Technological innovation systems and the resource based view - Resources at the firm, network and system level

Jochen MARKARD and Hagen WORCH

Cirus – Innovation Research in Utility Sectors
Eawag, Überlandstrasse 133, 8600 Dübendorf, Switzerland
Phone: +41 44 823 5671, email: jochen.markard@ewag.ch
www.cirus.ch

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Abstract

Innovation system studies devote a key role to organizational actors in the development of new technologies. However, little effort has been made to incorporate a conceptual understanding of e.g. resources, capabilities and strategy making at the organizational level into the systems framework. In this conceptual paper, we explore the linkages between resource based reasoning in the field of management studies and the innovation systems perspective. The general idea is to work towards a micro-level foundation of innovation system analysis. We define and compare resources at the organizational, network and system level and highlight the fact that some types of resources can only be 'produced' at specific levels. On the basis of this concept, key questions related to the entry of actors into an innovation system and their commitment to 'system entrepreneurship' can be explained. Furthermore, the framework may allow for a comparison of the role of different actors and their contribution to TIS performance.
1 Introduction

The development and diffusion of novel technologies strongly depends on the interplay of various actors (organizations). A key lesson from innovation studies is that through this interplay, new structures emerge which have a decisive influence on the outcome of innovation processes. Socio-technical standards, design principles, search heuristics, collective expectations, reputation of a technology, formal regulations, inter-firm networks, initiatives, associations etc. are examples of such emergent structural entities. Together with the emergence of new structures, existing structures change which is why innovation processes can be understood as continuous as well as discontinuous structural changes at different levels over time.

In recent years, the systems of innovation perspective has been developed as a conceptual framework for the study of innovation and technological change that explicitly acknowledges the emergent properties and the non-linear nature of innovation processes. Studies on technological innovation systems (TIS), more specifically, are concerned with the identification of regularities and patterns of innovation processes in order to clarify the conditions under which new technologies develop quickly and become a success or fail. Comparative qualitative research designs, for example, study the development of a selected technology (e.g. wind power, biogas) and the corresponding technological innovation system in different countries to identify the factors that led to similar or different outcomes. With the TIS perspective, technology development is often framed as a competition between a new technology and established technologies and - possibly - further emerging technologies. In conceptual terms, technological innovation systems can be regarded as a set of networks of actors and institutions that interact and contribute to the development of a novel technology (Markard and Truffer, 2008b).

Although organizational actors such as firms are among the key analytical entities in TIS studies, little effort has been made so far to incorporate a conceptual understanding of resources, processes and strategic decisions at the organizational level into the systems framework. As a consequence, explanations why firms ‘enter’ an innovation system or not, i.e. commit themselves (or not) to the development of a novel technology, or how they organize their innovation activities have remained partial. In a similar vein, there is little theoretical background to address questions related to the specific roles of different actors in innovation systems, e.g. whether some actors or strategies are more important for the development and the performance of the system than others. A further open issue is how the innovation activities of firms add up or complement each other thus contributing to the overall performance of the innovation system (e.g. in the sense of technology development and diffusion).

With this conceptual paper, we want to strengthen the analysis of organizational actors in systems of innovation approaches. Our focus will be on the TIS framework (e.g. Bergek et al., 2008; Markard and Truffer, 2008b), for which we explore linkages with resource based concepts in the strategic management literature. The resource based view (RBV) and the
concept of dynamic capabilities have seen quite some attention and progress in their quest to explain the strategic moves of firms and how they achieve or maintain competitive advantage (e.g. Barney, 1991; Dierickx and Cool, 1989; Priem and Butler, 2001; Teece et al., 1997; Wang and Ahmed, 2007).

It is the success of single firms which is in focus of this strand of the management literature, not the success of technologies or the development of novel products. Still, we believe that the underlying concepts (e.g. resources, capabilities, routines) and the key lines of reasoning (e.g. mechanisms that limit the transferability and / or imitation of resources) are generic enough for this endeavor. Moreover, it has been argued that maintaining firm competitiveness through the deployment of dynamic capabilities is - at least in rapidly changing market environments - inseparably tied to innovation (Teece, 2007). Finally, resource based thinking has also been applied to inter-firm networks (e.g. Dyer and Singh, 1998; Gulati, 1999) and industries (Foss and Eriksen, 1995), i.e. to higher levels of aggregation and complexity.

As an inroad for exploring the linkages between the TIS and the RBV literature, we follow up these latter concepts and propositions. The focus of this article is on the concept of resources and its transfer to different levels of aggregation (organization, network, system). From this results a conceptual framework that connects the system level with innovation activities and strategies at the firm level.

The article is structured as follows. In the following chapter we briefly introduce innovation system studies and sketch some of the unresolved issues at the organizational level. In chapter 3 we revisit the RBV literature and related concepts and define them in a way that allows a transfer of the resource concept to the network and system level. This conceptual transfer will then be described in chapter 4. Following this, we discuss the implications of our conceptual framework for the TIS literature (chapter 5). Chapter 6 concludes.

