

INNOVATIONS AND THE ROLE OF COMPLEMENTARITIES IN A STRATEGIC THEORY OF THE FIRM

NILS STIEGLITZ¹* and KLAUS HEINE²

¹ Department of Marketing and Management, University of Southern Denmark, Odense, Denmark

² Institute of Management, Freie Universitaet, Berlin, Germany

In the resource-based view of strategy and in evolutionary economics, complementary assets play a crucial role in explaining sustainable competitive advantages and innovations. Despite the apparent importance of complementary assets for the understanding of corporate strategy, their creation and the associated managerial problems have been much less discussed. We believe this to be a major weakness in the strategic theory of the firm. Interestingly, problems of coordination and cooperation are center stage in the contract-based theories of the firm, and we try to integrate some of their insights into a resource-based perspective. Specifically, we show how complementary assets raise the need for strategic direction by a firm's top management. Moreover, complementary assets magnify internal incentive problems, and their management has an impact on the innovativeness of a firm. Lastly, complementary assets play a crucial role in the internal appropriation of innovative rents. We demonstrate the fruitfulness of our integrated framework by relating some of our findings to the literature on corporate strategy, industry evolution, and organizational structures. Copyright © 2007 John Wiley & Sons, Ltd.

INTRODUCTION

The resource-based view of strategy is arguably the dominant theoretical foundation in strategic management today. In the tradition of Wernerfelt (1984) and especially Barney (1991), the crucial research question is what kinds of corporate resources lead to sustainable competitive advantages (for a recent appraisal, see Barney, 2001). Barney's (1991) approach is essentially static, and recent contributions have attempted to recast the analysis in dynamic terms by explicitly taking

account of industry dynamics and innovations. Following Schumpeter (1934), innovations are understood as the key drivers of market change and firms have to constantly adapt to a changing environment (Prahalad and Hamel, 1990; Teece, Pisano, and Shuen, 1997). Thus, a strategic theory of the firm (Rumelt, 1984; Foss, 2005) should not only analyze the exploitation of existing corporate assets, but also explain the emergence, development, and demise of new resources and capabilities.¹ To conceptualize the creation of new assets, the resource-based view increasingly draws on evolutionary economics (e.g., Montgomery, 1995; Barney, 2001).

Evolutionary economics has long stressed the Schumpeterian nature of the competitive process

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*Correspondence to: Nils Stieglitz, Strategic Organizational Design Unit, Department of Marketing and Management, University of Southern Denmark, Campusvej 55, 5230 Odense, Denmark. E-mail: nst@sam.sdu.dk

¹ In our paper, we follow Amit and Schoemaker's (1993) terminology. Resources are the assets of the firm, while capabilities allow the firm to employ the resources in useful ways.

and the essential role of firm differences for understanding competitive advantage (Nelson and Winter, 2002). In this perspective, the differing corporate resource bases are a constant source for innovations ('variation'). Subsequently the new products are tested in the market place ('selection'). As in the resource-based view, the firm's crucial task is to exploit its existing resources and capabilities while simultaneously developing new corporate assets for future business opportunities. It takes time, resources, and managerial effort to create new assets (Dierickx and Cool, 1989). Due to firms having different resources as well as opportunities to innovate and imitate, they differ in their potential strategic paths (Teece *et al.*, 1997). Established firms are constantly confronted by new threats to the value of their assets. Schumpeter (1934) termed this the process of creative destruction. To be able to survive creative destruction and to exploit future business opportunities, firms have to constantly choose which resources and capabilities to develop. As Teece (1986) points out, however, innovations often only diminish the value of technological assets while leaving the potential value of complementary assets untouched. According to Teece's (1986) definition, complementary assets raise the value of a firm's technological innovations. Examples for complementary assets include marketing capabilities, regulatory knowledge, client list, and so on. Since the values of complementary assets are interdependent, Christensen (1995, 1996) vividly speaks of inter-asset specificity. Given that complementary assets are often not affected by technological innovations, they insulate established firms against the gale of creative destruction. Their resource bases include critical complementary assets and they therefore have the potential to negate early mover advantages of technological leaders. Firms should hence vertically integrate complementary downstream assets (Teece, 1988; Afuah, 2001). On the other hand, complementary assets allow for the innovator's successful appropriation of Schumpeterian rents as they constitute important barriers to imitation. In the resource-based view, Dierickx and Cool (1989) highlight this important role of complementary assets in explaining sustainable competitive advantages by pointing to the interconnectedness of assets that prevent imitation. Correspondingly, gaining access to complementary assets is an important motive for entering cooperative arrangements and corporate networks

(Teece, 1996; Mowery, Oxley, and Silverman, 1998; Harrison *et al.*, 2001). Wernerfelt (1984) already emphasizes that complementary assets can foster the successful entry into new product markets. More recently, the empirical study of Klepper and Simons (2000) and the theoretical work of Helfat and Lieberman (2002) stress the importance of complementary assets for explaining entry and survival of firms over the industry life cycle.

Despite the apparent importance of complementary assets for the understanding of corporate strategy, innovations, and industry evolution, the management of complementary assets has received only limited attention. The need to actively manage the creation and usage of complementary assets is often acknowledged, but the corresponding coordination and cooperation problems that have to be addressed are rarely analyzed. Of course, it is always possible to point to the role of higher-level dynamic capabilities that solve these problems (Teece *et al.*, 1997). However, this leads to an awkward situation for a strategic theory of the firm: while the creation and usage of complementary assets are asserted to be of crucial importance for the understanding of corporate strategy, the corresponding management challenges often remain a black box. Moreover, relying on this kind of reasoning would mean giving up the hope of predicting patterns of firm behavior and restricts the normative value of the resource-based view and evolutionary economics for the management practitioner.

