' views on systems (Edquist, 2005). Most relevant for us is that some authors put emphasis on the role of institutional frameworks as the rules of the game that shape the behaviour of innovators (Lundvall et al., 2002), whereas others put emphasis on the agents and their inter-organizational relations in networks (Freeman, 1995). As we will see below, this agency-institutional dichotomy on how systems change is not particular to the economic discipline, but extends to other disciplines studying socio-technical and innovation processes.

The literature on Science and Technology Studies (STS) has also dealt with the contextual embeddedness of science and technology in a different, yet related way. We agree with the view that the ontological assumptions of STS and evolutionary economics are 'sufficiently similar' to be considered in the same paper (Geels and Schot, 2010). Drawing from general sociological theories about social action and social systems, particularly from Giddens' structuration theory, the STS scholarly tradition has examined the complex and co-constitutive nature of social action and science-technology. The Actor-Network Theory (ANT) developed by Callon and Latour focuses on the local dimension of technological development through actors and networks co-existence (Callon and Law, 1989; Latour, 2005). This development tends to be local and highly ad-hoc, with large elements of heterogeneity and spontaneously organized processes of 'bricolage'. Another central theory in the field of STS is the social construction of technology (SCOT). In their seminal work Trevor Pinch and Wiebe Bijker study how technologies are developed by focusing on social groups' interactions and the social meanings attached to the development of particular artefacts (Pinch and Bijker, 1987). However, it is worth noting that with some exceptions these two approaches within the STS community rarely make use of the notion 'system'. One might argue though, that beneath their understanding of technological development and change, the STS community shares the understanding that socio-technical systems are social systems formed by actors' interdependency relations, where technology and knowledge are recursively co-constituted and translated into meaningful action (Bijker et al., 1987).

However, one of the major differences between evolutionary-institutional economists and the STS scholarship is the tendency of the latter to focus on the socio-cultural context of socio-technical and innovation systems, in contrast to the more economic and market focus of the former. In other words, in spite of some commonalities in the ontological premises regarding agency and institutional frameworks shaping/being shaped by agency, the disciplinary traditions of the evolutionary economists and sociological background of STS continue to echo in their view of what constitutes the wider context of ST&I systems.

These remarks lead to the observation that in this vast literature there are at least two distinct dimensions through which these scholars conceptually approach the change of ST&I systems. The first dimension has to do with this difference, namely between those who focus on the market and economic context where socio-technical changes and innovation happens, and those who focus eminently on the socio-cultural context of such processes. Likewise, and as mentioned earlier, there is a second fundamental dimension that cuts across this large literature, namely the relative emphasis on the role of agency or on the role of institutions in processes of change. To be sure, agency refers here to the organizations and individuals that are agents of action in socio-technical and innovation processes. Institutions, for their part, are the formal or informal rules of the game constraining and enabling agents of socio-technical and innovation processes. This conceptual clarification, commonly accepted in most of the social sciences, allows us to see the analytical differences between those scholars focussing the analysis on individual agents' behaviour and the actual interactions and networks between them; and those putting the focus on the institutional 'rules of the game' as the main mechanism explaining changes in ST&I by means of changing agents' behaviour on what is possible or not.

These two dimensions must be seen as a continuum, rather than as completely separated axiomatic premises. Most of the literature includes agency and institutions, as well as socio-cultural and economic contexts at once. Hence, the differences in the literature reside on nuance and emphasis, rather than on the inclusion or exclusion of these elements. Keeping the gradual and nuanced emphasis on these elements in mind, table 1.1 illustrates the implicit way in which the literature has treated the governance of change in ST&I systems.

Table 1.1 The governance of change of socio-technical and innovation systems: implicit approaches in the literature

	Economy and market context	Socio-cultural context
Agency centred	Entrepreneurialism	Bricolage
Institution centred	Meta-coordination	Institutional coupling