2 Technological innovation systems and potential benefits of a micro-level foundation

The technological (innovation) systems framework has been developed to study the emergence and development of new technologies over time and to identify general patterns responsible for the course of such processes, including success and failure (e.g. Carlsson et al., 2002b; Jacobsson and Johnson, 2000; Markard and Truffer, 2008b). The framework is part of the broader family of innovation system approaches (see e.g. Chang and Chen, 2004; Carlsson, 2007 or Edquist, 1997 for an overview). These also include national systems of innovation (e.g. Freeman, 1997; Lundvall, 1992; Nelson, 1993), regional innovation systems (e.g. Cooke et al., 1997; Asheim and Coenen, 2005) and sectoral systems of innovation and production (e.g. Malerba, 2002; Malerba, 2004). Rooted in evolutionary economic theorizing on socio-technical change, systems of innovation highlight the influence of institutions on innovation processes and the
importance of actors collaborating in larger networks. As a general model, innovation systems acknowledge phenomena such as path dependency, lock-in, interdependence, cumulative effects and other non-linearities as well as coupled dynamics.

Due to our interest in the emergence of new technologies, we will in the following concentrate on technological innovation systems. A technological innovation system (TIS) can be defined as

“... a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology and/or a new product.” (Markard and Truffer, 2008b, 611).

Actors are individuals but also - and most importantly - organizations such as private firms or firm sub-units, governmental and non-governmental agencies, universities, research institutes, associations etc. Institutions are rules that influence the activities and decisions of the actors. They set incentives for actors to do certain things and to avoid others. Institutions include norms, laws, regulations, guidelines, contracts, values, culture, cognitive frames etc. Institutions can be interpreted as the rules of the game, while actors, or organizations, are the players (e.g. Edquist, 2005; North, 1990). Organizations can act in the sense that they formulate aims and pursue deliberate strategies to reach these aims, while institutions cannot (cf. Markard and Truffer, 2008a). In a way, institutions are passive as they cannot deliberately transform themselves like actors. Instead, they evolve and change as a result of the effects of other institutions and of the activities of organizations.

The relationships among the system components, i.e. among as well as between actors and institutions, are manifold. Actors may compete but also collaborate with each other or they may perform transactions, i.e. trade goods, services or knowledge. Institutions may support each other but they may also be in conflict (Edquist, 2005). Moreover, they may exhibit a certain hierarchy in their structural set up.

While much attention in innovation system studies has been devoted to both structural and functional analyses at the system- or meso-level, little effort has been made to systematically explore the link to the micro-level of innovating organizations. This is despite the fact, that actors or organizations are assigned the key role in innovation system concepts (Carlsson et al., 2002a; Edquist, 2005; Malerba, 2004) and empirical findings regularly report the influence of strategic decisions of particular actors or the

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1 It has to be noted, however, that different definitions for institutions have been proposed in innovation studies as well as in economics or the social sciences (see Hollingsworth, 2000 for an overview).

2 Cf. the notion of institutional entrepreneurs in this regard (Di Maggio, 1988). Edquist and Johnson (1997) have described the relationship between institutions and organizations as a dual subject-object relationship.
importance of entrepreneurs and prime movers (e.g. Carlsson and Stankiewicz, 1991; Jacobsson and Johnson, 2000; Negro et al., 2007).

In our view, it might thus be a worthwhile research endeavor to link innovation systems reasoning with established concepts in organizational studies (cf. Markard and Truffer, 2008a). Such a 'micro-level foundation' of innovation systems might improve innovation system analysis in different ways. First, it supports the explanation of the strategic moves of innovating organizations, e.g. why and how some firms commit themselves to the development of a particular technology while others do not or even exit an innovation field. A second issue is to distinguish the roles different actors (or actor groups) play in an innovation system. Are some more important than others as the idea of prime movers (see above) suggests? Are actors missing that would be important for system performance? Can the eventual exit of particular actors be easily substituted by others? Third, and may be most importantly, a micro-level foundation of innovation systems can also improve our understanding of how new properties and structures emerge through the interplay of actors and institutions. Why and how do organizations collaborate to change institutions that hamper technology development or create new ones in favor of their needs? If lobby networks of innovators, for example, succeed to convince policy makers to set up a technology-specific program or to change permission regulations in a favorable way, we would like to understand how these networks emerged and why they were able to influence policy makers.

In the following, we take the concept of organizational resources and the resource-based view of the firm as starting points to develop conceptual linkages between the TIS and the management literature. Resources, together with dynamic capabilities, have been identified as key factors that determine the competitive advantage of firms. Resources and capabilities, in other words, play an important role in strategic decision making at the organizational level.

3 Resources, capabilities and strategy in organizations

Resource-based reasoning can be traced back to the contributions of Penrose (1959), Wernerfelt (1984), Rumelt (1984) or Teece (1984) and has received increasing attention from the late 1980s on. At that time it was a major opposition to the dominant view that industry structure and the firm’s position in the industry is key to explain competitive advantage. Today, the resource based view has become a very influential framework in the strategic management literature and it has been complemented by related concepts such as core competences (e.g. Prahalad and Hamel, 1990), dynamic capabilities (e.g. Teece et al., 1997) and the relational view (e.g. Dyer and Singh, 1998).

