Chapter 1
Innovation Policy and High-Tech Development: An Introduction

Johannes M. Bauer, Achim Lang, and Volker Schneider

1.1 Introduction

The continued prosperity of high and medium income countries hinges on their ability to sustain comparative advantage through continuous innovation. Advanced technologies are an important component of such strategies, but the conditions for successful policies supporting them are undergoing rapid transformation. A widely shared view holds that, in a globally interconnected economy, routine and low-skill production activities will be relocated to low-cost emerging economies. Sustaining high living standards in high-income countries will depend on a strong presence in knowledge-intensive, cutting-edge industries. National and regional governments are therefore actively facilitating the development, production and application of advanced technologies. In the aftermath of the economic recession that started in 2008, national governments have further intensified their efforts to promote industries with high knowledge content.

However, advanced technology industries are organised in more complicated ways than this policy orthodoxy recognises. As Saxenian (e.g., 2007, p. 660) documents aptly, high-tech activities have become internationally mobile and are migrating to emerging economies. A growing number of entrepreneurs from Silicon Valley and other centres of leading edge technological innovation are repatriating to their countries of origin, including Taiwan, India, China, and Israel. More and more multinational firms, including industry leaders such as Nokia, locate parts of their research and development operations in emerging economies. These changing global conditions, in addition to the intrinsic challenges of continuous innovation in

J.M. Bauer (✉)
Michigan State University, East Lansing, MI, USA
e-mail: bauerj@msu.edu

A. Lang • V. Schneider
University of Konstanz, Konstanz, Germany
e-mail: achim.lang@uni-konstanz.de; volker.schneider@uni-konstanz.de

J.M. Bauer et al. (eds.), *Innovation Policy and Governance in High-Tech Industries*,
DOI 10.1007/978-3-642-12563-8_1,

high-tech industries, create daunting challenges for high-tech policy. Governments of advanced industrial countries and emerging economies are applying a broad spectrum of policies to support high-tech innovation, many of which are ambitious and risky. Whereas some may succeed, many may not bring the expected outcomes. The complexity of policy coordination and the conditions of successful high-tech policies are the main concerns of this book.

In this introductory chapter we will outline high technology development and related policies, the object of our investigation, and the broad analytical frame and the various methodological approaches that the contributions to this book are using. In a first step, we will discuss the topic of high-tech industries and the various efforts to conceptualise and measure this intricate complex. In a second step, we will present a systemic and actor-centred analytical framework in which governance and the challenges to policy coordination are key concepts in the study of advanced innovation processes and technology development. In a final step, we will give a preview of the different sections and chapters of this book.

1.2 Conceptualizing and Measuring the High-Tech Complex

After a relative lack of interest during the 1990s, innovation policy is experiencing a rejuvenation, as indicated by national and international initiatives to design forward-looking and comprehensive policy programmes (OECD 2010b). Surveys by the Organisation for Economic Co-operation and Development (OECD) reveal that practical policy is slowly becoming more aware of the complex coordination tasks of innovation policy, although not all countries have succeeded in developing workable approaches (OECD 2005). Early attempts at supporting innovation relied on a "linear" model, assuming that support for basic research was sufficient and would translate into applied research and development (R&D), and eventually into innovations that could survive market tests (Braun 2008; OECD 2005).

When research and practical experience suggested that this model might not reflect the dynamics of innovation sufficiently well, a second generation of approaches evolved during the 1980s: the national systems of innovation framework (Lundvall 1992; Nelson 1993; see also Werle, Chap. 2). This framework paid more attention to the systemic interactions between stakeholders and areas of policy. Nonetheless, many of the policy recommendations were generic and did not particularly well take the unique nature of national systems into account (Dodgson et al. 2010). With the continued development of technology, the weaknesses of the national systems approach have become more visible, contributing to the beginning of yet another theoretical extension. Many of the new efforts are inspired by systems theory and the theory of complex adaptive systems (Ahrweiler 2010; Frenken 2006). Most importantly, the challenges of coordination, typical for many advanced technology projects, were recognised. Systems theory is open to the possibility that multiple constellations of private and public sector roles are feasible that are capable of generating good innovation performance. The emerging "third generation" innovation research and policy therefore shifted the emphasis even further to the challenges and mechanisms of coordination, including the potential limits of governance.

The distinction between high-tech and other industrial activities and the relative standing of countries in high-tech industries is not clear-cut and can be operationalised in several ways. A generic definition of high-tech products, services and industries relies on the relative importance of scientific knowledge in the production process and/or the specificity of a product. Until the 1970s, most national statistics and international statistics generated by the OECD relied on input measures, such as the amount spent on basic research and development (Godin 2002). Up until the 1970s, only the U.S. made reasonable efforts to classify such industries. An early classification of industries as high, medium, and low-tech was based on U.S. conventions and was later modified to reflect the conditions of other countries. Because of the conceptual weaknesses of input-based data, the OECD started to also collect output-based data in the 1980s, including data on patents, the technological balance of payments (TBP) between countries, and trade in high-tech products and services. Each of these indicators has conceptual strengths and weaknesses, but they continue to form the backbone of the OECD's biannual publication of Main Science and Technology Indicators. Based on the share of resources spent on research and development, the OECD classifies sectors into "high-tech" (with a R&D intensity of 8.5% or higher) and "medium-high-tech" (with a R&D intensity of more than 3.5% but less than 8.5%). In international trade statistics, the OECD also uses a product-based definition (see Table 1.1). Industry and product-based definitions, however, do not yield the same results, so that aggregation from products to industries is not possible. Sector and product-based

Table 1.1 Alternative high-tech and innovation indicators

	First generation		Second generation	Third generation
	Sector	Products		
Main focus	Inputs	Inputs	Inputs, outputs	Multiple indicators
Examples	Aerospace technology, artificial intelligence, biotechnology, energy, nanotechnology, robotics, optoelectronics, telecoms, nuclear physics, instrumentation	Aerospace, computers and office machinery, electronics, pharmacy, chemistry, scientific instruments, electrical machinery, non-electrical machinery, armaments	Patents, technological balance of payments, international trade in high-tech products	Patents and trademarks, new to market innovators, modes of innovation, collaboration in innovation, clusters, innovation hotspots

Source: Godin (2002), OECD (2010a)

approaches have become very influential in international comparisons. Often the global competitiveness of a country is judged solely on the share of these sectors in its exports.

