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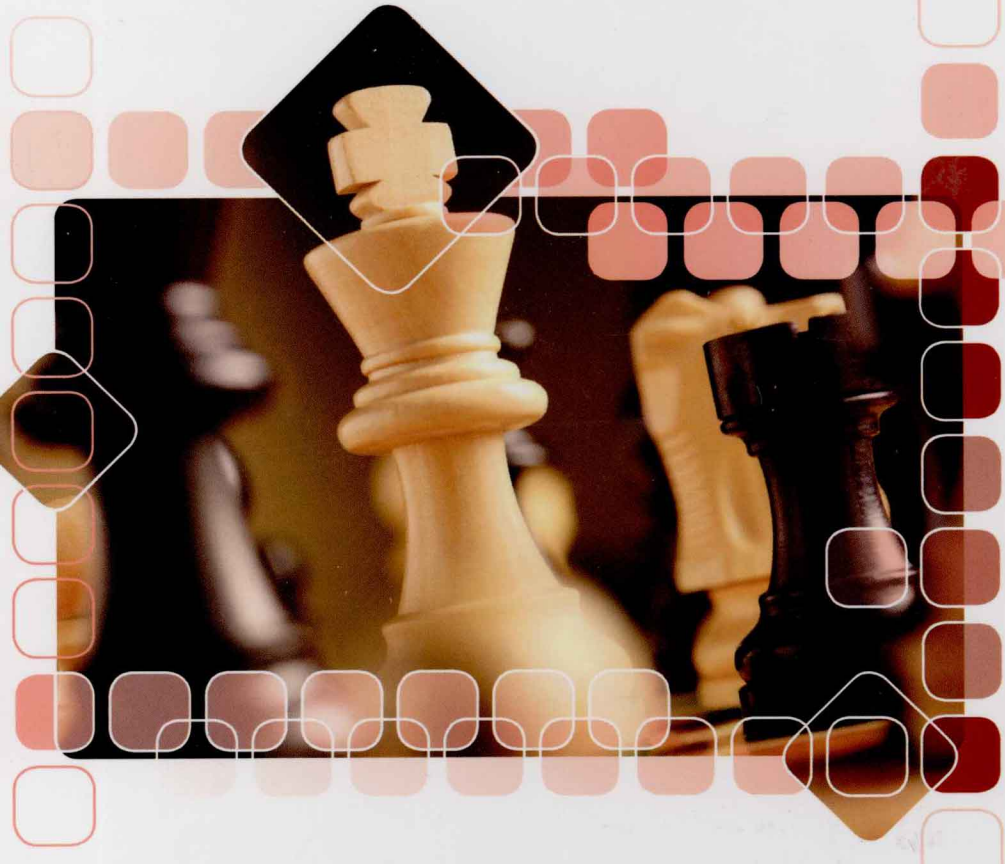
Technology Strategy and Innovation Management



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Technology Strategy and Innovation Management

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Introduction

Michael J. Leiblein and Arvids A. Ziedonis

Technology Strategy and Innovation Management provides a strategic perspective on management in complex, knowledge-intensive, and dynamic environments. These settings pose unique challenges to the successful identification and pursuit of competitive advantage compared with those chronicled in traditional strategic management frameworks. Although tradeoffs between different resource allocation policies and forms of organization remain critical, settings characterized by innovative activity require new tools to address issues such as (a) how to evaluate highly uncertain investment proposals involving new (often unknown) products and services, (b) whether and how to capture value from assets in 'product' or 'knowledge' markets, (c) whether and when to shift from 'old' to 'new' sources of advantage, and (d) how to design organizations that assemble and organize resources in a manner that facilitates exploration of new opportunities and exploitation of existing advantages.

In this volume we have assembled a collection of writings that consider how different forms of innovation create value, how business organizations capture the value generated by their innovations, and how firms may allocate resources and organize their activities to deliver value through innovation. We conclude with suggestions of future research opportunities that could identify how different investments and organizational forms affect the creation, capture, and delivery of value through varying types of innovation.

The volume is organized into five parts. The five sections that follow each examine a particular conceptual element of a robust technology strategy. We then conclude by offering an organizing framework for future technology strategy research. Although we have endeavored to spotlight some of the central and most influential writings within each category as well as several pieces that we believe contribute new perspectives, the breadth and complexity of technology strategy and innovation management as a field prevents this from being a truly comprehensive volume. We begin our compendium in Part I by first asking the fundamental question, 'what is innovation?' The literature has identified several distinct varieties, each posing unique organizational and strategic challenges. The articles in Part II explore the factors that determine who captures the value from an innovation. Parts III and IV delve more deeply inside the firm to understand what makes a firm innovative, first from a resource allocation perspective followed by consideration of organizational issues more broadly. Part IV, in particular, expands this intra-firm focus by investigating firm boundaries and firm interaction. Finally, the papers in Part V examine an emerging perspective in technology strategy, 'real options.'