Resource-oriented approaches argue that the performance of firms strongly depends on factors, so-called resources or capabilities, located within the organization. This argument is based on the fundamental insight that not all factors that are of strategic importance to firms can be traded in markets (e.g. Dierickx and Cool, 1989). Firm reputation, customer
loyalty, organizational culture, highly motivated teams or technological know-how are examples of immobile assets that cannot be traded in factor markets. In order to use such assets, a firm has to develop and/or accumulate them over time. Such immobile assets can be valuable sources of sustained competitive advantage if they are also rare, inimitable and non-substitutable (Barney, 1991). Several explanations (or so-called mechanisms) have been proposed why certain resources can hardly be imitated: time compression diseconomies, asset mass efficiencies or accumulation effects, asset stock interconnectedness and causal ambiguity (Dierickx and Cool, 1989) as well as unique historical conditions, social complexity and again, causal ambiguity (Barney, 1991).

Despite the rapidly growing body of literature in the field, the resource-based view (RBV) and the related dynamic capabilities approach are still characterized by a large variety of different conceptualizations of the core terms (see e.g. Ambrosini and Bowman, 2009 and Wang and Ahmed, 2007 for an overview). In the following sections, we thus briefly review the notion of resources, competences, (dynamic) capabilities, routines and strategy to clarify their interrelation and how we will use them. Our intention is also to formulate an explicit understanding of resources that provides sufficient clarity for transferring it to the network and system level and - in the later parts - to discuss the conceptual linkages with the constructs from the TIS literature typically used at these higher levels of aggregation.

3.1 Organizational resources

A number of different definitions exist for resources at the organizational level. According to Barney (1991) “firm resources include all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness” (p.102). In this definition, the guiding principle for conceptualizing resources is strategic value. No distinction is made between assets, processes and capabilities. Put differently, everything can be thought of as a firm resource as long as it is of strategic relevance. This view is in line with an earlier proposition of Wernerfelt (1984): “By a resource is meant anything which could be thought of as a strength or weakness of a given firm.” (p.172). The ‘all-inclusive’ concept of resources has been criticized by Priem and Butler (2001) because it hampers general prescriptions of how to deal with resources.

Teece et al. (1997) focus on assets in their definition and clearly differentiate resources from routines, competences and dynamic capabilities. “Resources are firm-specific assets that are difficult if not impossible to imitate.” (Teece et al., 1997, 516). In a later paper, also Barney considers “a simpler definition of resources (i.e., resources are the tangible and intangible assets a firm uses to choose and implement its strategies).” (Barney, 2001, 3. We concentrate on business firms in the following although in our definitions we use the broader notion of organizations to underline that applicability of the concepts goes beyond the scope of primarily profit oriented organizations.
The proposition of Teece et al. (1997) is also distinct as quasi inimitability is introduced as a criterion resources have to meet. Inimitability is relevant for Barney (1991) as well because it represents a pre-condition for achieving sustained competitive advantage on the basis of resources. However, it is not part of his resource definitions.

Note that the later definition by Barney (2001) also points to the fact that the assets are actually used, which implies that only those assets which are strategically deployed are regarded as resources. The same asset, in other words, can be a resource for one (business) strategy, while it remains just an asset or production factor for a different strategy.

In summary, two major differences can be identified in the existing concepts. The first is the type of elements included in the definition and whether a distinction between resources, processes, capabilities etc. is made. The second is about the criteria the chosen elements have to meet in order to be considered as resources. In our view, both issues deserve attention. With regard to the former, we will focus on assets (in the sense of elements), which we distinguish from e.g. processes (or organizational routines) that make use of these elements and may also change them. We also differentiate resources from competences and capabilities (see below). An important implication of this proposition is that there are more ‘factors’ than just organizational resources that have an impact on firm performance.

With regard to the second issue, we suggest concentrating on the strategic relevance of resources, which means that we acknowledge for the fact that the strategic value of organizational assets depends on the chosen strategy and the market environment the strategy is directed at. Furthermore, we want to highlight the idea that not all assets a firm controls are equal. In our view, assets that are generated or accumulated by an organization are of particular importance (cf. Dierickx and Cool, 1989). Take for example internal quality standards or organizational culture, which emerge from the interplay of individuals and/or teams within the organization. Or firm reputation or power that accumulate over time through the activities a firm performs. Such kinds of assets are emergent properties of an organization that have developed and changed over time and continue to do so. They represent the aggregated outcome of complex processes at the firm-level and elsewhere that again involve other assets. They have in common that they are inseparably tied to the firm (inseparable, unique assets). From a formal point of view, they are either attributes, i.e. characteristics of the organization that cannot exist without the object they relate to or constructs that have been defined in a way that they are inseparable of the object they relate to. Other assets, in contrast, do not need another object to exist and they can - at least principally - be transferred to other organizations. Examples are natural resources, human resources, codified knowledge or financial capital. We will refer to these as separable or autonomous assets.

On the basis of these considerations we propose the following definition:

Organizational resources are tangible and intangible assets (or elements) of strategic value that are owned or controlled by the organization. Of particular interest are those
assets that are generated and accumulated by the organization in a way that they have become inseparable and thus unique. Potential examples of organizational resources are employees, technological know-how, production facilities, patents and licenses, contracts, brands, access to natural resources, reputation, organizational culture, internal quality standards or customer contacts.

Note that organizational resources are not the only kind of resources an organization can strategically deploy. In alliances or other forms of inter-firm relationships, firms may also get access to (and then use) the organizational resources of their partner(s). The same applies to network and system resources (cf. section 4).