The lack of consideration in managerial problems associated with the creation and usage of complementary assets is especially puzzling if one turns to contract-based theories of the firm like transaction costs economics (Williamson, 1985) or the incomplete contracting framework (Hart, 1995). These contributions point to important incentive and coordination problems as soon as complementary assets enter the picture (Santos and Eisenhardt, 2005). However, as these theories remain silent on the larger issues of competitive advantage, innovations, and industry evolution, their value as a conceptual foundation for a strategic theory of the firm is problematic (Foss, 2005). In this paper, we clarify some of the ideas developed in the contract-based theories and try to integrate their insights into a resource-based theory of the firm. Thereby, a deeper understanding of the link between corporate strategy, innovation, and internal managerial processes is gained.

Our paper is organized as follows. In the next section, we offer a general definition of complementarity and identify the coordination problems associated with the deployment and development of complementary assets. A discussion of incentive problems follows in the third section. Complementary assets magnify internal incentive problems and their management has an impact on the innovativeness of a firm. In the fourth section, we point out the crucial role of complementary assets in managing the internal appropriation of rents. In the fifth section, we relate our key propositions to the industry life cycle. A sixth section concludes.

STRATEGIC DIRECTION: COMPLEMENTARY ASSETS AND PROBLEMS OF COORDINATION

Complementarity defined

While complementarity seems to be a crucial concept in a strategic theory of the firm, it is seldom clearly defined. Milgrom and Roberts (1995) put forward a general definition, which we follow in our analysis. Assets or activities are mutually complementary if the marginal return of an activity increases in the level of the other activity. In other words, if doing (more of) an activity x , the marginal benefits of doing (more of) a complementary activity y increases.² For example, when a manufacturer raises the reliability of its product by investing into better quality controls, it becomes more attractive to extend the warranty as well. Thus, complementarity gives rise to 'synergy' among the complementary activities, with the total being more than the sum of the parts. On the other hand, activities may be substitutes, if doing more of an activity x lowers the marginal benefit of an activity y .

Thus, to reap the full potential of corporate activities, managers have to take account of complements and substitutes among activities. A failure to recognize the substitutability of activities may result in organizational slack and other forms of inefficiency, because a firm performs redundant activities (for a detailed analysis of organizational substitutes, see Siggelkow, 2002). Not taking account of complementarities leads to a loss in

value creation, revenues, and, ultimately, in profits for the firm, because it fails to realize its full potential. For example, a firm that invests in product reliability, but does not change its warranty policy at the same time, partly gives up the ability to further strengthen its competitive position. Hence, the firm might have been better off by foregoing the investments into product reliability if it chooses not to change its warranty policy. Furthermore, extending the warranty without increasing product reliability might even be damaging to its competitive position. Thus, there seems to be two consistent or coherent ways to coordinate the two activities. Either of the companies increases product reliability and extends product warranty or it chooses to leave both unchanged. Both approaches leave the firm better off than changing only one of the complementary activities.

We can exemplify this crucial aspect of complementarity and consistency between activities by way of a very simple formal illustration.³ Two activities x and y may be set either 'low' or 'high', with π denoting their joint performance. The activities are complementary if $\pi[x_{\text{low}}, y_{\text{low}}] \geq \pi[x_{\text{high}}, y_{\text{low}}]; \pi[x_{\text{low}}, y_{\text{high}}]$ and $\pi[x_{\text{high}}, y_{\text{high}}] \geq \pi[x_{\text{high}}, y_{\text{low}}]; \pi[x_{\text{low}}, y_{\text{high}}]$. While $[x_{\text{low}}, y_{\text{low}}]$ and $[x_{\text{high}}, y_{\text{high}}]$ represent consistent activity systems, the choices $[x_{\text{high}}, y_{\text{low}}]$ and $[x_{\text{low}}, y_{\text{high}}]$ are inconsistent, delivering a lower overall performance. Porter (1996) offers the classic example of a consistent system with many activities: Southwest Airlines pursues a successful cost leadership strategy that relies on complementary activities and has built a consistent activity system that aims to minimize operating costs. The business strategy consists of fast turnarounds at the gate to keep planes flying longer than that of rivals, no offering of meals, no assigned seats, and no premium class of service. Additionally, Southwest employs automated ticketing to bypass travel agents. The fleet has been standardized by 737 aircraft, thereby minimizing maintenance costs. An effective selection of destinations (mid-size cities and secondary airports in large cities) rounds out the strategy.

Coordinating the use of existing resources

If corporate resources are complementary, the need for some kind of coordination is apparent, since

² In simple mathematical terms, the activities x and y are mutual complements if $\partial^2 \pi / \partial y \partial x \geq 0$. An increase in activity x raises the marginal return π of the activity y .

³ See, for example, Schmidt and Spindler (2002), and for a more formal illustration Milgrom and Roberts (1995).

the added value of one resource depends on the use of other resources and their individual deployment has to be consistent. In organization science, this basic coordination problem has long been acknowledged by Thompson (1967) and Simon (1976). Simon (1976) argues that complementarities ('task interdependency') increase the complexity of decisions since more variables have to be observed and taken account of. Consequently, according to Simon (1976), different organizational subsystems are established to reduce the complexity for bounded rational planners.