Starting with the cell on the upper left side in Table 1.1, scholars emphasizing the role of agency and operating in contexts that are seen as primarily of economic and market nature tend to look at the change of ST&I systems as being related to the role of entrepreneurialism. Entrepreneurs are in fact key in Joseph Schumpeter's evolutionary view of the 'creative destruction' (Schumpeter, 2005/1942), later refined by evolutionary economists in the 1980s. Economists following this agency perspective tend to see change as the outcome of agents' intentionality (Cañibano et al., 2006) or the result of an explicit action from innovation networks (Schienstock and Hämäläinen, 2001; Freeman and Soete, 1997). Sociologists have also focused on agents' intentionality. One interesting work in this direction is the study by Hargadon and Douglas on the role of Edison. Their argument is that Edison's entrepreneurship generated change as he created robust designs to make a market breakthrough and the subsequent displacement of existing market alternatives socially acceptable (Hargadon and Douglas, 2001). This 'robust design' approach has been used in organizational studies on how the performance of technology-intensive entrepreneurial firms is affected by the design of their business models as boundary-spanning (Zott and Amit, 2007). Therefore, the literature with this agency/market context perspective implicitly tends to see the governance of change as the fruit of entrepreneurialism, or the specific set of entrepreneurial agents' actions and their successful individual 'design' of strategies of change, primarily taking place in the market place. In other words, governance by strong agents often means that economic entrepreneurs who, by carefully designing the introduction of socio-technical novelties and innovations in the market, in fact actively design the change of the entire system. These entrepreneurs might be strong individuals, like Edison, or strong innovation networks collaborating with the same purpose of change.

The second set of the literature, those stressing the role of agency in a more socio-cultural context, put less emphasis on individual entrepreneurs and more on the agents' collective embeddedness in wider set-ups. This is naturally the case in the ANT and SCOT literatures in the

STS scholarship, mentioned above, where the context of the market and the economy in processes of socio-technical relations and change is overshadowed by the socio-cultural aspects of agents' bricolage in terms of various forms of individual and ad-hoc sense-making by combining different elements. Other scholars in organizational sociology have discussed the central role of entrepreneurs as culturally embedded agents in networks who generate change by processes of path creation (rather than path dependency) (Garud and Karnøe, 2003). This relates nicely to a similar view on agents creating niches in a wider social and knowledge-based context (van den Belt and Rip, 1989). These niches can then become strategic pathways in the overall process of socio-technical change and innovation as they become devices that enable broader technological breakthroughs. This has been particularly stressed and analysed in the area of environmental sustainability and the related management of transitions towards sustainability (Nill and Kemp, 2009). More recently, several possible pathways towards transitions have defined several possible processes of change (Smith, Stirling et al., 2005; Geels and Schot, 2007). From this perspective we can say that these scholars implicitly consider the governance of change as the accumulation of specific successful niche solutions and of agents' bricolage.

The third set of the literature, according to our two dimensions, considers ST&I system changes as the result of transformations in the institutional set-up which is operating mainly in an economic context. This literature has taken the complementarity of different sets of institutions as its main explanatory variable. Inspired by the school of 'varieties of capitalism' in the field of comparative political economy, which looks at different modes of coordinating institutions in capitalist economies (Hall and Soskice, 2001), scholars of innovation systems argue that specific forms of institutional complementarities are behind innovative performance and overall socio-technical change (Coriat and Weinstein, 2004; Casper and Soskice, 2004). This is essentially a national or regional perspective on innovation systems, as these institutions are complementary to each other and to the specific knowledge basis of the industrial specialization in a given territory (Asheim and Coenen, 2006). However, the theoretical assumption that liberal market economies (UK, USA, and so on) innovate more radically than coordinated market economies (Germany, France, Austria, and so on) has been empirically challenged (Akkermans et al., 2009). Closely linked with the institutional complementarities axiom is the recent functionalist turn in the innovation systems literature (Edquist, 2005; Hekkert et al., 2007; Bergek et al., 2008). These authors argue that the institutions in a socio-technical and

innovation system perform specific functions to enable innovation generation and application (Hekkert et al., 2007). Changes in the nature of the system and its performance are largely related to the (transforming) functional dynamics of the institutions in the system. Taken together, it can be stated that the varieties of capitalism and functionalist scholars view the governance of change as the meta-coordination of the institutions' complementary performance in socio-economic terms.