3.2 Organizational capabilities

Like resources, organizational competences, capabilities and dynamic capabilities have been defined and used differently in the management literature. Teece et al. (1997), for example, use the terms organizational routines, competences and capabilities somehow interchangeably and from the definitions they propose the exact relationship or the differences between these notions are difficult to tell. Grant (2008) also suggests using competences and capabilities synonymously. So it is worthwhile to have a closer look at the underlying definitions.

According to Grant (2008, 135) “An organizational capability is a firm’s capacity to deploy resources for a desired end result.” The definition of Amit & Schoemaker (1993) is similar. They define capabilities as “... a firm’s capacity to deploy resources, usually in combination, using organizational processes, to effect a desired end. They [capabilities] are information-based, tangible or intangible processes that are firm-specific and are developed over time through complex interactions among the firm’s resources.” (Amit and Schoemaker, 1993, 35). Both definitions highlight that capabilities represent the capacity (or ability) of an organization to use resources for a specific purpose. The difference is that Amit and Shoemaker (1993) also argue that capabilities are processes, which is in line with e.g. Winter (2003) who defines an organizational capability as “a high-level routine (or collection of routines) that, together with its implementing input flows, confers upon an organization’s management a set of decision options for producing significant outputs of a particular type.” (Winter, 2003, 991).

In the latter definitions, we see the difficulty that little room is left for strategic decisions. Organizations have specific capabilities and - if they are interpreted as processes - they execute them continuously. While this might be the case, we may as well think of situations, in which standard operating procedures are not performed or circumvented due to strategic considerations. In a similar vein, firms might deploy established competences for some of their products (or innovations) while they do not for others. In our view, it thus makes sense to think of competences and capabilities as the potential of an organization to achieve a particular end. Competences and capabilities depend on processes (and resources) but are no processes themselves. Rather they are attributes of an organization.
such as size or turn-over. And again, they are - by definition - inseparable from the object they relate to.

Competences and capabilities are typically applicable to different products or business fields in multi-business firms. This holds in particular for core competences, which relate to the key business of a firm (e.g. Prahalad and Hamel, 1990; Teece et al., 1997).

Organizational capability (or competence) is the ability of an organization to do something and to achieve specific ends on the basis of a particular combination of assets, resources, processes and routines.

3.3 Organizational strategy

Another key notion of the management literature is strategy. It is closely related to the concepts discussed above. On the one hand, strategy is concerned with the deployment and configuration of resources, processes and organizational structures in order to reach a specific goal. On the other hand, strategy also depends - among other factors - on the resources and competences readily available in a firm. Furthermore, strategy making is an organizational activity, which can include routines but does not have to (see above).

A core element in the strategy concept is a goal or plan. “Strategy can be defined as the determination of the basic long-term goals and objectives of an enterprise, and the adoption of courses of action and the allocation of resources necessary for carrying out these goals.” (Chandler, 1962, 13). However, strategy does not necessarily have to be based on a specific plan. A firm can, for example, perform a series of concerted, but unplanned activities of strategic character, which in the end turn out to be (or are interpreted) as strategy (emerging strategy). As a consequence, Mintzberg (1987) proposes a more complex model of strategy including plan, pattern, position, perspective (or vision) and ploy.

We think, strategy is important in the discussion of firm resources, competences and capabilities because it is the basis (or nexus) for the actual decision of where and how to apply existing competences, to re-configure existing resources and processes, to acquire or create access to new resources or to work towards external change (see above). Whether a firm applies its resources and competences in a new business field or commits itself to the development of a new product or technology depends on a strategic decision. Therefore, strategy is an essential element in a conceptual framework that links organizations and technological innovation systems. It can be interpreted as a key factor that regulates the inflow of resources and thus determines the availability of organizational competence for a selected innovation system, cf. Figure.

To sum up, resources can be thought of as elements (what an organization owns or has access to), capabilities represent a potential, i.e. what an organization can do and strategy finally represents intention, i.e. what an organization wants to achieve. Having discussed and defined the core elements of a resource oriented perspective at the organizational
level, we will now turn to the concept of resources at the levels of networks and innovation systems.

4 Resources at higher levels of aggregations

While resources at the organizational level are certainly in the focus of the management literature, the resource concept has also been applied to higher levels of aggregation including inter-firm networks (e.g. Gulati, 1999) and industries (e.g. Foss and Eriksen, 1995). The underlying reasoning from a management perspective is that these higher levels of aggregation also produce assets that can be of strategic value for business firms. Networks, for example, have been identified as a source of informational advantages firms can draw upon when they set up formal alliances (Gulati, 1999). This general line of thought is also important for the study of innovation systems, in which emergent properties of technologies (e.g. norms, standards, collective expectations) have been identified as key factors in the development process. In the following, we will thus discuss in detail how network and system level resources can be conceptualized.

4.1 Networks and network resources

Cooperation of business firms and other actors in networks can be important for achieving strategic goals. In the past decades, an increase of inter-firm alliances has been observed that has caught the attention of organizational scholars to address the network phenomenon (e.g. Gulati, 1998; Borgatti and Foster, 2003; Dyer and Singh, 1998). For the development of new technologies networks are important as well (e.g. deBresson and Amesse, 1991; Jacobsson and Johnson, 2000; Pyka and Küppers, 2002). From a resource based perspective, a key advantage of an alliance or a network is that it enables a firm to use resources possessed by a cooperation partner (Lavie, 2006). As a consequence, the partner’s resource(s) can be used without the need to transfer or own these resources. Networks, in other words, represent an organizational arrangement, which may enable access to assets that are immobile or very costly to transfer.