Milgrom and Roberts (1990) have readdressed this problem of coordinating complementary activities in game-theoretic terms.⁴ Their starting point is the empirical observation that the adoption of modern manufacturing technologies was followed by widespread changes in organizational structures, human resource policies, and market positioning. This led to the emergence of the modern manufacturing firm as a new system of production (Milgrom, Qian, and Roberts, 1991). For example, technologies like computer-aided-design and computer-aided-manufacturing made the production process much more flexible. With less specialized equipment, it was possible to offer more varieties of major products, and to update the product line more frequently. Thereby, forms of 'on-demand' production became feasible in numerous industries. In addition, firms implemented new human resource policies with fewer job classifications, reduced inventory stocks, and put a higher emphasis on speed in order processing, production, and delivery. Milgrom and Roberts (1990) explain this new organizational arrangement by arguing that the various activities are mutually complementary, and, consequently, tend to be adopted together.

Through their impact on marginal returns of an activity, complementarities direct the adaptation and the search for improvements and new ventures. But decentralized coordination is often not enough to exploit these benefits, since local search processes often fail to fully take account of the interdependencies (Levinthal and Warglien, 1999). In game-theoretic terms, complementarities

lead to coordination games.⁵ For example, if new flexible machines are installed in the production department, marketing managers may fail to identify the full potential for product variations, and human resource management may underestimate the impact on job descriptions and staffing policy (Milgrom and Roberts, 1995). Thus, general management's active central direction is necessary to induce and coordinate the appropriate changes across departments. Central direction means that general management tells lower-level managers what activities (not) to engage in and advises them on the general level of each activity, while leaving the specifics to lower-level managers. We call this form of central direction 'strategic direction'. Through strategic direction, general management brings about the consistency of the various activities performed by the firm. For example, in the case of Southwest Airlines, the general management's task was to decide on the standardization of the fleet (but not on the specific model), on whether to eschew the hub-and-spoke concept or frequent flier programs, and on the retail channels of Southwest tickets. Lower-level managers cannot make these strategic choices, because they would fail to account for the complementarities between these choices, possibly resulting in an inconsistent activity system.

Strategic direction is knowledge intensive and time consuming for general managers. Their capability to actively direct the different activities of the firm is therefore limited. Demsetz (1995: 34) argues that 'the larger the firm and the more complex it is, the more severe are the problems of controlling the interdependencies among its parts. ... Centralized [direction] is more important the greater are the task interdependencies involved in the firm's production and the more specialized is the knowledge needed to take these interdependencies into account, but these very conditions place limits on the size of the efficient organization.' Consequently, the need to strategically direct the firm's diverse activities puts an upper bound on the size and the growth of firms (Penrose, 1959).

To economize scarce managerial capacity, a substitute for strategic coordination is needed. An alternative mechanism to coordinate complementarity activities is the setting of appropriate objectives and organizational rules that delineate

⁴ Compare also Levinthal (1997), Levinthal and Warglien (1999), and Ghemawat and Levinthal (2000) for a different modeling approach employing the NK-simulation model developed by Kauffman (1993). *N* stands for the number of choices, and *K* for the number of variables each choice depends upon, thus highlighting the complexity of interdependent decisions.

⁵ See Milgrom and Roberts (1995) and Schelling (1960) for a classic treatment.

decision and control rights by general management, thereby providing lower-level managers with a stable formal organizational structure. The organizational rules restrict the behavior of lower-level managers, while the objectives serve as guideposts to channel their discretionary behavior into certain directions and thereby coordinates complementary activities. Within the limits set by the organizational rules, lower-level managers are free to concentrate on their objectives without having to worry about activities in other parts of the organization. It is a sign of inconsistent coordination of complementary activities if lower-level managers feel they cannot accomplish their goals because other parts of the organization ‘do not perform’. The intervention of general management, i.e., strategic direction, is then needed to resolve conflicts and adapt the organizational structure to remedy this situation.

Proposition 1: Strategic direction and the setting of organizational rules and objectives by general management represent alternative mechanisms to manage organizational complementarities and to bring about consistent systems of activities. Organizations that rely more on a formal organizational structure exhibit a lower requirement for strategic direction, freeing scarce managerial capacity, and vice versa.

Coordinating the creation of new assets

So far, we have treated the firm’s assets as given and implicitly assumed that an organization can carry out any possible activity. This does not have to be the case from a resource-based perspective. Besides organizing their activities in such a way as to exploit their current corporate assets, firms have to develop new resources and capabilities if they want to perform certain activities in the future. Entirely new assets that allow firms to perform certain activities are usually the outcome of specific investments and individual learning processes (Ghemawat, 1991). These individual learning processes are themselves interdependent and require coordination. Winter (2000: 984) has stressed that ‘to create a significant new capability, an organization must typically make a set of specific and highly complementary investments in tangible assets, in process development, and in the establishment of relationships that cross the boundaries of the organizational

unit in which the process is deemed to reside.’ Consequently, by coordinating these investment projects and the corresponding individual learning processes, general management and organizational structures have an impact on the creation of new assets. The role of general management is especially significant if entirely new resources and capabilities are developed.⁶ In this case, general management cannot rely on the organizational structure, e.g., the existing set of organizational rules and objectives. The creation of a new corporate asset implies new complementarities among learning processes, while the use of the created assets enables new activities and makes new complementarities between activities possible. General management must strategically coordinate these new relationships and only after they are understood and become more routine can they be coordinated through formal organizational structures.