Last but not least, the fourth perspective, the one based on institutional driving forces in a socio-cultural context, has looked mostly at the role of institutions in innovation systems, and conducted institutional analysis of socio-technical change processes. As with the other approaches, this is not a fully-fledged theory of socio-technical change and innovation process, but rather an analytical approach with a meso-level theoretical range. In this sense, this literature looks at 'how the institutional make up of a society impacts on its innovativeness' (Hollingsworth, 2000, p. 595). Other than considering the structure and cohesion of the institutional set-up, Hollingsworth also takes into consideration the structure and culture of its organizations, as a crucial factor in innovation processes. In a similar vein, the transition approach has initially focused on institutionally-driven evolutionary changes in a broad socio-cultural context (Kemp et al., 2001; Geels, 2002). Recent approaches to institutional analysis of innovation systems have a dynamic view on institutions, as not only do they change through time, but they are also subject to strategic action from the part of agents (Rohracher et al., 2008). These authors see socio-technical and innovation system change as 'institutional coupling', a process used by actors for the alignment and embedding of their strategies. This has assisted the authors in bringing their views closer to the transitions approach (Markard and Truffer, 2008), which examines different transition pathways in the system depending on institutional features in the economy and technologies themselves (Dolata, 2009). These scholars have recently started to examine the issue of the governance of the transitions towards more environmental sustainable socio-technical systems (Kern and Howlett, 2009; Shove and Walker, 2010) and they generally see the governance of change in terms of institutional coupling, or the purposive management of the system's overall institutional set-up towards specific and pre-defined collective goals (that is, sustainability).

1.3 THE NATURE OF SOCIO-TECHNICAL AND INNOVATION SYSTEMS

In our initial example at the onset of Chapter 1, we illustrated the main idea of socio-technical and innovation systems. More formally, we can define socio-technical and innovation systems as:

Articulated ensembles of social and technical elements which interact with each other in distinct ways, are distinguishable from their environment, have developed specific forms of collective knowledge production, knowledge utilization and innovation, and which are oriented towards specific purposes in society and economy.

The main elements of a system are new knowledge and technological artefacts, the individual and organisational actors that produce, adopt, diffuse and use knowledge and technological artefacts, as well as the various forms of infrastructure (physical, market, financial, regulatory, etc) that enable that production, adoption, diffusion and use of knowledge and technological artefacts. Crucially, it is the interactions between those elements that constitute the system. These interactions among the constitutive elements of a system are complex and recurring, stabilising the system and creating specific dynamics. While elements of a system interact with other systems, we can nevertheless define boundaries of a specific system, beyond which interactions and inter-relations are less dense and less relevant for the underlying socio-technical system's purpose. This follows Metcalf (2003) in that to understand systems we need to understand that they are not only defined by their components and the information flow between those components, but that the nature of systems and their internal relations are related to their specific purpose (Metcalf, 2003, p. 65).

There is a range of well-known reasons why ST&I systems become unstable, are changing or are under pressure to change. The production of knowledge and innovation itself is inherently uncertain, we cannot know in which direction technological advancement will go. Equally, there is uncertainty and societal contestation as regards the opportunities and threats that new knowledge and innovation offer for users, for producers and citizens more generally. Pressures for change do not only stem from scientific and technological advancement and the effects actors associate with it, but from a change of societal preferences and a re-interpretation of what the problems and opportunities of new knowledge are and to what ends innovation shall contribute to them. This leads to new demands for certain technological solutions or to the discontinuation of

the applications of certain technologies. These demands, however, are often not clear cut and straightforward, exactly because of the uncertain nature of technological and knowledge advancement, because actors and organizations have ambiguous experiences and conflicting expectations themselves as to the contribution of new knowledge and technology to future challenges, and because of the very heterogeneity of societal preferences.

This discussion highlights the importance of the social dimension of ST&I systems. Individuals and organizations have an existing body of knowledge, skills and routines, and they have vested interests, different value systems, take advantage of existing ST&I systems in varied ways and interpret potential change differently. Actors are reflexive, that is, they are conscious about the functioning (or lack thereof) of the ST&I system in relation to its purpose and assign a certain value to its outcomes and elements; all of which has an influence on the way in which society organizes itself, producing and making use of new scientific and technical knowledge. When it comes to change, different stakeholders will attribute different kinds of benefits and costs to new knowledge and innovation, with some actors pushing for change, while others resist, some engaging in change debates, raising their voices and investing resources, while others are passive, choosing not to invest in the debates on change and subsequent change dynamics or are unable to make their voices heard and influence the direction of change. This is a crucial point of departure: the conscious, intentional action of agents, in terms of taking advantage of an existing ST&I system features, in terms of trying to change it, and/or in terms of trying to prevent change from happening.

1.4 THE GOVERNANCE OF CHANGE

As mentioned earlier in this chapter, the literature has generally dealt with the issues of governance of change in the system in an indirect and implicit way. Hence, there remains a considerable conceptual indeterminacy in the literature about what is the governance of change in ST&I systems. Reducing this conceptual indeterminacy of the term will provide a necessary foundation for the development of a conceptual framework to understand governance of change and the subsequent analytical use of the term in the study of this phenomenon.