In the case of inter-firm networks, the condition that resources have to be owned or controlled by a firm in order to become a source for competitive advantage is relaxed. Instead it is argued that access to resources (controlled by somebody else) can be sufficient (Lavie, 2006). As a consequence, the analytical focus shifts from single firms to inter-firm networks which is why the so-called relational view has been proposed as an extension of the RBV (Dyer and Singh, 1998). Dyer and Singh (1998) argue that “... idiosyncratic interfirm linkages may be a source of relational rents and competitive

\[\text{4} \] This shift has even been interpreted as a new and very distinct path of explanation because it leads to different management recommendations than the RBV with its firm focus (Duschek, 2004).
advantage.” (p. 661). It has remained an issue for debate though, where the sources of relational rents are located. Are the partner’s organizational resources the main source in a network relation or can some of the advantages also be assigned to the ties or to the network as such (cf. Lavie, 2008)? This debate also relates to the more general question of what is considered as a network.

In a rather general way, two types of networks can be distinguished. Networks may have been deliberately established for strategic reasons (e.g. initiatives, alliances) or they may have emerged in a less purposive way through the "natural" interaction of organizations (e.g. at a regional level) (cf. Molina, 1999). The latter type of networks is comparable to social networks or the broader social context firms are embedded in. Social networks are also highlighted in the work of Gulati (1998) as a key determinant for the establishment and development of strategic alliances because they provide informational advantages, which may represent valuable assets for a firm. Against this background, Gulati (1999) has introduced the notion of network resources. “Network resources inhere not so much within the firm but in the interfirm networks in which firms are located. ... They are distinct from the resources that reside securely within its boundaries ... firm network resources result from the informational advantages they obtain from their participation in interfirm networks that channel valuable information.” (Gulati, 1998, p. 399). In contrast to Gulati (1999), Lavie (2006) has defined network resources as “... resources of alliance partners transferred via direct interfirm interactions...” (p. 641). These include for example the reputation of a partner or the access to venture capital or technological capabilities through a partnership (ibid.). Lavie’s concept of network resources leaves no room for strategically relevant assets beyond the level of single firms and for the emergent properties of networks.

In the development of the relational view, however, the latter kind of resources that are rooted in the broader context of firms has received particular attention. Dyer and Singh (1998, 1999), for example, refer to the institutional environment in Japan, which fosters trust among cooperating partners and controls opportunism (Dyer and Singh, 1999). Such a source of competitive advantage is beyond the scope of the traditional RBV so their argument, which is why the relational view is conceptually different from the RBV. In the relational view, the effects of the institutional environment are directly linked to what Dyer and Singh call ‘effective governance’ of interfirm relationships (Dyer and Singh, 1998). By means of particular governance mechanisms the transaction costs for cooperating partners can be lowered significantly.

We think the important issue here is that there are particular mechanisms (or resources) located outside any firm in the network. Mutual trust, common culture, shared

5 This distinction between formal and informal networks (REF) is similar in this regard.

6 Lavie (2006, 2008) also has an implicit focus on formal networks.
expectations, proximity etc. may be highly valuable assets at the level of networks, or even beyond, that cannot be possessed by a single network member.

Through cooperation in a network, firms thus not only get access to organizational resources controlled by their partners but also benefit from resources that emerge through the interplay of cooperating actors. In contrast to the former, the latter type of resources would not exist if firms were not interacting in a specific way. Moreover, they typically do not emerge immediately, e.g. as soon as an alliance is established but they develop over time. For the following, we suggest referring to the latter type of resources as network resources.

Network resources are assets generated (intentionally or not) through the interplay of actors in the network. They are of strategic value for actors participating in the network although different assets may be of different value for different actors. Network resources can not exist without the network. Potential examples of network resources are network culture, trust, network standards and modes of governance, power and influence, or - more aggregated - the guidance a network provides.

Note that in the definition of network resources, we have not included assets localized at the organizational level. This does not imply that these assets are not of importance in the formation of networks and / or for the competitive advantage of firms participating in networks.

4.2 System resources

If particular kinds of resources emerge through the interplay of actors we expect them at different levels of aggregation including networks, innovation systems or entire industries. In fact, industry resources such as services provided by an industry trade organization or lobbyists have been identified and described in the literature (Foss and Eriksen, 1995). In the following, we focus on resources that emerge at the level of technological innovation systems (TIS).

In the literature on innovation studies, the notion of resources has been used together with the system functions concept. Resource mobilization is regarded as one of the key functions that determine the performance of a technological innovation system (e.g. Bergek et al., 2008; Johnson, 2001). A resource that is often in the focus here is the funding of R&D activities (Hekkert et al., 2007). “As a TIS evolves, a range of different resources needs to be mobilized ... Hence, we need to understand the extent to which the TIS is able to mobilize competence/human capital ..., financial capital (seed and venture

7 In fact, the underlying processes that lead to the creation of resource are probably very similar in networks, systems or other levels of aggregation. The differentiation between network resources and system resources in the following is made because both networks and systems represent established units of analysis in the literature on innovation studies and strategic management. In conceptual terms the differences are rather small.
capital, diversifying firms, etc.), and complementary assets such as complementary products, services, network infrastructure, etc.” (Bergek et al., 2008, 417). Resources, in other words, are interpreted as different kinds of factors necessary for the development of a particular technology but they have not received further attention in conceptual terms. Furthermore, resources have not been explicitly linked to the competitive advantage of (innovating) firms. As we transfer the conceptualization of resources from the management literature to the field of TIS studies, we have to keep in mind these differences.