I Types of Innovation

Ever since Schumpeter (1934) first advanced the notion of innovation as 'creative destruction,' or the dynamic process by which technological and organizational transformations cause

upheaval of existing firms and industries, innovation scholars have attempted to classify innovation into typologies and distinguish among their effects on firm performance. The three articles in Part I each present a different perspective regarding innovation and its affect on business organizations. A recurring theme in these papers is the tension between incumbents and entrants in the commercialization of new technology.

Chapter 1, by Michael Tushman and Philip Anderson, is concerned with technological evolution and the major shifts or discontinuities that often occur as a dominant technology's development unfolds. Building on Abernathy and Utterback's (1978) product-process innovation model,[1] Tushman and Anderson consider an innovation as an event occurring within a technological trajectory. Such a trajectory is characterized as technological progress along a path of incremental improvement interspersed by infrequent technological breakthroughs. Tushman and Anderson observe that these breakthroughs or 'discontinuous' innovations may be of one of two classes. Breakthroughs that render previous technology obsolete, but build upon incumbent firms' core strengths and capabilities are defined as 'competence-enhancing.' The skills and capabilities that firms had developed in producing the earlier technological generation remain critical to participating in the displacing technology. In contrast, a second class of innovation not only displaces the earlier technology, but also renders obsolete existing know-how and technological assets. This innovation is termed 'competence-destroying.'

The distinction between competence-enhancing and competence-destroying innovation suggests the types of firms that are likely to succeed in each of these settings.[2] Incumbent firms benefit from competence-enhancing innovation as their existing skills and capabilities retain their value in the new technological generation. Incumbents are disadvantaged when a competence-destroying innovation occurs, however. Thus, new entry and displacement of leading incumbents are often associated with competence-destroying innovations. Tushman and Anderson find empirical support for their characterization of the evolution of technology and competitive interaction in such disparate industries as airlines, cement, and minicomputers. As we'll see from our other papers in this part, competence-destroying innovations are not the only class of innovations which incumbents must beware.

In their seminal paper, Rebecca Henderson and Kim Clark (1990; Chapter 2) take issue with the simple depictions of innovation as incremental or radical in economic or competence terms. Henderson and Clark examine a class of seemingly incremental innovations, termed 'architectural,' that results not in the reinforcement of the incumbent's position, but its displacement. As does radical innovation, architectural innovation greatly diminishes the value of an incumbent's existing capabilities. Unlike radical innovation, however, architectural innovation destroys the usefulness of knowledge regarding the interaction of components of a technological system rather than the knowledge of the components themselves. Because such knowledge often defines the patterns of interaction between units within an organizational structure, technological changes in the way components interact may go unrecognized within the organization. Thus a seemingly minor change may have profound effects on an organization's ability to respond. The implication is that successful adjustment to architectural innovations will require substantial organization changes to support modified communication channels and information filters.

In Chapter 3 'Customer Power, Strategic Investment, and the Failure of Leading Firms,' Clay Christensen and Joseph Bower agree with Henderson and Clark that the very organizational structure that may lead a firm to success may also prevent it from detecting and responding to

certain innovations. Whereas Henderson and Clark emphasize that subtle changes in the way product components interact can lead to the downfall of industry leaders, Bower and Christensen draw attention to the difficulty existing organizations designed to meet the needs of existing customers effectively can have in dealing with 'disruptive' innovations that initially do not meet the need of those critical customers. Bower and Christensen distinguish between innovations that sustain the improvement trajectory of an existing technology from those that redefine that trajectory. Incumbents are well positioned to benefit from the former – these innovations often benefit the very customers these firms are organized to serve and leverage existing resource allocation policies and information channels. In contrast, disruptive innovations, while improving performance on one or more dimensions, actually fall below current standards on the dimension existing customers value most and often call for substantial changes in resource allocation policy. In this situation, even if incumbents are fully capable of understanding and even producing a disruptive innovation, their need to maintain close relationships with existing critical customers and challenges to existing policies and organization structures often prevents them from doing so. Disruptive technologies often gain traction by appealing to different customers or addressing needs of an emerging market. This in itself is not a danger to incumbents if the situation were static. The performance trajectory of disruptive technologies on technological dimensions that matter most to the established market, however, often exceeds the trajectory of the existing technology. By the time absolute performance of the new technology exceeds that of the existing technology, it is too late for the incumbents and they are often displaced.