Our entry point is the origin of the term 'governance' in political science. Despite the diversity of approaches, there are some commonalities in the political science literature on governance. In contrast to the

approach on ‘steering’ by the state, the governance approach of the early 1980s pointed at the fact that an increasing number of empirical cases showed that political institutions have limited capabilities to ‘steer’ because social systems have dynamics that are determined by all kinds of institutional, cultural, technological and other factors. This observation led to another commonality of governance approaches in political science, namely, that systems are not influenced or changed through political institutions alone (as in ‘steering’), but by the interplay of societal and state actors (Benz, 2003; Mayntz, 2003). This means that the boundaries of state and non-state action are becoming blurred (Héritier and Lehmkuhl, 2008; Lyall and Tait, 2005). Some authors tend to see the emergence of new (reflexive) forms of governance as an implicit criticism to specific forms of modern production and social organization (Voss and Kemp, 2006).

To develop our understanding and definition of governance of change in ST&I systems, we want to make two propositions.

First, a general definition of governance must include societal actors, but it must also not neglect the possibility of hierarchical governance mechanisms. Hence, we need to look at two dimensions, namely, the nature of the actors (state or non-state actors) and the nature of the coordination (ranging from hierarchical to non-hierarchical). Table 1.2 represents these two dimensions, depicting the breadth of different modes of ‘governance’. The two by two matrix, obviously, is a heuristic simplification of a much more nuanced picture with gradual moves along both dimensions. It represents what is commonly perceived as the broad notion of governance, or ‘the multiplicity of *all* forms (processes and structures) of collective regulation of issues of societal relevance, ranging from institutionalized self-regulation of civil society to all forms of interaction and coordination of private and state actors and finally including hierarchical action of state actors’ (Mayntz, 2003, p. 72).

Table 1.2 Stylized typology of governance modes

	Driven by state actors	Driven by societal actors
Hierarchical, dominated	Command and control	Oligopoly
Heterarchical, non-dominated	State as primus inter pares	Self-regulation

Our working definition of governance in general is in line with this broad notion, that is, governance as the mechanisms whereby societal actors and state actors interact and coordinate to regulate issues of societal

concern. This definition implies that the role of the state can, in the extreme, be minimal ('self-regulation'). This is close to the definition of Peters who defines governance as a particular form of political steering where public sector and private sector in conjunction are capable of providing direction and control to society and economy (Peters, 2012).

Our second proposition is that we need a concept of the governance of change that puts emphasis on the intentionality of different types of actors fostering (or preventing) change. As mentioned earlier in this paper, economists, STS scholars and political scientists are concerned with different aspects of governance in socio-technical systems in a way that puts little explicit focus on the different modes of governing change (described in Table 1.1), and hence on the different forms of agent's expression of intentionality in the various modes of governance. Naturally, in situations in which state actors are driving forces fostering change in a socio-technical system, its intentionality will be expressed in terms of political and bureaucratic strategies and public statements; whereas in situations in which societal actors drive change, that intentionality might be much more diffused and difficult to grasp. To be sure, in a wide concept of 'governance' like ours, the change in a ST&I system might almost always be 'governed' by one or another type of actors and by interaction of actors. But there might be situations in which the self-regulation of change is done in such a diffused coordinated form and by a widely decentralized number and type of actors without any presence of state-actors, that it might be difficult to determine the expression of intentionality in the 'governance' of the change that took place in that ST&I system. Besides, the intentionality of some actors is naturally always contested and hence, the direction that the governance of change (or non-change) takes depends ultimately on political power and economic dominance.

These two propositions lead us to our understanding and definition of governance of change in ST&I systems. In our view, a basic definition of governance of change in ST&I systems is needed and possible. Hence, our working definition of governance of change in ST&I systems is the way in which societal and state actors intentionally interact in order to transform ST&I systems, by regulating issues of societal concern, defining the processes and direction of how technological artefacts and innovations are produced, and shaping how these are introduced, absorbed, diffused and used within society and economy.

This definition needs four further qualifications. First, and without entering into a long discussion regarding the nature of social ontology, it is important for us to mention that the 'intentional' nature of action does not mean we see actors as rational in terms of utility-maximizing their

interests. What we are saying is that in the processes of governing change in socio-technical systems, agents have different intentions and considerations according to what they see as desirable or non-desirable 'change', and that these intentions and considerations might be anchored in what March and Olsen see as the logic of consequentiality or the logic of appropriateness (March and Olsen, 1989).