Against the conceptual background of organizational and network resources defined above, we would classify the examples from the TIS literature as assets that are mostly autonomous and, for example, located at the level of firms committed to the development of a specific technology (or TIS). Assets generated at the level of networks or the system, have not been labeled as resources in the TIS literature. Still, such kinds of assets or emergent properties have been taken into account in innovation studies, e.g. framed as institutions or system functions. We will address the conceptual overlaps later in section 6.

Similarly to the definition of network resources, we propose to use the notion of system resources for emergent properties (or assets) at the system level that are strategically relevant for innovating actors.

System resources are assets generated (intentionally or not) through the interplay of actors in the technological innovation system. They are of strategic value for actors participating in the development of the new technology although their importance may vary. System resources are inseparable from the system. Potential examples are technological standards at the system level, technology related expectations, acceptance and reputation of a technology, specific regulations supporting the focal technology or the guidance a system provides.

It has to be noted, that system resources can hardly be developed or shaped by single organizations unless these organizations are exceptionally influential. In most cases organizational actors have to coordinate themselves through networks (e.g. lobby networks, technical committees) in order to deliberately establish or alter system resources. Networks in other words may generate network as well as system resources (see also Table 2).

4.3 **Strategic relevance of network and system resources**

Resources at higher levels of aggregation are characterized by the fact that a number of firms have access to these resources. The reputation of an alliance, for example, may provide benefits for many or all of the alliance members and a technical norm may lower uncertainty and transaction costs for a large number of firms in a technological innovation

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8 The government may be an example of a non-firm actor with the competence to set up TIS resources (e.g. public research programs) in a rather autonomous way.
system. Assets that generate such collective benefits, of course, cannot be considered as sources of competitive advantage with regard to competition between insiders, i.e. firms that have equal access to the resource. This is different however, for competition between insiders and outsiders. In that case, the collective resource can well be of strategic relevance for a firm (cf. focal firm compared to competitor in Figure 1). A technological standard or an emission regulation that favors the technological variant developed by an insider firm, while putting innovation variants of competing firms outside the TIS at a disadvantage, is an example of a system asset that represents a valuable resource for insiders. The strategic value of an asset, in other words, depends on what lines of competition we are looking at.\(^9\)

Figure 1: Focal firm with access to resources of partners \((R_3, R_4)\) and network \((R_n)\) and system resources \((R_s)\) in comparison to competitor without these possibilities

With regard to network and system resources, a key question relates to the determinants of boundaries, i.e. on what does it depend whether a firm has access to a collective resource or not. In the case of (formal) networks, access to resources is often regulated

\(^9\) In a more general way, competition (and competitive advantage) can also be conceptually transferred to higher levels of aggregation, i.e. in the sense that different networks or innovation systems are competing. At the system level, competition may not only occur between two emerging innovations but also (and very typically) between a new and an established technology. Such a perspective is often applied in innovation studies. However, in this paper we understand competition in the traditional way, i.e. applied to interfirm relationships.
explicitly, e.g. by contracts or other rules that determine membership ('club'-resources). In the case of innovation systems, such regulations do not exist and system resources rather have the character of (semi-)public goods. Still, access to system resources may be limited for some actors, as it depends for example on how compatible a firm’s existing (technological) competences are with the requirements of the new technology (see also section 5.2). If these (and other) entry barriers are rather low and outsiders expect to benefit a lot from getting access to system resources, we will see rather high entry rates and vice versa.

Note that network and system resources - in our definition - can just be produced by specific networks or systems (in fact, they are inseparable from the network or system). In that sense they are difficult to imitate, which - in a general way - increases their strategic relevance.

Figure 1 shows the different kinds of resources a focal firm may have access to. These include its own organizational resources (R₁ and R₂), resources of network or alliance partners (R₃ and R₄), network resources available within the network (RN) and system resources (Rs).

4.4 Examples of resources at different levels

Table 1 depicts examples of assets at different levels of aggregation that may become sources for the competitive advantage of firms. We distinguish autonomous or separable from inseparable assets (including attributes). Autonomous assets are principally transferrable from one organization to another and also from one level of aggregation to another, while inseparable assets cannot. For illustration, we also added the individual level and an unspecified macro level although we have not discussed these levels in the text.
4.5 Conceptual comparison of resources at different levels

We want to conclude this section with brief conceptual comparison of resources at different levels of aggregation. Three dimensions will structure our analysis. The first is the issue of ownership and control that has been emphasized for the level of organizational resources. The second relates to the question, where the resources are generated. This dimension has gained particular attention in the definition of network and system resources and it is related to the issue of whether resources are separable or not. The third dimension captures the potential benefits that arise from the assets: who can capture these benefits?
The comparison shows that organizational resources are owned and controlled by a firm, while network and system resources cannot be owned or controlled in a narrow sense. Note that we do not assume that the processes of asset production at the organizational level are the same as at the network or system level. Nor do we say that the development of network or system resources is always a deliberate or clear-cut process. Rather the contrary is true. Still, there might be firms that have a stronger influence on the emergence and development of network, and possibly even system resources. The key characteristic of network and system resources is that they emerge through the interplay of various actors and thus tend to be inseparable from the actor structures that generate them. At the organizational level, similar resource generation or accumulation processes may occur but organizational resources may have been acquired as well. Moreover, development of resources at the network or system level is not necessarily a deliberate process driven by a specific strategy. Especially at the system level, we may see that resources emerge in a rather unpredictable and also non-reproducible way.