II Capturing Value from Innovation

The papers in Part II address a central issue within technology strategy, how to capture the value of innovation. The first article in this group, Chapter 4 by David Teece, is one of the most influential and highly cited papers in the innovation literature. His pioneering 'Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy' has defined a stream of work for the past two decades, so much that the 20th anniversary of the publishing of this article was celebrated by a special issue in the journal *Research Policy* (**35** (8), October 2006). This article separates the act of innovation from the factors that influence whether the innovator can realize the returns from that innovation or whether returns will likely accrue to others. Teece's seminal insight is that in environments in which intellectual property rights are weak (i.e., offer little protection from imitation or substitution by rival innovations) returns often are realized not by the innovator, but by the holders of 'complementary assets,' such as superior manufacturing, distribution, or marketing positions. Considering the interaction of the 'appropriability regime' and the complementary asset positions of the innovator and rivals, Teece predicts who will most likely profit from the innovation. Moreover, he offers detailed prescriptions to innovators on firm boundary strategies (whether to integrate or utilize markets for technology such as licensing) depending on the strength of intellectual property protection surrounding the innovation.

In the year following the appearance of Teece's landmark article, contemporaries Richard Levin, Alvin Klevorick, Richard Nelson, and Sidney Winter published in the *Brookings Papers on Economic Activity*, the widely known and influential 'Yale Survey' of R&D managers on

the means by which their corporations appropriate returns from R&D (Chapter 5). This survey of R&D managers from large R&D performing corporations found that industries vary considerably in the extent to which patent and non-patent (e.g., secrecy or lead time) mechanisms afford protection to innovators in capturing value from R&D. Survey responses from this study have been used by many scholars to construct measures of overall industry appropriability conditions. The Yale survey results were updated in 1994 by the 'Carnegie Mellon survey' (Cohen, Nelson, and Walsh, 2000).

Sidney Winter, one of the collaborators in the original Yale Survey, contributes in Chapter 6 a piece directed towards a managerial audience that links many of the ideas in the Teece (1986) article and the findings of Yale and Carnegie Mellon surveys. Winter thoroughly dissects the various value appropriation mechanisms to innovation and offers managers detailed strategic guidelines intended to help them understand the appropriability environment they find themselves in. Managers with unquestioning belief in the efficacy of patent protection will find their confidence shaken and their understanding of value appropriation much more nuanced after reading the Winter article.

The final two articles in this part also build on the 'shoulders of giants' above who pioneered much of our understanding on the capturing value of innovation. Joshua Gans and Scott Stern (Chapter 7) extend Teece (1986) by contributing a framework intended to explicitly guide managers in understanding the appropriability and strategic conditions they encounter in attempting to commercialize a new innovation. They identify four combinations of complementary asset importance and excludability conditions to offer detailed prescriptions to entrepreneurs and innovators on whether to 'go it alone' and challenge incumbents, or to profit from innovation indirectly through the 'market for ideas'.

Ashish Arora and Marco Ceccagnoli (2006; Chapter 8) provide a recent careful cross-industry study of the extent to which the strength of intellectual property protection influences firms' boundary choices. Building on the central ideas outlined in the above articles and based on R&D managers' survey responses in the aforementioned Carnegie Mellon survey, these scholars find that when firms lack the complementary assets needed to commercialize a new technology, they are more likely to license that technology as the effectiveness of patents in protecting the technology increases. Firms that possess the requisite complementary assets, however, are found to be less likely to license a technology than to pursue commercialization internally, although they are more likely to patent.

Our final article in Part II synthesizes heretofore largely independent streams of academic research on the various types of innovation (highlighted in Part I) and the mechanisms to capture value from these innovations. In 'Unraveling the Process of Creative Destruction' (Chapter 9) Mary Tripsas asks why incumbent firms succeed or fail in the face of radical technological change. Specifically, Tripsas examines: (1) how economically radical innovation affects investment incentives of entrants and incumbents, (2) how competence-destroying innovation affects the utility of incumbents' skill base and resource allocation policies, and (3) how the effect of an innovation on the value of complementary assets affects the ability of entrants and incumbents to appropriate value from an innovation. Through a detailed account of the evolution of the typesetting industry, Tripsas emphasizes the effect of the need for new technical skills and new architectural knowledge on incumbent firms' performance in the face of innovative change.

The ideas and findings presented by Arora and Ceccagnoli and the other articles included in Part II suggest that the strength of intellectual property protection and location of complementary

assets needed in successful commercialization are key determinants of the vertical structure of firms in innovative industries, as well as the extent to which markets for ideas function within those industries. And, by reminding the reader of the need to broadly consider how different types of innovation affect competition, the Tripsas article provides an important bridge to the topic of Part III – how to deliver value through innovation.