To study the impact of innovations on the coordination of complementary activities, we draw on the taxonomy developed by Henderson and Clark (1990). In their seminal paper, they distinguish four different types of innovation (Table 1).

Incremental innovations build on existing technological resources and refine traditional product architectures. An established, consistent activity system facilitates incremental innovations, because lower-level managers concentrate on their individual part of the innovative effort within the bounds set by the organizational structure. Strategic direction is therefore not needed to implement incremental innovations.

Architectural innovations change the linkages among key product components while leaving

Table 1. Types of innovation

Product architectures	Technological resources	
	Existing	New
Unchanged	Incremental	Modular
Changed	Architectural	Radical

Adapted from Henderson and Clark (1990).

⁶ The importance of strategic direction in the creation of new assets is highlighted by Maritan (2001). In her case study of decision-making processes in the paper industry, she found that top management decides about and coordinates investment projects that lead to the build-up of new organizational capabilities.

the underlying technological assets untouched.⁷ While architectural innovations draw on existing resources, the new product architecture implies different complementarities between activities, because the product can be designed, produced, and marketed in new ways. For that reason, architectural innovations can diminish the value of an established activity system.⁸ If an incumbent firm wants to preserve profits, it must reorganize its whole activity system, not just parts of it. Otherwise, it runs the risk of ending up with an inconsistent system. In this case, strategic direction has to play the leading role in integrating the changes. The new activity system does not come into existence ready-made. Since activity systems are complex phenomena, they represent the key area for learning (Foss and Foss, 2000). It takes time and a good deal of experimentation to fully integrate the various activities into a new consistent system. The consistency of an activity system is thus an important barrier to imitation, because competitors not only have to reproduce a range of activities (and the corresponding assets which enable them) but also do so in a highly specific manner as well (Rivkin, 2000).

Modular innovations fundamentally change the technologies of established product architectures. For that reason, they are major process innovations. Established firms have to create new technological resources to take advantage of modular innovations. Strategic direction is required to make the necessary investments and coordinate the associated learning processes, especially if they cut across the traditional organizational boundaries of the formal structure. The organizational changes do not end here, however. Milgrom and Roberts (1990, 1995) have forcefully argued that major process innovations like flexible production technologies induce widespread changes of the whole activity system. If firms want to reap the whole benefits of modular innovations, they have to adapt the whole activity system by identifying new or changed complementarities between activities. Strategic direction is not only required for coordinating the build-up of new technological resources, but also for integrating the new

activity system. Much the same is true for radical innovations. Since they change the technologies and product architectures, they are a key challenge for incumbent firms. Radical innovations tend to magnify the coordination problems associated with architectural and modular innovations. In the case of architectural innovations, incumbents can rely on their existing resources, while modular innovations preserve the complementary resources (Teece, 1986). Radical innovations thus often call for both new technological and marketing resources. Strategic direction is for that reason needed to coordinate both the creation of new assets and the consistent integration of new activities. The following propositions follow from our discussion:

Proposition 2: Innovations differ in impact on the resource base and the activity system of the firm.

Proposition 2a: Incremental innovations enhance the resource-base of the firm and reinforce the existing activity system. A firm heavily draws on its existing formal organizational structure to coordinate incremental innovations.

Proposition 2b: More radical innovations call for new resources and/or a realignment of complementary activities. They call for strategic direction to create new resources and to adapt the activity system. That is, a firm implementing more radical innovations shows a higher intensity of strategic direction and relies less on the formal organizational structure to implement changes.

TEAM PRODUCTION, INCENTIVES, AND PROPERTY RIGHTS

Since the value of complementary assets depends on the action of others, they lead to team production and the associated incentive problems (Demsetz, 1995): the marginal returns of individual assets are interrelated and the individual contribution and added value of a specific asset are harder to isolate. The notions of synergy and activity system draw attention to this. According to the contract-based theories of the firm, there is subsequently an incentive to free ride or to shirk, since agents do not have to bear all the costs

⁷ Compare Christensen (1995) for a more detailed discussion of different types of innovations and their impact on the technological assets of the firm.

⁸ See Siggelkow (2001) for a detailed case study of the impact of architectural innovation on the activity system of the fashion apparel company, Liz Claiborne.

of their behavior (Alchian and Demsetz, 1972). Hence, transaction cost economics (Klein, Crawford, and Alchian, 1978; Williamson, 1985) and especially the theory of incomplete contracts (Hart, 1995) have shown that ownership matters for the creation of relationship-specific and complementary assets.⁹ In this kind of analysis, the allocation of ownership rights, defined as the right to exclude others from using an asset, influences the *ex post* distribution of the surplus generated in a contractual relation (Grossmann and Hart, 1986). Assuming that bounded rational individuals foresee this basic link between ownership and surplus distribution, the allocation of property rights influences the incentives to generate the surplus. Incentives to invest in or to build up complementary assets are higher the more of the generated surplus a contracting party is able to secure. For instance, the incentive to invest into a specific and complementary asset is higher if the individual who decides over the investment owns both assets.