However, the concept of treating whole societal sectors as more or less advanced has come under increasing criticism. Research points to the fact that most advanced technologies develop as complex and interrelated systems, in which some parts may be highly advanced and cutting edge, but other parts may use low-tech components with important complementary functions. For example, advanced computing systems may be composed of massive parallel arrays of processors that in and of themselves do not qualify as high-tech. There are also sectors that are overall classified as low-tech in which highly advanced technologies play an important role. For example, agriculture may use sophisticated communication systems to coordinate business processes. Moreover, important synergies and interactions exist between high-, medium-, and low-tech industries. Hauknes and Knell (2009), in a study of the direct and indirect flows of knowledge between different knowledge-intensive industries, show that such industries are complementary to each other. Knowledge exchange between these segments is essential for the production, diffusion and use of technology. Countries with a presence in all segments may therefore do better than countries with only a presence in high-tech.

However, neither input nor output-based measures fully capture the processes of innovation and technology development in various sectors that constitute modern economies. Many advanced technologies, products and services require the complex combination of multiple technological artefacts and components, and hence, the collaboration of multiple specialised firms from various sectors at different levels.

Useful conceptual schemes of various technology configurations and their combination possibilities have been proposed by Shenhar (1993) and Hobday (1998). Their multidimensional perspectives extend the conventional system perspective, in which systems consist of components and relations that are separated from environments (Bunge 1996), into a "system-of-systems" perspective, with multiple layers and various degrees of nestedness (Maier 1998). Figure 1.1 outlines this multi-level perspective in a two-dimensional space. Technological products are distinguished with respect to their sophistication (horizontal axis) and with respect to their systemic levels (vertical axis).

Shenhar (1993) differentiates between low and high technology not just on the basis of R&D input but also through qualitative criteria relating to specific features of advanced technologies such as novelty and technological uncertainty. Low-technology products are based on established technologies, whereas medium-technology products incorporate some new features. High-technology products consist mostly of recently developed technology, such as advanced computing hardware, and software or new biotechnologies. In addition, there are super high-technologies that are based on completely new artefacts, skills and materials. Super-high-tech also involves high levels of uncertainty, risk and new investment (e.g., spacecraft and satellite systems).

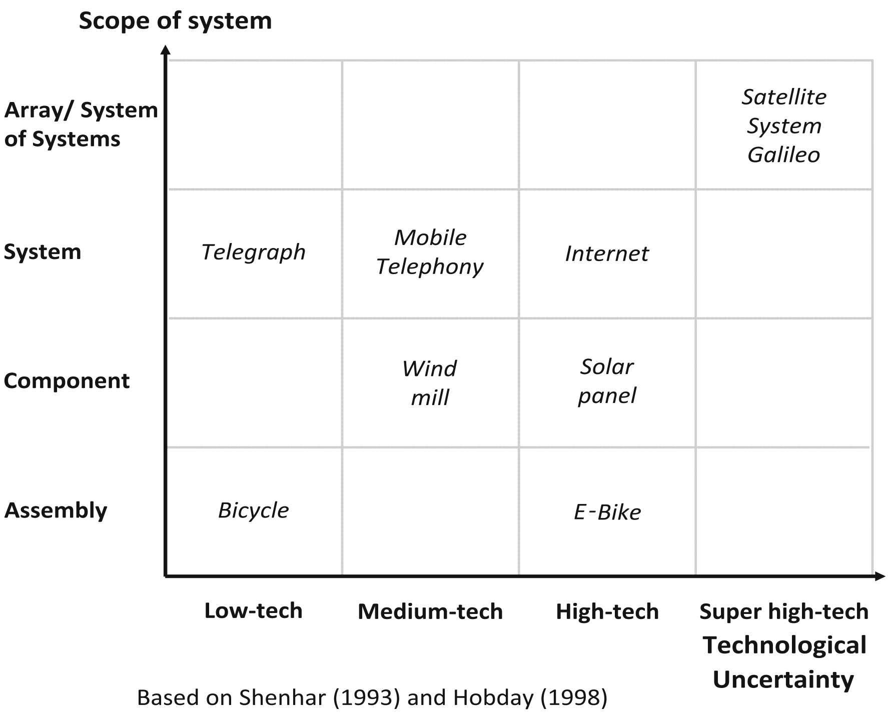

Fig. 1.1 Types of technologies

The vertical dimension differentiates between levels of integration. An "assembly", the category at the lowest level, is a mass produced stand-alone product that performs a single function and is not a part of a wider system (e.g., a bicycle) unless it is connected by a network. By contrast, components are always embedded and functionally integrated in a larger system. Systems integrate components, relations, control mechanisms, and are built to perform common goals (e.g., communication, defence). Finally, an array is a system of interrelated or nested systems, each performing independent functions that are integrated into a common super system (Hobday 1998).

This nested systems perspective acknowledges that the degree of "advancement" of a technology is not only related to the sophistication of its individual components but also to the complexity of its relational and functional integration. A technological masterpiece thus is not only demonstrated by the construction of its various parts but also through the coordination and integration of a heterogeneous complex of multiple components and subsystems into an overall super system. Super-high-tech systems of this kind may be airplanes (e.g., the Airbus 380), supersonic transport systems, or satellite navigation (e.g., GPS, Galileo), but can also be smart cards used in the financial, security, and health sectors which integrate hybrid systems. In this view, technological advancement does not only relate to technological artefacts in the narrow sense, but also includes arrays and networks of social technologies, such as organizational patterns, logistical systems, and complex forms of social coordination.

Since the 1980s, such integrated technological systems have also been conceptualised as "large technical systems" based on multiple technical and social components. These structural features – social and technical heterogeneity and interdependence – have specific implications for their developmental logic (see Hughes 1983; Mayntz and Hughes 1988; Coutard 1999). In order to gain "momentum" and "viability," these systems have to solve a number of critical problems ("reverse salients") which generally requires governmental support (Hughes 1983). Early examples of state sponsored large technical projects can be found centuries ago, but focused support on most advanced technologies are symbols of the technology race since World War II, of which the most famous projects have been the Manhattan Project and the Apollo Program (Steinberg 1985).