III Delivering Innovative Value Through Resource Allocation and Organization Activity

The central premise common to the papers in Part III is that a firm's ability to recognize, assimilate, and apply information to commercial ends is critical to its capability to deliver innovative value. Wesley Cohen and Daniel Levinthal's seminal article entitled 'Absorptive Capacity: A New Perspective on Learning and Innovation' (Chapter 10), is one of the most influential works within this literature (see also Cohen and Levinthal, 1989). Cohen and Levinthal reason that the basic skills, shared language, and cognitive structures that underlie an organization's existing knowledge base dictate its ability to assimilate and utilize new knowledge. By redirecting attention from the immediate consequences of R&D investment to the innovation process itself, these scholars suggest that the cumulative nature of prior knowledge has important implications for the development of absorptive capacity and the innovative performance of organizations. Further, the observation that R&D creates a capacity to assimilate and exploit new knowledge provides a explanation for why some firms may invest in basic research even when the preponderance of their findings spill out into the public domain. Cohen and Levinthal propose that business firms are often motivated to conduct research not only to solve specific problems but also to develop general skills and understanding that would permit them to exploit external scientific and technological knowledge, a theme picked up by our next article.

Lee Fleming and Olav Sorenson examine the association between scientific research and innovation in their paper 'Science as a Map in Technological Search' (Chapter 11). Consistent with work that describes the various impediments associated with different forms of innovation, these scholars propose that the nature of scientific research itself alters the form of innovative search. In exchange for up-front investment in learning (absorptive capacity), science provides insights and heuristics that allow researchers to (1) conduct comparatively inexpensive offline experimentation, (2) quickly winnow unproductive directions, and (3) identify global optima. While local search processes such as trial and error learning are associated with simple innovations involving independent components, Fleming and Sorenson suggest that a scientific approach is strongly linked to innovation problems that involve multiple, tightly coupled bits of knowledge.

Jack Nickerson and Todd Zenger's Chapter 12 entitled 'A Knowledge-Based Theory of the Firm – The Problem-Solving Perspective' extends Fleming and Sorenson's approach by suggesting ways managers may craft governance forms to influence the innovative search process. Nickerson and Zenger maintain that if problems systematically differ in complexity and if different governance forms are comparatively superior to others in facilitating particular search processes, then a key managerial task is to select the governance device that aligns a particular problem type with a particular search process. Emphasizing distinctions in the

allocation of decision rights, the intensity of incentives to motivate search, and the availability of communication channels to support knowledge transfer, these scholars suggest that the selection of market, authority-based hierarchy, or consensus-based hierarchy differs in their support of various forms of search. Market organization is seen as a low-cost and efficient means of supporting directional search, authority-based hierarchy is an efficient means of directing heuristic search in moderately decomposable environments, and consensus-based hierarchy fashions an efficient means to stimulate heuristic search in non-decomposable settings.

In their joint article titled 'Untangling the Origins of Competitive Advantage' (Chapter 13), Ian Cockburn, Rebecca Henderson, and Scott Stern discuss the importance of distinguishing between the influence of initial conditions and directed managerial action on competitive advantage. They exploit the recent diffusion of science-based discovery processes through the pharmaceutical industry to provide evidence suggesting that initial conditions and purposeful strategic adjustment are jointly associated with leading positions. Their work calls attention to opportunities for future research that explore how organizational endowments and *ex ante* organizational decisions influence the manner by which particular firms are able to create and sustain advantage. Future studies could focus on the effect on competitive advantage by decision making on resource allocation policies, use of particular managerial tools, scope of networks, diversification, outsourcing versus relational contracting, or off-shoring and multi-national organization choices, for example.

IV Delivering Innovative Value Through Inter-Organizational Drivers

The papers in Part IV examine factors that determine the boundaries of the firm (i.e., the determinants of which activities are more effectively performed internally and which activities are better accomplished through contracts or alliances).

Gary Pisano's 1990 article, 'The R&D Boundaries of the Firm: An Empirical Analysis' (Chapter 14), is one of the first to apply transaction-cost economics (TCE) reasoning to firm boundary choices within the pharmaceutical industry, and research and development procurement decisions more generally. Pisano highlights two forms of transaction costs as being particularly critical in the choice of whether to conduct R&D in-house or to contract with outside entities (in this context, specialized biotechnology firms). These are bargaining hazards arising from specialized R&D activities and the degree of difficulty that the firm would have in defining and appropriating the value of intellectual property arising from R&D outcomes. The specialized knowledge required for successful research and development of an innovation often reduces the number of potential partners or suppliers in the innovation value chain to a small number. A lack of alternative suppliers with the requisite specialized knowledge can render the downstream firm especially vulnerable to possible opportunistic behavior by the supplier. Pisano finds that in such situations the procuring firm is more likely to conduct R&D internally than through external agreements. Likewise, as the number of rivals grows, firms are more likely to stay out of the market for specialized R&D services to avoid the greater opportunities the supplier would have to leak strategic information to rivals.