Second, we have made a very conscious choice to define governance as intentional interaction (and coordination) towards some end. We concede that many scholars, especially in the STS tradition, have a broader view of governance of change, including all informal and formal interactions of actors that contribute to transformation, no matter if there is explicit intentionality or not. In this interpretation, all interaction that contributes to or influences change – no matter if actors are conscious and intentional about it – still contributes to governance. While we concede that change of ST&I systems can be spontaneous, 'unguided' and 'ungoverned', in our approach we are interested in governance, that is the way in which actors trigger, seek to influence change or avoid change in ST&I systems. This does not preclude that there are change dynamics that are not governed (that is, not driven by intentional actors). But even in those situations, one can fruitfully analyse the absence of intentionality, the absence of any meaningful intention to stop, alter or accelerate change in socio-technical systems, and thus the failure of actors in a system to purposefully shape the future state of a ST&I system. To label 'governance' any kind of social interaction that leads to some kind of change would render the very concept of governance meaningless. As we do not want to understand dynamics of change *per se*, but the way in which change is intentionally influenced, we are compelled to include intentionality as a constitutive element of our governance definition.

Third and related to the above, we speak of governance of change, if the governance has made a difference, if there is some sort of transformation in a given ST&I system. This transformation can be judged 'good' or 'bad' by different actor groups, it can contribute more or less to define and solve societal problems. The normative content of the transformation (that is, the outcome of the governance process) as well as the normativity of the process of governance are matters of judgement and not directly relevant for our definition. What is important is the fact that intentional action has transformed something. However, this includes intentional action to stop change that is underway from happening, that is, the transformation here lies in influencing a trajectory, in terminating a specific opportunity for a system to develop in certain directions,

triggered by advances in knowledge or by interested stakeholder groups or any other trigger.

Fourth, we understand that governance of change, defined as intentional interaction, might produce tensions between actors (Borrás, 2012). Those tensions originate in different material interests, normative values and perceptions of what change means in relation to specific interests and values. This means that the governance of change might ultimately be related to the exercise of certain forms of political power and economic dominance, reflecting actors' differences in their ability to mobilize resources and support when influencing change (or preventing it). In other words, the tensions and contestations are enhanced in the very process of governance, as governance ultimately entails notions of economic dominance and political power. In some countries and contexts (unfortunately not all) the first is based on fair market competition and the second on democratic processes.

1.5 THE CONTENTS OF THIS BOOK

The book is organized in the following way: Chapter 2 outlines the basic concept of three pillars to understand the governance of change in socio-technical and innovation systems. It develops the building blocks for a conceptual framework of the governance of change in socio-technical and innovation systems (socio-technical systems) by identifying three conceptual pillars: the opportunity structures and capable agents, governance instrumentation and democratic legitimacy. These pillars constitute the theoretical foundations on which a set of specific assumptions to understand the governance of change are developed.

This approach sets the scene for the individual case study contributions of the book. This collection represents a broad variety of different socio-technical systems, discussing different manifestations and combinations of the pillars, and different stories of change and its governance.

Arthur Daemmerich's Chapter 3 on anticipatory markets and technical standards in the development of biodegradable plastics argues that standards are instrumental to the co-production of social systems and markets for new technologies. Standards for novel materials can reduce consumer mistrust and strengthen product claims made by manufacturers. Managed by private organizations rather than government agencies, standardization involves negotiations among experts from industry, government and academic institutions. Daemmerich argues that especially in the course of setting standards for new environmental technologies, these agents undertake a process characterized here as anticipatory market

building in which they envision product lifecycles, including raw material sourcing and the manufacture, purchase, use and disposal of products. The case study of BASF's biodegradable plastic Ecoflex sheds light on situations in which the co-production of technology and social institutions is challenged by consumer behaviour which does not align to expectations embedded in the standards. Standardization functions as an open opportunity structure for socio-technical innovation, compared to more rigorous but less flexible environmental or consumer product safety regulation. Technical standardization thus operates as a powerful but flexible instrument for governing change.

In Chapter 4, Allison Loconto and Marc Barbier continue with a focus on standards as governance instruments, focusing on their role in the transition towards sustainability. They start with the observation that a variety of sustainability standards have emerged from social movements that stake claims on different niches in the market for sustainable food and agriculture products. They see the beginning of a transition towards a regime of 'certified sustainability' which is characterized by the use of standards to govern agri-food systems and a second layer of standards to govern the standards. They ask how this regime is constructed and how standards are used to govern the transition to sustainability. Drawing upon a case study of the International Social and Environmental Accreditation and Labelling (ISEAL) Alliance's assurance code development process, they highlight the framing practices that characterize the shape of a multi-layered governance of 'governing by standards'. They discuss how the framing of certified sustainability opens up new issues like the relationship between credibility and legitimacy, the embodiment of skills in auditors or the call for evidence-based systems in order to tame risk.