Since the 1970s and 1980s, such strategies of "High-tech Colbertism" have proliferated among some advanced industrial countries (Cohen 1992). Governments have provided support for advanced technological projects, and new programmes to promote high-tech have emerged during the past decade. Examples include initiatives to promote the deployment and use of (then) state-of-the-art communications systems, such as the French Minitel initiative in the 1970s or the German *Bildschirmtext* (BTX) project (see Dutton, Schneider and Vedel in this book). Similarly ambitious projects have been the Concorde or high-speed rail. Some of the projects have not succeeded (e.g., BTX), some only in a limited way (e.g., the Concorde), and others in a fully unanticipated fashion (e.g., the emergence of the Internet from the early research funded by the U.S. Department of Defense).

A third aspect of high-tech activities is the vital contribution of advanced crosscutting infrastructures (e.g., information networks and systems) that support and enable other economic and social activities. Infrastructural systems are not like other conventional societal subsystems, such as economy or health, but are general purpose technologies on which the operation of many other systems hinges. For instance, advanced computing and communication networks are a prerequisite of innovation processes in many other sectors, ranging from advanced logistics to sophisticated financial services. A high-tech economy is critically dependent on these infrastructures and their near-universal availability. Röller and Waverman (2001) have found that information and communication technologies have the highest impact on productivity growth if they are widely diffused throughout the economy. These findings are also compatible with a new complexity perspective on growth and development economics in which diversity and product ubiquity, rather than sectoral specialization, are the key to competitiveness and successful economic development (Hidalgo et al. 2007).

Complex linkages between economic sectors and communication, transport and energy infrastructures are important prerequisites for innovation in general, and high-tech innovation in particular. Advanced data centres, for example, need a reliable high-quality energy supply. Not only material assets are needed, as education and continued professional training also could be considered immaterial

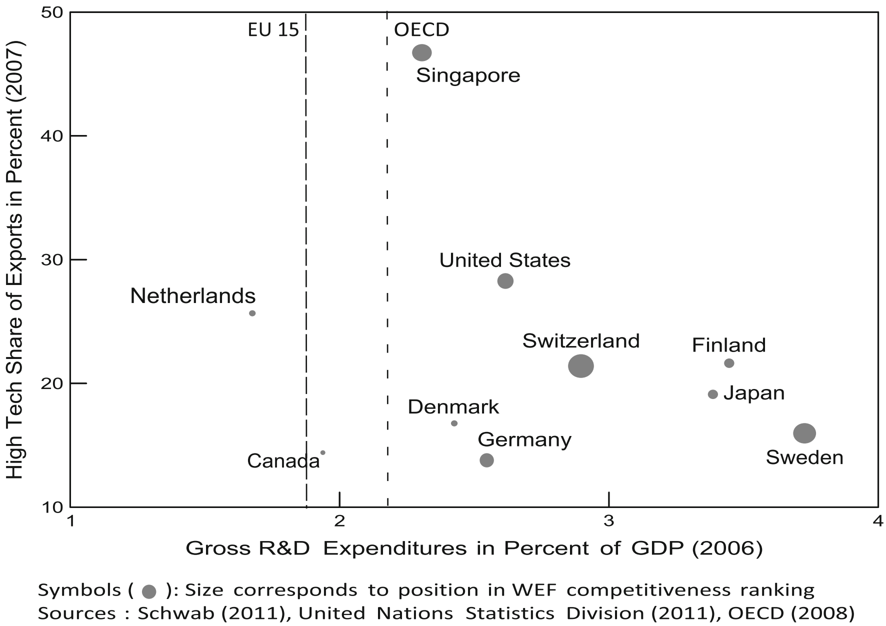

Fig. 1.2 R&D intensity and high-tech export shares (Schwab (2011), United Nations Statistics Division (2011), OECD (2008))

infrastructures. Whereas the systemic view of high-tech emphasises the pervasive complementarities between different economic activities, the infrastructure perspective highlights general preconditions for high-tech policy. Projects such as high-speed railways, the introduction of a new health identification card, or the wide deployment of e-government could consequently be seen as high-tech activities, even if they do not meet the R&D intensity thresholds used in the narrow product-based definition.

The relationships among these variables are more complex and multifaceted than linear statistical models can show. Contributors to this book thus use the case study method extensively. Several of the countries depicted in Fig. 1.2 are covered in-depth by examining high-tech sectors and policy programmes (particularly Germany, the United States, and Switzerland).

1.3 High-Tech Policy and Governance

The central theme of this book is how governments support high-tech industries and to what extent they succeed. Which strategies and programmes do they initiate in different economic sectors and at different socio-political levels? Which particular policy measures and instruments are applied, and which governance mechanisms are used to coordinate the growing spectrum of activities? However, a concentration on governmental activities alone would exclude many actors and contexts that are important in the innovation policy domain. During the last few decades, the policy perspective was thus extended to non-governmental actors and civic institutional mechanisms. When, for instance, policy analysis discovered that many governmental programmes had failed due to policy implementation problems, the focus shifted to specific governmental and non-governmental actor constellations in policy programmes (Mayntz 1983). When it was discovered that coordination and implementation problems could be avoided if private stakeholders were incorporated into the process of policy-formulation, the traditional state-centric actor constellation in policy-making perspective was broadened to the more inclusive governance perspective (Mayntz 2003; Schneider and Bauer 2009). In view of politics and society, policy networks play a major role in public policy-making and societal self-regulation (Scharpf 1997; Kenis and Schneider 1991). Governance is largely conceived as the process of governing, including all relevant actors and policy instruments that are involved in private and public policy-making. The major advantage of this concept is to provide a general framework to cover the broad array of actors and institutional arrangements by which the coordination, regulation and control of social systems and subsystems is enabled and facilitated.