Walter Powell, Kenneth Koput, and Laurel Smith-Doerr also investigate firm relationships within the biotechnology and pharmaceutical industries, but come to a very different conclusion

than Pisano regarding the primary drivers of firm boundaries and organization. In their 1996 *Administrative Science Quarterly* piece (Chapter 15) these scholars emphasize that in an emerging science-based industry such as biotechnology, knowledge creation is widely dispersed. In such an environment individual firms rarely possess the complete range of scientific capabilities necessary to stay competitive and current. Research breakthroughs and technological development therefore are often products of wide collaborations involving biotech firms, university scientists, and pharmaceutical firms. The central challenge for firms in such an environment is to actively participate in and successfully manage these collaborations. Powell, Koput, and Smith-Doerr argue that the firms that are most centrally located within knowledge networks are those that are best positioned to access the needed capabilities and thus enjoy the greatest prospects for growth.

Whereas Powell et al. highlight the importance of knowledge transfer across firm boundaries, David Mowery, Joanne Oxley, and Brian Silverman look more closely at how it occurs. In their influential article 'Strategic Alliances and Interfirm Knowledge Transfer' (Chapter 16), they assess the effects of cross-firm knowledge transfer on capability development. One novel feature of the paper is their use of firm patent holdings to measure technological capabilities and their transfer. The paper provides modest support of Dan Levinthal and Wes Cohen's notion of 'absorptive capacity' facilitating external knowledge acquisition by the firm (Chapter 10).

While Oxley and Sampson (2004; Chapter 18) concur that alliances can effectively facilitate exchange of technological knowledge, they argue that such organizational arrangements can also leave the alliance partners vulnerable to misappropriation of proprietary knowledge not intended for exchange. They emphasize that the scope of the alliance may be used as a mechanism to limit misappropriation. While narrowing the scope of an alliance may reduce the amount of knowledge that can be transferred across firm boundaries, it can also serve to protect technological assets. Oxley and Sampson find that among R&D alliances involving electronics and telecommunications firms, firms that form partnerships with direct competitors are likely to do so in a limited fashion. Such alliances tend to be restricted to R&D activities rather than encompassing more commercial marketing activities. Equity-based alliances are found to be broader in scope in general, consistent with prior research on alliance governance choice.

Two papers highlighted in this section investigate performance implications of firm boundary decisions. Michael Leiblein, Jeffrey Reuer, and Frédéric Dalsace (Chapter 17) explore outsourcing alliances and vertical integration choices in an industry characterized by innovative activity, semiconductor manufacturing. Like Pisano, these scholars incorporate the transaction cost economics framework into their analysis, and largely confirm his pharmaceutical industry predictions in the semiconductors. Continuing where Pisano left off, however, they examine the performance consequences of these organizational boundary decisions. One of their most important findings is that firms that chose integration when TCE would predict they should enjoyed higher technological performance than they would if they chose the counterfactual, and vice versa. By documenting the costs of transactional misalignment, Leiblein, Reuer, and Dalsace thus provide an important contribution to the empirical transaction cost economic literature.

As do Mowery, Oxley and Silverman, Ahuja and Katila (2001; Chapter 19) measure firm technological capabilities and knowledge bases with patent-based measures, but apply these measures to understanding acquisition performance. A unique feature of this paper is that the authors disaggregate acquisitions into those that are motivated by access to technology and

those that are non-technological. While non-technological acquisitions are found to have little effect on post-acquisition innovation output in their sample of chemicals industry firms, acquired technological knowledge bases do influence innovative performance. Similar to the mixed results reported in Mowery, Oxley, and Silverman regarding the influence of absorptive capacity on a firm's ability to integrate knowledge from an alliance partner, Ahuja and Katila find that absorptive capacity is most valuable for acquiring firms whose knowledge bases moderately overlap with that of the acquired firm. Firms whose knowledge bases are either too similar or too dissimilar suffer from reduced post-acquisition innovative performance compared to the moderate firms.

V Real Options

The final six papers in our volume address the 'real options' perspective on technology strategy. The emphasis of this approach on providing a rational method to make sequential decisions under uncertainty suggests that it may offer a logic well-suited to the uncertainty and dynamism typical in technologically intensive settings.