With regard to the benefits, finally, the comparison shows that system resources may provide benefits to a large number of actors, while organizational resources are typically rather restricted in terms of access/provision of benefits.

### Table 2: Conceptual comparison of resources at different levels of aggregation

<table>
<thead>
<tr>
<th>Type</th>
<th>Control</th>
<th>Resource creation</th>
<th>Appropriation of benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizational</td>
<td>Owned and controlled by the firm/organization(^{10})</td>
<td>Some resources are created/accumulated at the organizational level, some are acquired.</td>
<td>Organization per default realizes all potential benefits but it may share benefits with other firms.</td>
</tr>
<tr>
<td>resources</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Network resources</td>
<td>Controlled to a limited extent by network members</td>
<td>Network is the locus of resource creation(^{11}); resources are inseparable from the network</td>
<td>Network members realize benefits but not necessarily to the same degree.</td>
</tr>
<tr>
<td>System resources</td>
<td>Mostly beyond the control of organizational actors</td>
<td>Network or system is the locus of resource creation; resources are inseparable from the system</td>
<td>System members realize benefits(^{12}) but not necessarily to the same degree.</td>
</tr>
</tbody>
</table>

\(^{10}\) This is the core issue in the definition of organizational resources.

\(^{11}\) This is the core issue in the definition of network resources.

\(^{12}\) This is the core of the definition.
5 Implications of the proposed concept for TIS analyses

The analysis of technological innovation systems may benefit in several ways from the proposed concept of resources at different levels of aggregation. Most importantly, the model supports establishing a conceptual link between the system level and the activities of innovating firms. On this basis, we can explain why firms contribute to the development of network and TIS resources. We can also analyze the conditions under which actors commit themselves to the development of the selected technology, i.e. why they enter a TIS (or leave it). Furthermore, the concept provides the opportunity to assess and compare the contributions (or roles) of different actors in the generation of system resources. On this ground, it can improve our understanding of how network and TIS resources are created but it can also inform some kind of assessment in how far actors differ in their importance for TIS development (cf. Markard and Truffer, 2008a).

5.1 Understanding strategic moves of organizational actors

The questions why firms commit themselves to the development of a new technology and why they contribute to the development of resources at the system level are certainly crucial for understanding innovation processes at the actor level. Within the proposed framework we can now argue that firms try to develop and expand the resource base they can draw upon in a way, in which they expect to fare better than competitors that cannot benefit from these resources. Firms have different options to shape their resource base (cf. section 4.3). They can acquire or develop organizational resources, they can form alliances to get access to resources of other firms and they can set up or enter into (formal) networks in order to development and get access to network resources. They can also decide to contribute to the development of a novel technology in order to benefit from the underlying knowledge and the (potentially) emerging market. In our framework, this decision can be interpreted as entering into a technological innovation system. With the entry, a firm is assumed to get access to system resources (e.g. technology-specific R&D programs, reputation of a technology) and these resources can make a difference with regard to competitors that cannot benefit from these resources. Of key important here are the mechanisms that make access to system resources more or less easy for different firms. In many cases, for example, complementary resources such as a certain stock of technological expertise or specific equipment may be required at the organizational level in order to reap the benefits of system resources. As the development of these complementary resources may take time or is aggravated for other reasons (cf. isolation mechanisms of resources), some firms can more easily enter a TIS and use system resources than others.13

13 The metaphor of TIS entry (and exit) is certainly a simplification in this context as the TIS can rather be seen as a continuum of system resources some of which (in the ‘outer areas’) are
It may be argued though that TIS entry can also be explained without the concept of system resources if the technology as such (and the) is considered as the main reason why actors enter. In our view, system resources provide additional incentives that go beyond the potential benefits of the core technology. Take for example the case of companies, for which the potential success of the core technology is not the primary importance. Instead, they are interested in learning about the technology and e.g. transferring these insights to other technological fields (e.g. Markard and Truffer, 2008a). Such strategies can be better explained with a broader model that also includes incentives provided by system resources.

A second key issue is why firms contribute to the development of resources at the system level although they cannot benefit exclusively from these system resources. As system resources provide benefits for TIS actors (compared to outsiders) there is a general incentive that TIS actors also engage in ‘system resource entrepreneurship’ as they deliberately develop and shape system resources. Some actors may, for example, commit themselves to political lobbying in order to increase public R&D funding or other support for the technology at hand. Whether and in how far a TIS actor engages in system building depends on the expected firm-level (individual) benefits it can obtain from the system resource(s) and the corresponding costs for its commitment. Moreover, actors have to take into account that competitors within the TIS may wait for them to take the first move and still reap the later benefits of the system resource. Such intended free-riding, however, bears the risk that first movers shape system resources (e.g. technological standards) in a way that puts technological variants or business models of the followers at a disadvantage. This leads us to the issue of how homogeneous the positive effects of system resources are.