However, the cooperation problem does not cease to exist as soon as assets are placed under single ownership. It is far from obvious why lower-level managers should follow the rules and organizational objectives set forth by the formal organizational structure. If one is interested in how new knowledge is created within the firm, the static efficiency criteria of the principal–agent theory does not seem to be a useful point of reference. A more finely grained framework is needed to understand the theoretical relationships between ownership, incentives, and decision rights on the one hand, and the creation and usage of complementary assets on the other. Employees' discretionary rights to use a corporate asset are an important starting point to disentangle these relationships. In an important way, discretionary rights to use an asset are the prerequisite for creating new knowledge, as Foss and Foss (2000: 39) point out: 'This connection is a consequence of the fact that learning by doing usually requires the exercise of use rights over some assets. This implies that pattern of learning by doing . . . depends on the allocation of use rights between different individuals over time, and the division of labour may be one reason for the reallocation of user rights.' To acquire new knowledge, employees need discretionary rights to

use and experiment with an asset. What and how much is learned then depends on the specific structure of user rights within the organization. The use of existing assets, however, may be curtailed if discretionary rights are privately consumed through shirking. The firm then fails to exploit its existing resources. There is thus a fundamental trade-off between the creation and use of assets (March, 1991), because the creation of new assets gets in the way of an efficient use of existing resources.

It is the general management's task to settle this basic trade-off through the firm's business strategy (Cohendet, Llerena, and Marengo, 2000). The business strategy and the corresponding activity system decide the expected level and speed of the firm's innovative activities. The resulting organizational structure—the allocation of user, decision, and income rights—has to be consistent with the business strategy to enable the necessary activities and learning processes. The Chandlerian notion of 'structure follows strategy' therefore has to be extended to the business level. A useful starting point could be Burns and Stalker's (1961) classic distinction of 'organic' and 'mechanistic' organizational structures.¹⁰ In mechanistic organizations, discretionary rights are restricted to facilitate the efficient use of existing corporate resources. Weakly defined use and decision rights and wider possibilities for discretionary behavior of employees characterize organic organizations. Since employees have more room to experiment than in mechanistic structures, we expect to see structures that are more organic in firms that put a premium on exploration and innovations in their business strategies.

To align the business strategy with the corresponding activity system and organizational structure, general management needs the control and decision rights over the firm's assets, including the rights to redefine and reallocate specific use and decision rights. Otherwise, they would not be able to change and adapt organizational structures. Moreover, to begin with, they would not be able to experiment with the activity system. In this sense, the allocation of internal property rights has an impact on the solution of the outlined coordination problem as well. If general management is not permitted to change organizational structures and experiment with new ways of doing things,

⁹ See Hart (1995) and Williamson (2000) for a discussion of the differences between transaction cost economics and incomplete contract theory.

¹⁰ See also Lawrence and Lorsch (1967), Mintzberg (1979), and Tushman and O'Reilly (2002).

the development of new corporate assets may be seriously hampered.

Proposition 3: The business strategy of the firm and its corresponding activity system influences the level and speed of innovations. An explorative business strategy tends to be organized as 'organic' structures with weakly defined use and decision rights. A business strategy focusing on exploitation tends to be more mechanistic, with narrowly defined use and decision rights.

THE PRE-MARKET APPROPRIATION OF INNOVATIVE RENTS

The discussion of cooperation problems usually focuses on the problem of shirking and free riding of contracting parties or organizational members. As discussed above, the idea is that individuals do not put all their productive effort into collective activities, but use their discretionary user rights for their own benefit. But there are related forms of behaving in a non-cooperative way. One form is especially relevant from a Schumpeterian perspective, namely the pre-market appropriation of potential innovative rents. Bhidé (2000) reports that 71 percent of the firms included in the *Inc* 500, a list of young, fast-growing firms, were founded by people who are marketing product ideas created by the previous firm that employed them. This finding highlights the fact that many inventive firms are not able to test and exploit the profit opportunities they generate. They create new knowledge, but fail to use it, since employees leave the firm and start their own enterprise before the product ideas are tested in the market. As a result, the seeds for potential competitors are often sown in the established firm, since the internal link between the creation and use of new knowledge is no longer a given, but poses a persistent dynamic challenge.¹¹

According to Rajan and Zingales (2000), complementary assets provide the economic link that

glues the firm together, and they enable the firm to internally use the knowledge it has created.¹² Rajan and Zingales (2001b) equate complementary assets with specialized, firm-specific assets. Complementary assets are the outcome of the specialization of individuals and other firms to the existing knowledge base of the firm. This creates a quasi-rent (Klein, Crawford, and Alchian, 1978), since the asset is worth less in other settings. In this case, the firm wields bargaining power over the legal asset owner, because leaving the firm would jeopardize the quasi-rent. Since they make them more economically dependent, individuals and firms are only ready to acquire firm-specific assets if the long-term rewards outweigh the costs. This is especially the case if employees are given privileged access to a critical core resource (Rajan and Zingales, 1998) that is valuable and in short supply (Wernerfelt, 1984). Examples of core resources include existing customer and client lists, single individuals with outstanding skills, brand reputation, and corporate culture.