Rita McGrath's paper titled 'A Real Options Logic for Initiating Technology Positioning Investments' (Chapter 20) provides one of the first applications of real options thinking to technology strategy. The paper conceives of technology strategy in terms of a sequence of investments in technology development, technology commercialization, and the right to extract returns from the technology. McGrath treats early investments in technology development or commercialization as options with a claim on future (uncertain) returns from the technology (e.g., through licensing or product-market competition). A key point in the paper is that firms may create competitive advantage by proactively initiating 'strategic actions' that influence the level and structure of uncertainty in subsequent revenue streams. McGrath describes a number of such actions including consumer education, standard setting, and the development of appropriability regimes. She contends that real options logic suggests how actions that alter the structure of demand uncertainty affect the magnitude and timing of potential revenue streams and may offer an under-appreciated means to improve returns.

Bruce Kogut and Nalin Kulatilaka's article entitled 'Capabilities as Real Options' (Chapter 21) further advances our thinking by providing the conceptual apparatus to understand strategic capabilities as real options. The paper employs concepts from strategic management regarding the importance of scarce factors of production, concepts from strategy and organizational ecology regarding irreversibility and inertia, and concepts from complex systems regarding landscape ruggedness and option values to formally illustrate how capabilities and organizations act to derive potential future value.

Kogut and Kulatilaka's provocative paper contributes to the innovation literature in a number of ways. The authors suggest that capabilities act as options to change positions in a competitive landscape, identify the coupling of bundles of assets as a primary source of irreversibility, and describe how option theory may help to evaluate investment in a capability to change a market position of uncertain and changing value. Further, by formally modeling the benefits of exploiting current capabilities and maintaining or switching (at a cost) these capabilities in the future, the paper creates opportunities to carefully explore how firms dynamically choose an optimal set of capabilities over time.

In Chapter 22, titled 'Entry in the Presence of Dueling Options,' Tim Folta and Jonathan O'Brien empirically explore the association between uncertainty and entry or investment in a new business segment. In contrast to prior work that emphasizes the negative ramifications of uncertainty on investment, Folta and O'Brien frame the question of entry in terms of deferral and growth option value. Arguing that growth options are more sensitive to uncertainty than deferral options, they propose that uncertainty has a non-monotonic effect on entry decisions. In their pooled cross-sectional analysis of firms in the Compustat database, they find that uncertainty negatively affects the probability of entry throughout most of the range of measured uncertainty but the effect reverses under very high levels of uncertainty (above the 93rd percentile in their study). In addition to providing one of the first empirical tests of growth and deferral option logic, Folta and O'Brien contribute to the innovation literature by suggesting opportunities to consider questions involving the likelihood and timing of investment in real option terms.

Michael Leiblein and Arvids Ziedonis (Chapter 23) also discriminate between growth and deferral options in their exploration of investments in environments characterized by continual technical progress. They present a model that considers decisions to invest in existing or expected future technologies and the timing of those decisions. Leiblein and Ziedonis employ real option logic to support their claim that environmental-, firm-, and technological-characteristics dictate an optimal investment timing strategy. They describe how growth and deferral option value differ on the object of uncertainty, the mechanisms used to secure a claim on the opportunity to act flexibly in the future, and the expected arrival time of the future opportunity. Leveraging these differences, they suggest how certain characteristics affect the optimal investment strategy. Their paper contributes by outlining a general theoretical framework that helps to distinguish, *ex ante*, between different sources of option value and with which to analyze the factors that influence whether and when firms should adopt a given technology. It also suggests the opportunity for future work that could marry real option logic with theories of competitive advantage based on the timing (early or late) or nature (reversible or irreversible) of investment.

In Chapter 24, titled 'Real Options and Technology Licensing,' Arvids Ziedonis examines the use of options contracts by firms acquiring rights to commercialize university technologies to conduct one of the most careful empirical tests of real options logic published to date. Whereas data constraints have prohibited much of the prior empirical options literature from examining factors that influence the decision to invest in an option or have been forced to rely on proxies of 'virtual' or 'implied' options, this study overcomes these limitations by leveraging a unique dataset which includes observations on decisions by firms whether or not to purchase option contracts in the licensing of technologies arising from university research.

In addition to offering a test of the predicted associations between uncertainty and the propensity to invest in options, the paper offers insights regarding the association between firm-specific knowledge, the propensity to invest in options contracts, and the propensity to exercise these options. In so doing, the study suggests that option value can be firm-specific and that the decision to license a technology is as at least partially conditioned by prior decisions to invest in option agreements.