1.3.1 Metatheory

Policy analysis and governance studies are research fields or research agendas rather than approaches. Both are primarily defined by a given research object and do not necessarily imply specific theoretical orientations. Recent overviews of the literature show that the landscape of policy theory is quite diverse and inclusive (Sabatier and Weible 2007; Schmidt 1993; Schneider and Janning 2006). Theories range from "grand theories" to "middle-range theories" and even "single-item theories" (Bunge 1996). The first group includes theories such as systems theory, institutionalism, and rational choice, to name but the most important ones. All of these grand architectures assume general laws in society and political life that account for all social phenomena, regardless of sectors, levels, and subsystems. The second group restricts its explanations to specific societal domains, such as specific governmental institutions, the interaction between interest groups and the state, or specific policy areas. Single-item theories – the third group – are focused on particular socio-political phenomena. For instance, the party difference hypothesis assumes that policy outputs are largely determined by party orientations of governments (Schmidt 1993).

In search of better explanations, many studies use approaches or frameworks that combine multiple theories and analytical perspectives. Widely accepted are the "Institutional Analysis and Development" approach (Ostrom 1999), the "Actor-centred Institutionalism" (Mayntz and Scharpf 1995), and the advocacy coalition framework (Sabatier 1988). Whereas the first two approaches stress actors, choice and institutional constraints in policy-making, the advocacy coalition framework emphasises policy discourses and belief systems.

Another framework that is broadly used in innovation policy studies is the "innovation systems" approach, which combines some middle-range theories in the area of science, technology and innovation studies in a fruitful way (see Werle, Chap. 2). Similar to the above mentioned institutionalist approaches, it tries to take into account major actors and institutional frameworks through which innovation is driven and policy-making is shaped. Main components of innovation systems are governmental institutions, public and private research organisations, firms and business associations, as well as networks between actors and institutions (OECD 1999). More refined perspectives also integrate consultancy firms, professional societies and industrial research organisations into the picture. These operate as intermediary institutions between industry and academic research (Metcalfe 1995). An innovation system's "organizational ecology" is populated by all actors and institutions that are involved in the production, accumulation and diffusion of knowledge, in education and training, technology development and its regulation (Kuhlmann et al. 2010). The regulatory policy space includes all actors shaping regulatory norms and standards, not only government, political parties and associations, but also relevant media. Since innovative technologies and their regulation are also affected by public discourse, innovation studies must take media actors into account, as they can play supportive but also obstructive roles in technology development (see Waldherr, Chap. 4). The innovation systems approach thus provides a rather inclusive and heterogeneous perspective on technology development. Several chapters in this book will apply this complex systems perspective.

1.3.2 Methods

With respect to methods, the state of the art in public policy analysis and governance studies is also manifold. It varies in two dimensions: qualitative versus quantitative studies, and Large-N versus Small-N studies. The strength of case studies is to study political processes in great detail in order to uncover causal mechanisms and complex context conditions. In policy analysis, case studies usually open the black box and trace policy developments from problem perception to agenda-setting, decision making and implementation of political programmes. The chapters on high-tech policy in Switzerland and in the U.S. adopt this approach.

Large-N studies as a rule use quantitative methods to test for the effects of one or more independent variables on a given policy outcome, controlling for the variation in context conditions. Fink's contribution to this book, for instance, uses this method to test for the relationship between the strictness of embryo research laws and innovation in the biotechnology sector. Most chapters in this book are small-N case studies or even concentrate on a single case. The recent methodological debate highlights the epistemic potential of case studies: They are not necessarily restricted to mere descriptions and hypothesis development but can also be used in an explanatory manner if they identify a supposed mechanism or trace a specific process pattern (Gschwend and Schimmelfennig 2007). From a mixed method perspective, case studies may also be combined with quantitative methods, as emphasised in the “nested analysis” approach (Lieberman 2005).

A particular mixed method type is the application of “social network analysis” to public policy-making, innovation and technology development. This approach is increasingly used also in the area of innovation, science and technology studies (Pittaway et al. 2004). Inquiry in this perspective concentrates on the relational dimension of the actor system and traces the exchange of resources, flows of communication, information diffusion, membership to policy committees, and other types of influence vectors. Policy network studies are quantitative case studies because their analysis concentrates on single cases (a policy domain or a policy process) which are studied in great detail at the level of actors and relations. Lang and Mertes (Chap. 11) and Dutton, Schneider and Vedel (Chap. 3) use this method.

1.3.3 Analytical Framework and Key Concepts

In the preceding section we presented a multi-dimensional view on high-technology development and high-tech sectors. A major point was that high-tech products and sectors cannot be reduced to isolated metrics and market segments, as their development and evolution is always embedded in complex “product spaces” and cross-cutting infrastructures.

The complexity of such product spaces is in most cases accompanied by complex organizational settings in which a myriad of organizations from different policy domains – such as education policy, research policy and economic policy, to name just a few – are involved. The technological and social complexity of innovation processes potentially constrains and undermines the feasibility of innovation governance. If the degree of complexity is too high, governance, seen as the coordination and regulation of interdependent organizations (Rhodes 1996) aimed “to craft order, thereby to mitigate conflict and realise mutual gains” (Williamson 2000), may be difficult or impossible to achieve. Moreover, the outcomes of governance decisions, even if they can be effectively coordinated, may be difficult to anticipate. Governance in highly complex systems, therefore, is, to a certain degree, experimentation.

Complexity theory provides an analytical framework to conceptually integrate these complex social settings. It focuses on the interdependence and adaptation of systems, and on the creation of order that makes it particularly suitable for analysing innovation policy and governance (Schneider 2012). Complexity theory first emerged in the natural sciences and then quickly diffused into other research fields such as economics (Arthur 1994; Beinhocker 2006) and sociology (Sawyer 2005). It emphasises self-organization processes in diverse research applications such as the evolution of species (Kauffman 1993), the emergence and coordination of collective action in bio-populations (Strogatz 2003), and the growth of network infrastructures such as the World Wide Web (WWW) and air traffic (Barabási 2002, 2003; Newman et al. 2006).