As a result, firms are better able to exploit internally the generated growth options if they have the necessary complementary resources in place and are able to create new growth options faster than competitors. In such a setting, the incentives to leave the firm are small for employees, since they would risk failure in direct competition. Moreover, the expected rewards for being loyal would be high. Accordingly, firms with a narrow, focused corporate strategy are in a better position to create and exploit growth options than diversified firms (Rotemberg and Saloner 1994). More focused firms not only provide the complementary assets to successfully market innovations, but offer the potential to retain innovative leadership in their field, since they build on their existing technological assets to exploit new technological opportunities.¹³

Employees have an incentive to leave the firm if they anticipate that they are able to generate a higher surplus elsewhere *and* to capture more of the surplus in absolute terms. A competitor will be an attractive new employer if she is ready to pay higher wages. This is possible if the competitor

¹¹ The resource-based view of strategy has identified the same appropriation problem in more static settings (Peteraf, 1993). Here, employees or, more general, resource owners are able to appropriate most of the generated surplus through bargaining. For example, Chacar and Choff (2000) find empirical evidence that research analysts in investment banking are able to extract most of the generated surplus. Accordingly, Rajan and Zingales (2001a: 209) claim 'the problem of appropriability, rather than managerial shirking, may now be the more important problem of governance.'

¹² See also Lippman and Rumelt (2003), who analyze the impact of a co-specialization on long-term competitive advantages.

¹³ See Markides (1995) for detailed empirical evidence supporting the relative superiority of focused corporate strategies. Of course, the reasons may be different from the one given by Rajan and Zingales (2001a).

has a more valuable web of complementary assets in place. The employee will then switch firms as long as the wages are higher, even if the share of the captured surplus decreases. In other words, the employee shares relatively more of the generated surplus to gain access to the more valuable web of assets. Individuals might even be ready to accept temporarily lower wages in the hope that they will receive higher wages in the future.

To start a new enterprise, individuals must expect to produce a larger surplus by themselves than the surplus that they can capture by staying in their old firm or by switching to a competitor. These constellations emerge if existing webs of complementary resources and capabilities fail to add much value to innovations (Anton and Yao, 1995) or even prevent them. In the latter case, the existing firm might fail to perceive the economic potential of these new ideas (Henderson and Clark, 1990). Radical innovations are often competence-destroying (Tushman and Anderson, 1986; Christensen, 2001), or make new value networks (Christensen and Rosenbloom, 1995) and the corresponding activity system economically feasible. Because of this, incumbent firms are not in a good position to exploit the radical new ideas, since the old web of complementary assets is nearly worthless for that venture. Accordingly, employees could be better off by leaving the firm and starting their own new venture. The more radical an innovation, the more new ventures will be started, and the seeds of creative destruction will often be sown in the incumbent firms.¹⁴

To conclude, existing firms are webs of past investments that created complementarities around

a critical resource (Ghemawat, 1991; Zingales, 2000; Lippman and Rumelt, 2003). Since it takes time to build such a web, it cannot be reproduced instantly (Dierickx and Cool, 1989). As argued above, an essential managerial task is the strategic direction of investments into new complementary resources and of the associated learning processes to prevent the pre-market appropriation of innovative rents and preserve the firm's competitive advantages. This brings us back to the starting point of our discussion, but it adds an important aspect. The task of general management is not merely to identify complementarities and coordinate their creation and usage. Complementary relationships are often not deterministically given, but are the outcome of past managerial decisions to create certain resources. General management has therefore to make choices about which resources are critical to the firm's future success and to search for original possibilities to build complementarities around them. For example, architectural innovators like Southwest Airlines are frequently firms that create new complementarities among well-known activities (Markides, 1997).

To sum up our analysis, we offer the following propositions:

Proposition 4: If human capital is critical to the success of a business, firms tend to invest more heavily into the search for and the creation of complementary assets to bind employees to the firm and to strengthen their bargaining positions.

Proposition 5: A firm with a narrow business strategy built around a critical resource tends to be characterized by a lower rate of spin-offs and by a higher retention rate of key personnel than a more diversified firm.

INDUSTRY DYNAMICS AND THE EVOLUTION OF FORMAL ORGANIZATIONAL STRUCTURES

Complementary assets raise severe coordination and cooperative problems. If firms want to exploit the economic benefits that the resource-based view ascribes to them, they have to grapple with these problems in one way or another. As outlined above, key instruments in dealing with these are strategic direction, formal organizational

¹⁴ For a different view, see Klepper (2001). It will depend on the exact nature of the technology and of the market structure to pinpoint how radical innovations are (Tripsas, 1997; McGahan and Silverman, 2001). In many cases, seemingly radical technological innovations only destroy complementary assets in parts of the value chain, while leaving the basic value net intact. For example, in the pharmaceutical industry the advent of biotechnology fundamentally changed the nature and organization of research and development. Many new firms entered the industry, and their primary task is the creation of new knowledge, as they are very R&D intensive. But these ventures still rely on the vertical integrated pharmaceutical firm to market their products. The reason is that the resources and capabilities of the traditional pharmaceutical firms like marketing, regulatory management, and brand names are complementary to the new ventures' innovations (for empirical studies, see Arora and Gambardella, 1990; Shan, Walker, and Kogut, 1994; Rothaermel, 2001). The biotechnology firms are ready to share part of the innovative rent to gain access to these valuable complementary assets. Accordingly, vertical integrated biotechnology firms have remained the exception.

structures, and the creation of complementarities between assets. To illustrate this, and to elucidate some of the framework's implications, we look at the evolution of formal organization structures during the industry life cycle.