Although we have defined system resources as assets that are widely accessible within a TIS, we expect that the benefits they provide cannot be reaped by all TIS actors to the same extent (limited homogeneity). R&D programs, for example, may be of particular interest for researchers and technology developers while downstream service providers benefit less or at a later stage of development. Similarly, technological standards may be designed in a way that some technological applications or variants within a TIS benefit more easily to access, which others (in the ‘center’) require more upfront investments into complementary resources.

14 From the perspective of a single actor, costs have to be lower than the expected benefit from the system resource(s). This cost-benefit relation can, of course, be changed in favor of system resource entrepreneurship if actors pool their resources directed at the development and shaping of system resources. Formal networks (e.g. strategic alliances) represent organizational set-ups, in which organizational resources are combined (aggregated in terms of mass as well as combined in a complementary way) in order to shape system resources in a way favored by the network. It also has to be noted that the applicability of rational cost-benefit argumentation is compromised in situations of high uncertainty characteristic for innovation processes.
more than others. Consequently, we will see a struggle of strategic interests within a TIS. Different actors will try to shape system resources in a way to increase their individual benefit. At the same time, they have to take into account that the positive externalities of the system resource are not compromised too far.

Another reason, why actors may commit themselves to the creation of system resource may be a significant degree of uncertainty prevailing in emerging technological fields. In such situations, firms may choose to participate in different kinds of networks and initiatives although they are not able to assess the actual costs and benefits beforehand. Cooperation in general may appear to be less risky than ignoring some developments and then being excluded from processes that turn out to be crucial for the TIS at a later point in time.

The proposed model, in our view, helps to see the strategic moves of TIS actors and potential entrants in a new light. It offers new explanations but also leads to new questions, many of which still need to be addressed more thoroughly. The emergence of system resources, for example, is not just a matter of strategic moves of TIS actors but may also be the result of implicitly coordinated or even non-coordinated processes at the system level. Take, for example, the case of collective technological expectations which rather emerge as the result of the innovation and discourse activities of a large number of actors instead of being formed in a deliberate way by specific organizations or networks (e.g. Borup et al., 2006; Ruef and Markard, in print).

5.2 Assessment of actor roles and establishing a conceptual link with TIS performance

Resource oriented theorizing is based on the two core tenets that i) some resources are difficult if not impossible to transfer between organizations and that ii) firms differ in their resource endowments. Against this background, it is possible to distinguish organizational actors with regard to the resources they control and to identify those resources that are more difficult to transfer, e.g. existing customer contacts, firm reputation, technological expertise etc. Moreover, we can assume that the success of new technologies depends on the availability of a set of resources, some of which may be bound to particular types of actors (or networks). Such resources may become critical bottlenecks for TIS development if they are also scarce, difficult to imitate and not substitutable. As a matter of fact, TIS development may depend on the intentions and strategies of the organizations, which control such critical resources.

This means that TIS performance and the direction of technology development, in some cases, may be closely coupled with the strategic decisions of particular actors. The link between TIS performance and the (organizational) structures of an innovation system, in other words, may be closer than typically expected in innovation studies. Where this is the case, TIS performance can - at least to some extent - be traced back to the availability of critical resources and the strategies of organizations that control them.
This line of argumentation can also be applied to resources at higher levels of aggregation. There might be particular resources at the network or system level that are crucial for TIS development. A novel environmental technology, for example, may need specific governmental support in the form of financial incentives or emission regulations for established technologies in order to compensate for the positive externalities of its application. Or a new high-tech product may crucially depend on the skills of local service companies for maintenance and trouble-shooting. Whether and how these resources are provided, again, depends on the resources and strategies of organizational actors and on their ability to combine their resources. The proposed model assumes that the effectiveness of network or system resources depends on how different organizations have supported their creation and development with the help of resources at the organizational level. As we understand the processes by which organizational resources are combined and - partly - transferred into network or system resources, we will be able to distinguish the roles of different actors in a more systematic way.

6 Summary and outlook

In this conceptual paper, we explored some first linkages between the technological innovation systems framework and the resource-based view in combination with related concepts from the strategic management literature. The core idea is that assets of strategic value exist not just at the level of organizations but also at higher levels of aggregation, i.e. in formal networks and in technological innovation systems. Some network and system resources are inseparably intertwined with a network of actors or broader organizational structures, which means that they are not transferable and difficult to reproduce and imitate. These characteristics make them scarce and so they may become very valuable for those actors which have access to them in comparison to competitors which do not have access. On the basis of this framework, some key processes at the TIS level such as the entry of actors or the commitment of actors to ‘system entrepreneurship’ can be explained. Moreover, the concept also provides an inroad for assessing the role of different actors (or actor groups) and the importance they have for TIS development.

However, we are just at the beginning of untangling the relationships between organizational characteristics and TIS performance in a more systematic way. Certainly, the concept of resources and the underlying ideas of the resource based view (especially its assumptions on isolation mechanisms) are only one way to approach these questions. Additional efforts will therefore be needed to formulate the limitations of this approach and to discuss alternatives. But also within the proposed framework some crucial issues are still unresolved. These include the connection between system resources and institutions.

15 This latter example points to the issue of how value chains develop in emerging technological fields.
at the TIS level as well as the question of how system resources are related to system functions.

7 References


Ruef, A., Markard, J., in print. What happens after a hype? How changing expectations affected innovation activities in the case of stationary fuel cells. Technology Analysis & Strategic Management,