Most approaches within complexity science consider four basic elements (Bunge 1996; Butts 2000, 2001): (1) the number of parts of a system (the composition); (2) the relationships between elements of the system (the structure); (3) the relationship to external systems (the ecological dimension); and (4) the roles and positions of elements within and between systems (the function). The totality of the parts of a system indicates the number of subsystems that make up the larger system. The structure formed by the parts of the larger system includes the number and types of links between the different parts of the system. In political terms, these links can be interpreted as influence functions. These are modelled by political economists who measure the lobbying success of one interest group, given its lobbying efforts, in relation to other interest groups' lobbying efforts (Becker 1983). Another example is the advocacy coalition framework that focuses on changes in belief systems by inter-actor learning mechanisms (Sabatier and Weible 2007). From a governance perspective, links between actors denote mechanisms through which they mutually coordinate their behaviour. Basic coordination mechanisms include observation, influence and bargaining.

The relationship between different systems designates the interdependence between systems (the ecology of systems). Changes in one system trigger or inhibit changes in other systems. In the ecological dimension, the concept of interdependence plays a major role. Thompson (1967) distinguishes three forms of interdependence: pooled, sequential, and reciprocal. In a *pooled* interdependence setting, each subsystem contributes to the final outcome without the need for direct interaction and coordination between them. Total output is simply the sum of individual outputs (Saavedra et al. 1993). *Sequential* interdependence refers to settings in which each system performs a different role and performs different tasks. Total output requires the sequential task accomplishment by each system. Here, coordination of tasks is essential, although outputs flow only in one direction. Pooled and sequential interdependence are basic tenets of the varieties of capitalism approach that assumes complementary institutional settings that mutually account for each other's weaknesses (see Werle, Chap. 2). Sequential interdependence can also be found in many governance settings, when administrative and policy coordination is carried out by different actors at different points in time (see Wassermann and Fuchs, Chap. 10, and Lang and Mertes, Chap. 11).

In a social setting with *reciprocal* interdependence, each subsystem produces outputs that become inputs to other subsystems. Reciprocal interdependence requires high role specification and coordination of task. Role and functional differentiation is another dimension put forward by complexity theory and network science (Butts 2001). Most chapters in this volume deal with some kind of interdependence and role and functional differentiation. Orlowski (Chap. 7) explores the role differentiation in the German high-tech advisory network, while Lang and Mertes (Chap. 11) explain the delayed implementation of the German e-health card by invoking missing functional differentiation. Dutton Schneider and Vedel (Chap. 3) model different types of interdependence as an ecology of games.

Complexity issues are ubiquitous in innovation policy and governance. Supportive policy programmes affect a broad array of actors in different policy domains with diverse institutional backgrounds. Governmental agencies may be affected because they occupy important functional roles and positions in the political division of labour. Business firms and interest groups are mostly concerned about intended and non-intended effects of a policy initiative. Policy measures generate "stakes" in which social, economic, and political actors get interested and mobilised. Stakeholders strive for policy engagement, but their specific involvement is often constrained by institutional factors. Diverse political systems provide different opportunities for participation and policy involvement. In countries where policy areas are more differentiated (research policy, industrial policy, etc. versus an integrated innovation policy domain), political battlefields get populated by more numerous and heterogeneous actors. Diverse policy domains in general imply "competing rationales" based on different histories and institutional practices. Different ministries, for instance, have different views of innovation policy, its nature and its role (OECD 2005). As shown in the contribution of Dutton, Schneider and Vedel (Chap. 3), these competing logics of policy-making can be conceptualised as an "ecology of games." In this ecology, multiple games are simultaneously played in decision-making and resource mobilization. Policy outputs emerge in a largely uncontrolled and spontaneous way. Another factor that increases policy complexity is the recent transformation of modern political systems towards a "regulatory state" (Majone 1994). The creation and proliferation of more and more agencies increases fragmentation and segmentation of policy areas (Schneider 2004).

A logical consequence is that policy actors become more heterogeneous and interest fissures get multiplied. Policy-making takes place in multi-actor arenas (Kuhlmann 2001; Edler and Kuhlmann 2008). In reaction to this diversification and heterogeneity, governments have to put more and more emphasis on policy coordination to avoid redundancy in resource allocation, inconsistency in policy actions and multiplication of interest conflicts (Braun 2008).

Based on particular institutional traditions and policy-making styles, national governments use different social technologies for policy coordination. Since neither spontaneous adaptation nor hierarchical top-down control alone works, governments promote alternative and new forms of governance such as "networks" or "bargaining systems" in which common goals and strategies are bargained and deliberated (Scharpf 1997; Kenis and Schneider 1991). Coordination systems are often constrained by their size and scope: In small systems the actors may discuss and explore all policy options (positive coordination). However, because of time and resource constraints, such inclusive strategies are impossible in large coordination systems. As it was observed by Scharpf (1997) in German policy making, in large actor systems bargaining and debate often is reduced to a subset of policy options which imply no negative externalities on actors with veto powers (negative coordination).

In the recent literature, such arrangements have also been called forms of "collaborative governance," which is an "arrangement where one or more public agencies directly engage non-state stakeholders in a collective decision-making process that is formal, consensus-oriented, and deliberative and that aims to make or implement public policy or manage public programmes or assets" (Ansell and Gash 2008). In these networked forms of governance, governmental authorities at regional, national and supranational level play an important and sometimes central role, but not a "commanding role". Often their role is reduced to mediation and facilitation (Kuhlmann 2001).

1.4 Contents of the Book

This book aims at sharpening the understanding of researchers and policy makers for the complexity inherent in high-tech policy and the challenges it implies for policy design and implementation. To this end, the book is organised in four parts. In part one, the state of research on innovation systems and technology development is critically reviewed and new analytical perspectives are introduced. The contribution by Werle overviews and discusses the strengths and weaknesses of three conceptual approaches, and sets the state for a more comprehensive approach drawing on recent developments in comparative political economy, innovation studies and the sociology of socio-technical systems. The national innovation systems literature focuses primarily on R&D efforts by business firms, public sector and government actors, and the research and education communities. The "varieties of capitalism" (VoC) literature in comparative political economy acknowledges the systemic nature of innovation processes too, but underscores differences in institutional systems that promote distinctive types of innovations. Werle challenges the view often articulated in this tradition that liberal market economies tend to produce radical changes and novelties, whereas coordinated market economies provide favourable institutional conditions for incremental innovations. Techno-sociological institutionalism, the third perspective, understands technology development and innovation as a result of coordinated interaction in which various modes of governance – market, network and hierarchy – come into play. Based on the strengths and weaknesses of these approaches, Werle proposes an extension towards more differentiated and multi-level perspectives emphasizing the co-evolution of technology and society.