To understand how formal organizational structures evolve, it is useful to discuss a stylized pattern of industry evolution and to draw some basic implications from the framework. Two aspects seem to be particularly useful in characterizing industry evolution. The first is industry growth, which is a proxy for the intensity of competition. It is a stylized fact that industries often evolve through stages of high growth into saturated stages of low growth (Klepper, 1997; Geroski, 2003). While industry growth is external to the individual firm, our second dimension, the cumulativeness of new knowledge, takes account of the internal resources of a firm. It is a rough measure of how radical a potential innovation is: 'Cumulativeness underlines the idea that today's innovations and innovative activities form the starting point for tomorrow's innovations and that today's innovative firms are more likely to innovate in the future in specific technologies and along specific technologies' (Malerba and Orsenigo 1996: 60). A low degree of cumulativeness, therefore, indicates a more radical innovation. In this case, firms have to create new assets to innovate successfully. Taken as a whole, we can distinguish four different constellations of industry evolution as depicted in Table 2.

New industries are often created by radical innovations that constitute new technological paradigms (Dosi, 1988). In the exploratory stage, major product innovations are taking place, which eventually consolidated into a dominant design (Abernathy and Utterback, 1978; Agarwal, 1998). While market volume is low, growth rates are increasing. The establishment of a dominant design and of a stable technological trajectory often marks the beginning of the growth stage, which is characterized by high growth. Later, an industry

shakeout and consolidation signals the transition to the mature stage with lower growth rates. In the fourth stage, the stagnant phase, two challenges for established firms are of interest for our discussion. First, since further growth opportunities are low in the stagnant market, established firms will look to other product markets to use their capabilities and diversify accordingly (Dosi, Teece, and Winter, 1992; Montgomery, 1994). Second, there is a threat that new entrants who attempt to redefine the industry via architectural or radical innovations erode the competitive advantages of incumbents (Foster, 1986; Christensen, 1997). Both of these challenges have in common that product diversification and the threat of innovative entrants are often characterized by low degrees of cumulativeness. To a varying extent, new assets are needed to create the opportunity for diversification and to blunt the threat of innovative new entrants.

We discuss each stage in turn, and ask:

1. how complementary activities are coordinated;
2. how the internal use and decision rights are structured;
3. how the pre-market appropriation problem is dealt with.

We offer propositions for each stage of the industry life cycle.

Exploratory stage

- (1) In the exploratory stage, the creation of resources is of paramount interest to early movers in the market. Because of the low degree of cumulativeness, the technology itself and the corresponding technological capabilities are key areas for organizational learning. As outlined above, strategic direction is needed to coordinate the complementary investments and learning processes to these assets, and to guide the initial search for a consistent activity system. Strategic direction allows to rapidly change learning processes and to restructure activities in the light of new knowledge about technologies and customer's preferences. The formal objectives for lower-level managers' and other employees' behavior are loosely defined, and open to constant revision through strategic direction, since there is a constant need to experiment with the evolving activity

Table 2. Stages of industry evolution

Cumulative- ness	Market growth	
	High	Low
Low	(1) Exploratory stage	(4) Stagnant phase
High	(2) Growth stage	(3) Mature stage

system. Formal rules only play a minor role in coordinating complementary activities. Therefore, the organization relies on strategic direction as the key instrument to manage complementarities.

- (2) Concerning the allocation of internal use and decision rights, the emphasis is placed on learning and experimenting. Subsequently, the organizational structure is 'organic': The employees' scope for discretionary action is broad, implying a low degree of internal division of labor. The above-mentioned objectives and the corresponding use and decision rights to achieve them channel the behavior of the employees.
- (3) The internal allocation of residual income rights, e.g., stock options or profit sharing schemes, is important for setting financial incentives to learn and to prevent critical employees from leaving the firm. Since a web of complementary resources is just beginning to be developed, the internal appropriation problem is a serious threat to an innovative firm. Surplus sharing may mitigate the appropriation problem. Above that, a crucial task for general management is the rapid build-up of these webs. A first step is to identify critical resources and possible valuable complementary assets and to decide whether to develop them internally or acquire them externally through mergers or acquisitions. Complementary assets do not only guard the firm against internal appropriation, but they are an important early barrier to imitation and a first step toward a sustainable competitive advantage (Teece, 1986; Barney, 1991).

Proposition 6a: A business in the exploratory stage tends to be characterized by a high intensity of strategic direction, an organic organizational structure, and a reliance on surplus-sharing schemes to bind key employees.

Growth stage

- (1) During the growth stage, the degree of cumulativeness of new knowledge increases. With the establishment of a dominant design, product innovations are becoming relatively more incremental. The creation of knowledge is still dominant, but the areas of the

firm's learning activities shift from product to process innovations (Utterback, 1994). The coordination of complementary activities relies less heavily on strategic direction, since vital complementarities have already been identified. Building on their experimentations during the exploratory stage early movers have established elementary, consistent activity systems. Only if the firm changes its business strategy and corresponding activity system will the full need for strategic direction come up again. Formal rules and specific, well-defined objectives are gaining significance. The internal division of labor deepens as the coordination of differentiated tasks and activities is more easily accomplished. Correspondingly, learning processes multiply and accelerate, and become more decentralized and incremental (Marengo, 1992).