Whereas the previous articles all assume that real option logic may generate new insights, in 'What is Not a Real Option' (Chapter 25) Ron Adner and Dan Levinthal remind us that many of the assumptions underlying real options logic may be violated in organizational settings. In particular, Adner and Levinthal examine two boundary conditions associated with the

application of real options logic to business and technology strategy. Noting that the benefits of flexibility of real options logic stem from the possibility of abandoning investment, they point out that the open-ended nature of search and the lack of explicit and exogenous expiration dates typical of many investments designed to stimulate innovation violate core tenets of the real options logic. Moreover, they propose that other factors such as bounded rationality, escalating commitment, and overconfidence may produce substantial costs in the application of the real options approach. Given the impossibility of proving failure and the absence of formal expiration dates for an option investment, a firm's internal selection regime dictates its ability to manage options. A well-managed real options strategy must necessarily guard against the natural momentum that could come with this approach.

Adner and Levinthal follow by questioning about the distinctiveness of the real options tool compared to the broader set of sequential decision making approaches such as 'slack search.' After comparing real option heuristics with other sequential search processes, they conclude that when target markets and technical agendas are flexible, activities may be more accurately described in terms of path-dependent processes such as slack search.

In the end, we believe the appropriate metric for a management theory is whether or not it is fruitful. As Adner and Levinthal point out, the benefits associated with the precision of a real options approach must be balanced against the boundaries of these initiatives.

Concluding Remarks

The articles selected for this volume illustrate how uncertainty, complexity, and dynamism in innovative settings impose tradeoffs across firms' resource allocation and organization policy decisions. It is our contention that technology strategy and innovation management's emphasis on these tradeoffs provides a number of unique insights and contributions to the broader field of strategic management.

Our compendium begins by reviewing in Part I several categories of innovation identified by leading academic scholars. The precision offered by these definitions sets the stage for delineating the strategic and organizational challenges posed by innovative activity, challenges which are tackled by the remaining articles in the volume. Part II provides a foundation with which to consider mechanisms such as patents, trade secrets, and lead time and their effect on the distribution of profits. Parts III and IV consider associations between intra- and inter-organizational forms and innovation. The volume concludes with a set of articles employing real options logic as a means to understand and manage uncertainty in Part V.

A fuller and more explorative description of our thinking regarding technology strategy and innovation management is summarized in Figure 1. Following an organizing structure commonly used in the fields of competitive and technology strategy, the outer ring of this figure is composed of three elements signifying the creation, capture, and delivery of value through innovation. Creating value involves identifying strategies that increase consumer willingness to pay and/or reduce supplier opportunity cost. Capturing value implies bargaining with consumers and suppliers using mechanisms that distribute portions of the total value created to members of the ecosystem. Delivering value requires the allocation of resources and design of organizational systems that facilitate the coupling and recombination of appropriate knowledge chunks. The inner ring in Figure 1 portrays smaller circles each depicting topical