New theoretical perspectives in the analysis of innovation and technology developments are introduced by Dutton, Schneider and Vedel, as well as by Waldherr. This expanded view more explicitly recognises complex and inclusive networks of public and private institutions shaping technology development in high-tech sectors. Emphasis is put on the multi-layer nature of coordination processes and the nestedness of systems. Innovation policy is modelled as an intervention by public authorities and private collective actors attempting to influence technological change. So defined, innovation policy also includes elements of other policy fields, such as infrastructure policy, R&D policy, industrial policy, and technology policy. The unique lens of this approach allows conceptual advancements regarding the nature of innovation systems, the underlying knowledge creation process, and the role of the media in framing the debates on high-technologies, thereby shaping expectations in innovation processes and appropriate policy action.

Ecological thinking in the social sciences is a promising theoretical perspective on the construction of order and change in technology development, inspired by various branches of biology and environmental sciences. Ecosystem ideas and related concepts to change and adaptation are applied to social and technical systems. Ecologically inspired models put emphasis on: (1) the dynamic interdependencies and interactions between diverse actors; (2) the multiplicity of relations between the components and outcomes of these systems; and (3) the existence of multiple and relatively autonomous layers and levels in such systems, along with the emergent relations between these levels.

In the social sciences, most of these approaches have been developed in the sociology of organizations (population ecology of organizations; organizational ecology). In the political sciences, such approaches were applied to understand the development of local communities, policy sectors and interest group systems. A subtype of this perspective is the concept of an "ecology of games," which emphasises the complexity of nested (public and private) decision-making processes in the context of social and technical interdependencies and related conflicts. The contribution of Dutton, Schneider and Vedel demonstrates the fruitfulness of the "ecology of games" perspective as a framework for the study of technology development in the communications and information technology sector.

The chapter by Waldherr explores the influence of the mass media on high-tech policy decisions in innovation systems, a perspective that is missing in most innovation studies. Her article shows from a process, a functional, and a structural perspective that mass media are highly relevant actors in innovation systems and therefore also need to be considered as critical variables in political processes leading to high-tech strategies. From a process perspective, the mass media are influential in technology development by creating awareness of innovations, and even more in the attribution process by labelling new technologies as innovations. From a functional perspective, the mass media's impact on important functions in innovation systems includes coordinating functions like knowledge diffusion, selecting functions like guidance of the search, and legitimacy creation for new technologies. In a structural perspective, the mass media are seen as an important communication forum in the public sphere, mediating between the political, the economic and the research subsystems of society.

Part two of the volume explores the variety of governance mechanisms and public policies utilised in national, as well as sectoral, innovation systems. It looks at institutional settings in high-tech industries and highlights commonalities and differences among them. The German system of innovation is juxtaposed with that of two of its most successful competitors, namely the United States and Switzerland. These in-depth case studies yield a detailed analysis of the overall approaches pursued in these nations.

The U.S. has long been seen as a liberal market economy whose national innovation system is particularly geared toward radical innovation. Bauer presents a more multifaceted analysis. Whereas the U.S. did not have an overarching innovation policy for most of the second half of the twentieth century, many government initiatives were instrumental in promoting R&D and innovation. In a way, the U.S. system was organised in a non-linear fashion before this was recognised by other countries as supportive for innovation in advanced technologies. However, during the past decades, the U.S. lead has narrowed and, in some areas, been lost to other countries. In response, the Obama Administration has launched a national innovation strategy, based around principles of network governance and coordination. The contours of the historical approach and its recent changes are discussed in general and for the information and communications technology (ICT) sector, a central component of past, present, and future high-tech initiatives.

Hotz-Hart presents a detailed and in-depth analysis of innovation policy in Switzerland. The country regularly ranks among the top industrialised nations with respect to innovation performance. This is the outcome of a unique approach, a fourth way between other national models of innovation policy. Switzerland's model can best be characterised as decentralised network governance. Strengths of this system include a highly educated work force, high quality research and development, and global sourcing of knowledge inputs by Swiss firms. Risk aversion, unfavourable demographic trends, and stagnating public funding for R&D are some of the challenges. Given increased competition from abroad and these internal challenges, the chapter concludes that concerted efforts will be necessary to maintain past performance.

The chapter by Orlowski analyses the High-Tech Strategy for Germany, initiated in 2006 as an overarching national strategy that integrates efforts by all government departments. To assist in the coordinating tasks, the German Federal Government established two advisory bodies, the Council for Innovation and Growth (CIG) and the Industry-Science Research Alliance (ISA). Using interlocking directorate analysis, the chapter focuses on the role, composition and function of these two advisory bodies. Orlowski finds that some economic interests are better represented than other societal players. Moreover, as many of these players already had existing links, he concludes that the two new bodies might have weaker integrating functions that anticipated.

These national perspectives are complemented in part three by studies of the implementation of high-tech strategies in specific industrial sectors. A recurring theme in these case studies is the participation of a variety of actors that normally do not take part in (German) innovation policy. However, as high-tech industries raise new issues, new actors become involved, increasing the challenges of finding feasible policies. Examples include the biotech industry, in which economic reasoning and religious beliefs collide, the wind energy and photovoltaic industries, characterised by divergent preferences of economic actors and environmental groups, and the implementation of the electronic health card that brings ICT industry representatives together with the traditional players in health politics. The industry studies also explore the impact of different technical bases of sectors – large vs. small technical systems – on high-tech strategies and actor constellations.

Schneider and Weyer analyse the power struggles underlying the German space policy domain. They observe a rollback in policy orientations since 2007, when the EU and the national governments returned to the traditional procedure of state-driven construction of big technology, exemplified by the failure to assure industry participation in the Galileo satellite project. Innovation policy in the space domain consists of overlapping policy and strategic games played at the national, European and global level.