Chapter 5, by Barberá-Tomás and Molas-Gallart, addresses the dynamic relationship between regulation as a governance instrument and technological change. More particularly, the authors focus on health regulation instruments and their role in shaping the dynamic evolution of medical technologies. By looking at the evolution of a specific technology (hip prosthesis) in the US, they show a dynamic relationship between technical change and regulatory frameworks. Regulatory frameworks are key instruments for the governance of change in socio-technical systems, but the previous literature has typically addressed it from a static perspective. Chapter 5 looks instead at the dynamic interplay between regulatory frameworks and technical change from the perspective of a product life cycle approach. Their case study shows how regulatory frameworks based on assumptions about how radical and incremental innovations are related to risk, lead to undesirable and

unexpected outcomes. The history of the hip prosthesis shows how incremental innovation can become riskier and ultimately fail once a technology has entered the mature stages of its evolution. The regulatory framework, which was biased in favour of incremental innovation, prevented more radical innovations in product development.

Stegmaier, Kuhlmann and Visser take a different perspective when looking at the change of systems. They do not focus on the emergence of a new system, but on the governance of the discontinuation of socio-technical systems or regimes. Their lead question is how discontinuation governance targeted at socio-technical systems or regimes can be grasped in its quality and scope. To answer this question, they develop an understanding of 'discontinuation' as purposeful governance action *sui generis* in socio-technical contexts. Their contribution aims at a theoretically driven analysis in the context of science, technology, innovation and policy studies (STIP) and governance and policy studies, looking for junctions and gaps from which the concept 'governance of the discontinuation of socio-technical systems' can be further developed. Stegmaier, Kuhlmann and Visser develop a heuristic of how socio-technical systems can be brought to a halt. They illustrate their approach with the example of the deliberate, purposeful exit from the production and/or usage of incandescent light bulbs in the EU within the framework of the European Commission's eco-design directive.

In Chapter 7, Translational Research: entrepreneurship, advocacy and programmatic work in the governance of biomedical innovation, Vignola-Gagné, Biegelbauer and Lehner focus on change not of entire socio-technical systems, but of key components of those systems, that is, the experimental and organizational practices in research programmes and organizations. Based on empirical case studies of biomedical innovation systems reform they trace the role of selected parameters in this process of transforming existing practices, namely: (1) programmatic statements; (2) their advocacy by entrepreneurs and (3) their interplay with existing and new policy instruments in explaining the governance of socio-technical change. Chapter 7 thus focuses on purposeful actors and research programming as an instrument to drive this change through learning processes. By doing so, the authors add some explanatory power for socio-technical change where policy design and implementation are defining parameters of the process.

Finally, in Chapter 8, Delemarle and Laredo investigate the processes of governing radical change as the development of accepted market infrastructure in an emerging technology, nanotechnology. They conceptualize market infrastructures as the necessary conditions for change, which are in turn developed through the interplay of rules, values and

norms. They argue that the market infrastructures are constructed in a number of different but inter-connected arenas, which they define as settings in which ‘individual and collective actors interact to define the cognitive and normative dimensions of a problem’ (Bonneuil et al., 2008, p. 204). The authors look at five arenas in nanotechnologies, that is, a standard setting body, a working party in the OECD, the international Council on Nanotechnology, the European Code of Conduct for responsible nanosciences and nanotechnologies research and NanoREACH. Delemarle and Laredo show how the market infrastructures developed in the various arenas together form the overall novel governance architecture which then determines the overall direction – and the limits – of market development and change. Chapter 8 develops an exploratory concept to understand what determines the success of arenas to contribute to the overall governance architecture to establish markets for emerging technologies. In doing so, it contributes to a better understanding of the legitimacy and effectiveness of governance processes and instruments.

In a final concluding essay in Chapter 9, Borrás and Edler reflect on how the various chapters mobilize and further enrich the three pillar framework, and how on that basis the theoretical concept should be developed further in the future.

NOTE

1. This book studies the governance of change in socio-technical systems and in innovation systems. For easier reading, the rest of the book will refer to ST&I systems. Occasionally the book might refer only to ‘socio-technical systems’ or ‘innovation systems’. However, it is the intention of the authors to include both systems as an object of study in the conceptual framework put forward by this book.

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