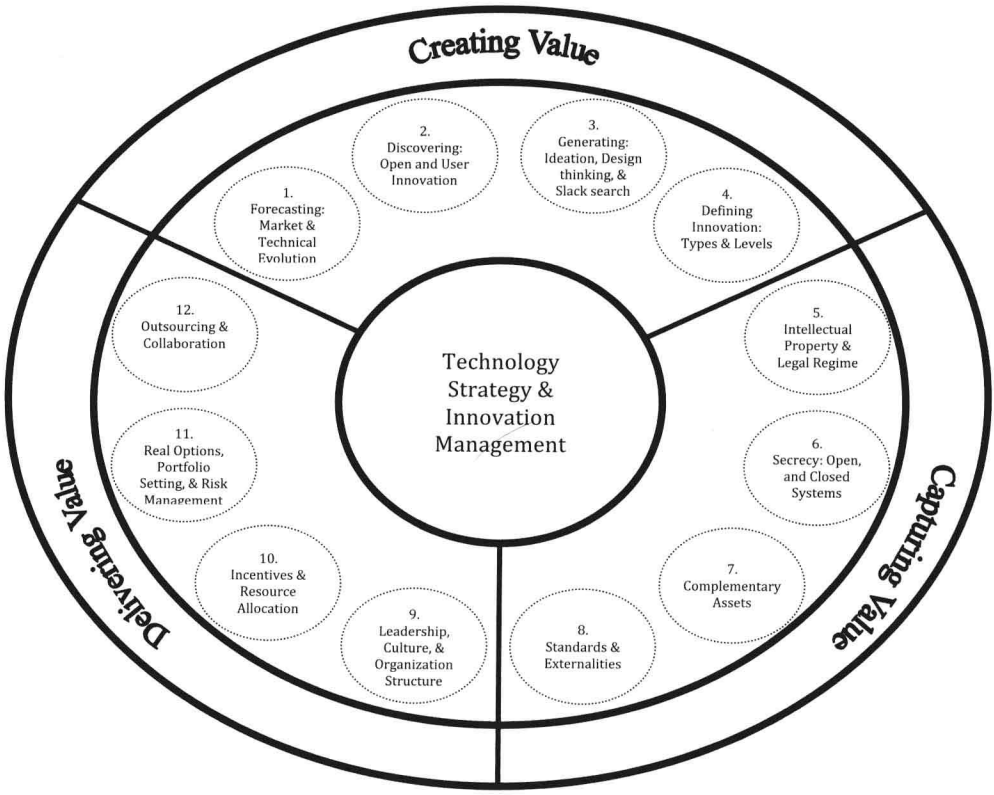

Figure 1 An overview of topics in technology strategy and innovation management

areas within each of the three broader topics. In sum, Figure 1 captures much of the understanding of innovation by academics and practitioners, and points to areas in need of additional research.

The first topic, creating value, captures how organizations harness the creative horsepower inside and outside the organization to increase top line revenue growth and reduce supplier opportunity cost. While our volume emphasizes different types of innovations of interest to managers, other work in technology strategy describes the processes that lead to innovation. Creating value through innovation also involves developing an understanding of the types of products that consumers will enthusiastically reward and an understanding of the improvements in resources and activities required to design, manufacture, sell and distribute these products. Figure 1 depicts processes used to forecast, discover, or generate insights associated with the creation of value through innovation such as trend- and scenario-analysis (e.g., Foster, 1988; Schwartz, 1992), open innovation (e.g., Chesbrough, 2003, 2006a, 2006b; Raymond, 1999) or user innovation (e.g., von Hippel, 1986, 1988), and ideation and design thinking.

Despite frequent discussion, less is known about the causes and consequences of these basic approaches. Future research may productively examine associations between particular

environmental characteristics, specific innovative processes, and the generation of various types of innovation. For instance, while analytical forecasting or real option techniques may be valuable in generating innovation in settings where there are high degrees of demand or technological volatility, ideation programs and 'design thinking' may be more useful when there are high degrees of ambiguity regarding consumer needs. Although the ability to develop deep pools of knowledge and support rich communication protocols may favor formal R&D labs for innovations involving poorly structured problems with high degrees of product- or technological complexity, better structured problems involving modular knowledge chunks may benefit from 'user' and 'open innovation' programs that provide access to a broader knowledge base through markets or social structures. In sum, we hope to stimulate additional work regarding the creation of value through innovation by illustrating major topical areas associated with the creation of value through innovation.

The second major component represents questions pertaining to traditional questions in technology strategy and innovation management regarding the mechanisms organizations use to capture value from their inventions. This section focuses on whether and how intellectual property management practices such as patents, secrecy, complementary assets, and lead time affect a firm's ability to manage, protect, and leverage knowledge to capture value. While a great deal of academic research has described these value capture mechanisms and their use in particular settings (e.g., Levin, Klevorick, Nelson and Winter, 1987; Teece, 1986 (Chapter 4); Winter, 2000 (Chapter 6)), opportunities remain to develop and test a robust theory suggesting whether and when each of these mechanisms is likely to be most effective. One promising alternative is to develop theory regarding the industry-, firm-, and technology-level conditions under which each of these mechanisms is most effective. Among other issues, such a theory may indicate conditions under which technology strategies stressing open innovation or secrecy are likely to be successful. Ultimately, an effective knowledge sharing and protection strategy should optimize revenue derived from a firm's patent portfolio (and IP licensing).

The final major element portrayed in Figure 1 summarizes how organizations may allocate resources and manage R&D operations to deliver value. This portion represents how various leadership roles, incentive designs, research portfolios and organization structures affect the level and type of innovation activity and the pursuit of subsequent competitive advantage. Building on the insights of Cohen and Levinthal's (Cohen and Levinthal, 1989, 1990 (Chapter 10)) notion of absorptive capacity, recognition that knowledge required for innovation is often 'sticky' (von Hippel, 1998), and the work on problemistic search (Fleming and Sorenson, 2004 (Chapter 11)) and organization (Nickerson and Zenger, 2004 (Chapter 12)) presented in this volume, we anticipate future opportunities may exist in clarifying and testing whether and how the economic organization of an ecosystem affects innovation activity and the development of an innovation trajectory. It may also be possible to link the insights from research emphasizing linkages between organization and search with real options logic reviewed in this volume suggesting how investment affects capability development (Kogut and Kulatilaka, 2001 (Chapter 21)), the efficacy of early and late mover advantages (Leiblein and Ziedonis, 2007 (Chapter 23)) and the pursuit of competitive advantage (McGrath, 1997 (Chapter 20)). Ultimately, this work should determine which components to source, how to identify and certify appropriate sourcing partners, and whether and at what level to collaborate and share technical, operations, and consumer knowledge.