The interaction between political factors, embryo research laws and the innovative ability of national economies is assessed in Fink's chapter on biotech policy. He demonstrates that embryo research turned into a commercially beneficial enterprise at the end of the 1990s. At that point, it attracted the attention of the pharmaceutical industry and government regulators. In particular, left governments and strong players in the pharmaceutical industry mobilised to liberalise existing regulatory systems. However, in some countries the Catholic Church and Christian democratic parties thwarted the liberalization of the stem cell research, successfully opposing scientific and economic interests.

The contribution by Fuchs and Wassermann examines high-tech policy in the photovoltaics industry. The authors argue that the emergence and development of the photovoltaic industry in Germany was based on the establishment of a protected niche market, which in turn depended on the creation and success of advocacy coalitions supporting the photovoltaic industry. At the beginning, the photovoltaics advocacy coalition included local politicians, the Green party, researchers, environmental societies, and business associations of the infant photovoltaics industry. The successive incorporation of some of the multinational companies increased the effectiveness of political pressure against strong opposition by German utilities.

Ronit explains the development of the wind turbine energy industry through international efforts to combat climate change. He states that while national governments still remain key players in environmental and innovation policies, intergovernmental organizations have gained importance in coordinating policies of states and mitigating conflicts. Initially, wind energy was a small subdomain in national energy policy making. At that time, national and regional business associations, as well as environmental groups, had already been established, but were still exclusively linked to domestic politics and national systems of innovation. More recently, agenda-setting and policy formulation have shifted to the international level. An increasingly large number of civil society organizations take care of climate policy and wind energy.

The e-health card in Germany is the focus of Lang and Mertes' essay. The authors examine the policy and administrative coordination in this temporary, domain-boundaries-transcending policy network that was formed to implement the e-health card. They identify structural barriers to coordination and inconsistencies in goals and task settings that resulted from power asymmetries. These frictions result from different institutional logics inherent in different policy domains. The authors point out that traditional sectoral interest positions play a dominant role in the structuration of the implementation network, which explains the slow and cumbersome process of implementation. Health care providers especially have turned out to be the stalling element in the whole process.

The lessons from theory, national practice and sectoral experiences for high-tech policy and future research are synthesised in the fourth part of the book. Major implications for high-tech policy-making and the design of governance structures supporting innovation are outlined and discussed. Complexity theory offers a versatile framework not only to analyse the existing experience with innovation policy but also to draw fresh conclusions as to workable policy options. One key insight is that high-tech industries differ in their economic and technological characteristics. Thus, no panacea policy exists that will fit all domains. Rather, policies need to be congruent with the respective domain and flexible forms of multi-level coordination will often be helpful. Another insight is the importance of support for diversity, experimentation, and the potential benefits of parallel and competing policy efforts. Successful high-tech innovation policy will also have to pay attention to supporting the adoption of high-tech processes, products and services. In a globally interconnected economy, high-tech policy will also have to seek international coordination.

References

Ahrweiler, P. (Ed.). (2010). *Innovation in complex social systems*. Milton Park/New York: Routledge.

Ansell, C., & Gash, A. (2008). Collaborative governance in theory and practice. *Journal of Public Administration Research and Theory, 18*(4), 543–571.

Arthur, B. (1994). *Increasing returns and path dependence in the economy*. Ann Arbor: University of Michigan Press.

Barabási, A.-L. (2002). *Linked: The new science of networks*. Cambridge, MA: Perseus.

Barabási, A.-L. (2003). *Linked: how everything is connected to everything else and what it means*. New York: Plume.

Becker, G. S. (1983). A theory of competition among pressure groups for political influence. *The Quarterly Journal of Economics, 98*(3), 371–400.

Beinhocker, E. D. (2006). *The origin of wealth: evolution, complexity, and the radical remaking of economics*. Boston, MA: Harvard Business School Press.

Braun, D. (2008). Organising the political coordination of knowledge and innovation policies. *Science and Public Policy, 35*(4), 227–239.

Bunge, M. A. (1996). *Finding philosophy in social science*. New Haven: Yale University Press.

Butts, C. T. (2000). An axiomatic approach to network complexity. *The Journal of Mathematical Sociology, 24*(4), 273–301.

Butts, C. T. (2001). The complexity of social networks: Theoretical and empirical findings. *Social Networks, 23*(1), 31–72.

Cohen, E. (1992). *Le colbertisme "high tech" : économie des Telecom et du grand projet*. Paris: Hachette.

Coutard, O. (Ed.). (1999). *The governance of large technical systems*. London/New York: Routledge.

Dodgson, M., Hughes, A., Foster, J., & Metcalfe, J. (2010). Systems thinking, market failure, and the development of innovation policy: the case of Australia. *Discussion Papers Series*.

Edler, J., & Kuhlmann, S. (2008). Coordination within fragmentation: Governance in knowledge policy in the German federal system. *Science and Public Policy, 35*(4), 265–276.

Frenken, K. (2006). *Innovation, evolution, and complexity theory*. Cheltenham/Northampton: Edward Elgar.

Godin, B. (2002). Outline for a history of science measurement. *Science, Technology, & Human Values, 27*(1), 3–27.

Gschwend, T., & Schimmelfennig, F. (2007). *Forschungsdesign in der Politikwissenschaft*. Frankfurt am Main: Campus Verlag.

Hauknes, J., & Knell, M. (2009). Embodied knowledge and sectoral linkages: An input–output approach to the interaction of high- and low-tech industries. *Research Policy, 38*(3), 459–469.

Hidalgo, C. A., Klinger, B., Barabási, A.-L., & Hausmann, R. (2007). The product space conditions the development of nations. *Science, 317*(5837), 482.

Hobday, M. (1998). Product complexity, innovation and industrial organisation. *Research Policy, 26*(6), 689–710.

Hughes, T. P. (1983). *Networks of power: Electrification in Western society, 1880–1930*. Baltimore: Johns Hopkins University Press.

Kauffman, S. A. (1993). *The origins of order: Self-organization and selection in evolution*. Oxford/New York: Oxford University Press.

Kenis, P., & Schneider, V. (1991). Policy networks and policy analysis: Scrutinizing a new analytical toolbox. In B. Marin & R. Mayntz (Eds.), *Policy networks: Empirical evidence and theoretical considerations* (pp. 25–59, Schriften des Max-Planck-Instituts für Gesellschaftsforschung Köln). Frankfurt/Main: Campus.