- (2) Changes in the internal allocation of use and decision rights reflect this shift toward more incremental learning processes. Residual use and decision rights become more specified and restricted, while still leaving room for experimenting within well-defined boundaries. In other words, since more is known about the technology and market conditions, contracts are becoming more 'complete,' and the room for employees' discretion narrows. The organization is therefore in a transitory stage towards a more mechanistic structure.
- (3) The complementary resources of the firm are still developing, but they already provide an important competitive advantage for early movers that entered successfully during the exploratory stage. Late movers are disadvantaged along two dimensions: they not only have to develop their resources but must also experiment with an activity system. Since early movers have already established elementary activity systems, experimenting and learning is more expensive for late movers. This appears to be one of the reasons why early movers often outperform later entrants (Mueller, 1997). Furthermore, the internal appropriation problem is becoming less severe. The emerging complementary assets bind employees to the firm, and make spin-offs more risky. While remaining an important challenge, the static internal rent appropriation through high wages begins to be the more serious threat, and firms are more

reluctant to establish organizational schemes for surplus sharing for later employees.

Proposition 6b: A business in the growth stage tends to be characterized by a lower intensity of strategic direction and a more stable organizational structure, a transition towards a mechanistic organization, and investments into complementary assets to bind key employees to the firm.

Mature stage

- (1) In the mature stage, market growth slows, and price competition often intensifies. Product innovations are incremental and directed toward product differentiation (Adner and Levinthal, 2001). The efficient usage of existing resources becomes increasingly important as technological opportunities and market conditions are well known. Firms that are still active in the market have a full-fledged, consistent activity system tightly in place. The internal division of labor is high, with a heavy reliance on formal rules, a deep and highly differentiated vertical structure, and inactive strategic direction. The level of incremental organizational learning depends on the exact nature of the industry, but it will usually be smaller than in the earlier stages of industry evolution.
- (2) The internal allocation of use and decision rights places emphasis on static efficiency and incremental innovations and less on experimental learning and building new resources. Respectively, use and decision rights are narrowly defined and well specified, and often require no revision. The transition toward a more mechanistic structure is thus completed during the mature stage. The textbook principal–agent theory can be fruitfully applied here.
- (3) Concerning appropriation, the problem of dynamic appropriation is not important anymore. Since a web of complementary capabilities and assets is now in place, firms are able to expropriate parts of the surplus generated by their employees.

Proposition 6c: A business in the mature stage tends to be characterized by a very low intensity

of strategic direction and a highly differentiated organizational structure, a mechanistic organization, and strong complementary assets.

Stagnant stage

The key threat to the competitive positions of an established firm in the stagnant stage comes from new innovative entrants. Because of their complementary resources and consistent activity systems, incumbent firms have sustainable competitive advantages over new firms. Architectural or radical innovations by new entrants may erode competitive advantages as they change the complementarities among activities, and, in the case of radical innovations, require new resources as well. An adapted activity system is needed to successfully cope with architectural or radical innovations. Incumbents often fail to recognize this and try to accommodate these innovations within the activity. It is only after developing new resources that they begin to adjust their activity systems. Established firms are thus overwhelmed by the parallel need to develop new resources and experiment with a corresponding new activity system. This idea is supported by Christensen and Rosenbloom (1995) and their analysis of the disk drive industry, as well as by Tripsas (1997: 139), who concludes her detailed study of the typesetter industry: ‘The initial products developed by established firms were consistently inferior to those of new entrants. The need for both new technical skills and new architectural knowledge proved difficult for incumbents to manage.’

In the stagnant stage, established firms often face the challenge to generate new growth opportunities. Since market growth is low in stagnant markets, firms look for business opportunities in other areas. Without analyzing in detail the decision to diversify, two observations seem to be possible from our analysis. First, a crucial question is which of the existing resources the firm is able to leverage to new markets, and the answer determines how much emphasis has to be placed on the creation of new capabilities. The second question is how to organize the new venture. Often, diversified firms have more than one autonomous organizational unit, and this reflects the need to have specialized activity

systems for different product markets.¹⁵ Both questions are interrelated, and the organizational challenge is to combine the desire to fully exploit existing complementary assets across different markets with the need to establish specialized activity systems for each one (Burgelman and Doz, 2001).

CONCLUSIONS

This paper has discussed the problems of coordination and cooperation associated with the creation and use of complementary assets. Since the values of complementary assets are interdependent, their use has to be actively coordinated. This leads to the central role of general management in coordinating complementary assets and activities.

To accomplish this task, two basic instruments were discussed, namely strategic direction and the formal organizational structure. Strategic direction is needed to experiment with and establish a new activity system. Dynamically, strategic direction is also required to coordinate complementary learning processes that lead to the creation of new assets. Since management's capacity is limited, formal rules and objectives substitute for strategic direction, if the complementarities among assets and activities are unchanged.

Furthermore, there are problems of cooperation associated with complementary assets as well. Their creation and use critically depend on the internal structure of decision, user, and income rights. Since the successful coordination of complementary assets depends on the cooperation of the employees, general management has to devise an organizational structure that facilitates and enables the firm's activities and learning processes.

The pre-market appropriation problem was identified as an important potential problem of cooperation in a dynamic setting. Employees are a potential threat to the firm's exploitation of newly created knowledge. The threat of innovative spin-offs is particularly severe if the complementary assets of the firm fail to add value to this new knowledge.

¹⁵ The literature on internal corporate venturing (e.g., Burgelman, 1985) and on ambidextrous structures (e.g., Tushman and O'Reilly, 1996) highlight the importance of temporally separating organizational units for established and new businesses. See also Siggelkow and Levinthal, 2003, who demonstrate that temporary decentralization leads to high performance if interactions among a firm's activities are pervasive.

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