Kuhlmann, S. (2001). Future governance of innovation policy in Europe: Three scenarios. *Research Policy, 30*(6), 953–976.

Kuhlmann, S., Shapira, P., & Smits, R. E. (Eds.). (2010). *The theory and practice of innovation policy: An international research handbook*. Cheltenham: Edward Elgar.

Lieberman, E. S. (2005). Nested analysis as a mixed-method strategy for comparative research. *American Political Science Review, 99*(3), 435–452.

Lundvall, B.-Å. (Ed.). (1992). *National systems of innovation: Towards a theory of innovation and interactive learning* (1st ed.). London: Pinter.

Maier, M. W. (1998). Architecting principles for systems-of-systems. *Systems Engineering, 1*(4), 267–284.

Majone, G. (1994). The rise of the regulatory state in Europe. *West European Politics, 17*(3), 77–101.

Mayntz, R. (1983). The conditions of effective public policy: A new challenge for policy analysis. *Policy & Politics, 11*(2), 123–143.

Mayntz, R. (2003). New challenges to governance theory. In H. P. Bang (Ed.), *Governance as social and political communication* (pp. 27–40). Manchester/New York: Manchester University Press.

Mayntz, R., & Hughes, T. R. (Eds.). (1988). *The development of large technical systems*. Frankfurt am Main: Campus.

Mayntz, R., & Scharpf, F. W. (1995). Der Ansatz des akteurzentrierten Institutionalismus. In R. Mayntz & F. W. Scharpf (Eds.), *Gesellschaftliche Selbstregelung und politische Steuerung* (pp. 39–72). Frankfurt: Campus.

Metcalfe, J. S. (1995). Technology systems and technology policy in an evolutionary framework. *Cambridge Journal of Economics, 19*(1), 25–46.

Nelson, R. R. (Ed.). (1993). *National innovation systems: A comparative analysis*. New York: Oxford University Press.

Newman, M., Barabasi, A.-L., & Watts, D. J. (Eds.). (2006). *The structure and dynamics of networks*. New York/Cambridge: Cambridge University Press.

OECD. (1999). *Managing national innovation systems*. Paris: Organization for Economic Co-operation and Development.

OECD. (2005). *Governance of innovation systems. Volume 1: Synthesis report*. Paris: Organisation for Economic Co-operation and Development.

OECD. (2008). *Main science and technology indicators. Volume 2008, issue 1*. Paris: Organisation for Economic Co-operation and Development.

OECD. (2010a). *Measuring innovation: A new perspective*. Paris: Organisation for Economic Co-operation and Development.

OECD. (2010b). *The OECD innovation strategy: Getting a head-start on tomorrow*. Paris: Organisation for Economic Co-operation and Development.

Ostrom, E. (1999). Institutional rational choice: An assessment of the institutional analysis and development framework. In P. A. Sabatier (Ed.), *Theories of the policy process* (pp. 35–71). Boulder: Westview Press.

Pittaway, L., Robertson, M., Munir, K., Denyer, D., & Neely, A. (2004). Networking and innovation: A systematic review of the evidence. *International Journal of Management Reviews, 5*(3), 137–168.

Rhodes, R. A. W. (1996). The new governance: Governing without government. *Political Studies, 44*(4), 652–667.

Röller, L.-H., & Waverman, L. (2001). Telecommunications infrastructure and economic development: A simultaneous approach. *The American Economic Review, 91*(4), 909–923.

Saavedra, R., Earley, P. C., & Van Dyne, L. (1993). Complex interdependence in task-performing groups. *Journal of Applied Psychology, 78*(1), 61–72.

Sabatier, P. A. (1988). An advocacy coalition framework of policy change and the role of policy-oriented learning therein. *Policy Sciences, 21*(2–3), 129–168.

Sabatier, P. A., & Weible, C. M. (2007). The advocacy coalition framework: Innovations and clarifications. In P. A. Sabatier (Ed.), *Theories of the policy process* (pp. 189–222). Boulder: Westview Press.

Sawyer, P. K. (2005). *Social emergence: Societies as complex systems*. New York: Cambridge University Press.

Saxenian, A. (2007). *The new argonauts: Regional advantage in a global economy*. Cambridge, MA: Harvard University Press.

Scharpf, F. W. (1997). *Games real actors play*. Boulder: Westview Press.

Schmidt, M. G. (1993). Theorien in der international vergleichenden Staatstätigkeitsforschung. In A. Héritier (Ed.), *Policy-Analyse. Kritik und Neuorientierung* (pp. 371–393). Opladen: Westdeutscher Verlag.

Schneider, V. (2004). State theory, governance and the logic of regulation and administrative control. In A. Warntjen & A. Wonka (Eds.), *Governance in Europe* (pp. 25–41). Baden-Baden: Nomos.

Schneider, V. (2012). Governance and complexity. In D. Levi-Faur (Ed.), *Handbook on governance*. Oxford: Oxford University Press (forthcoming).

Schneider, V., & Bauer, J. (2009). Von der Governance – zur Komplexitätstheorie: Rekonstruierung gesellschaftlicher Ordnungsbildung. In I. Schultz-Schaeffer & J. Weyer (Eds.), *Management komplexer Systeme*. Oldenbourg: München.

Schneider, V., & Janning, F. (2006). *Politikfeldanalyse. Akteure, Diskurse und Netzwerke in der öffentlichen Politik*. Wiesbaden: VS-Verlag.

Schwab, K. (Ed.). (2011). *The global competitiveness report 2010–2011*. Geneva: World Economic Forum.

Shenhar, A. J. (1993). From low- to high-tech project management. *R&D Management, 23*(3), 199–214.

Steinberg, G. M. (1985). Comparing technological risks in large scale national projects. *Policy Sciences, 18*(1), 79–93.

Strogatz, S. H. (2003). *Sync: The emerging science of spontaneous order*. New York: Hyperion.

Thompson, J. D. (1967). *Organizations in action*. New York: McGraw-Hill.

United Nations Statistics Division (2011). UNdata. A world of information. Online database, available at http://data.un.org.

Williamson, O. E. (2000). The new institutional economics: Taking stock, looking ahead. *Journal of Economic Literature, 38*(3), 595–613.