Section I

Introduction

1 Technological innovation: Oversights and foresights

Raghu Garud, Praveen R. Nayyar, and Zur Shapira

Technological changes offer firms some of the most important opportunities for maintaining corporate vitality. Indeed, there are many well known cases of firms capitalizing on technological opportunities. For instance, Sun Microsystems was among the first few firms in the computer industry to initiate the development of RISC chips that are now revolutionizing the computer industry (Alster, 1987). 3M has reaped benefits from its Post-it Notes as has Sony from its Walkman (Nayak & Ketteringharn, 1986). There are many other instances of such "technological foresights."

There are also several instances of firms failing to capitalize on technological opportunities. For instance, RCA, a recognized leader in broadcasting, chose not to invest in FM technology (Hughes, 1989). Xerox Corporation was among the first few firms to develop many of the elements of the personal computer that we now use but was unable to reap commercial benefits from its efforts (Smith & Alexander, 1988). There are many other instances of such "technological oversights."

Why do such technological oversights and foresights occur? One view is that oversights and foresights are inevitable[1] because technological outcomes are *uncertain* and *contingent* upon a match between the internal capabilities of a firm and its external environments, and because technological choices are *complex* and *constrained* by the past. These are the challenges that the chapters in this book attempt to address in an effort to develop a theory of technological innovation.

Challenges to the creation of a theory of technological innovation

Uncertainty

The uncertainty challenge is richly illustrated by Barney (chapter 2, this volume) in his use of a coin-flipping analogy to suggest "luck" as an explana-

tion of technological oversights and foresights. This challenge is all the more acute in the case of technological innovation wherein outcomes are less certain than the outcomes from the flip of a fair coin. By some accounts, only two out of 10 innovations succeed (Mansfield, 1981; Cooper & Kleinschmidt, 1990; Van de Ven, 1986; Rosenberg, 1994). Indeed, pushing this perspective a bit further, oversights and foresights cannot be determined ex-ante and are constructs that can only be applied post-hoc.

Contingency

Coins are flipped knowing ex-ante whether heads or tails constitutes a positive outcome. However, judging outcomes of technological innovation as successes or as failures is more difficult. This is because whether or not an endeavor leads to a positive or negative outcome is contextually determined (Langlois, chapter 5, this volume). Oversights and foresights, from this perspective, are contingent upon a match between internal competencies and external environments, the connections between which are often tenuous and emergent (March & Sproull, 1990). Moreover, these environments do not remain static. As these environments change, previous successes may be viewed as failures or vice versa. Thus, success or failure may only be determined post-hoc, although actions have to be taken ex-ante.

Constraints

In addition, choices made in the present are constrained by choices of the past. Successive investments in an approach, whether they be cognitive, behavioral, or economic, result in increasing momentum in a particular direction, thereby creating a "trajectory" (Dosi, 1982; Porac, chapter 8, this volume; Henderson, chapter 9, this volume). Such path dependencies (Arthur, 1988; David, 1985; Powell, 1991) can result in an escalation of commitment to a course of action that may be at odds with a different, larger emerging "reality" (Garud & Rappa, 1994; Levitt & March, 1988). Here again, outcomes of a technological choice made in the present are considered as oversights or as foresights only in hindsight (Utterback, 1994).

Complexity

To complicate matters, technology practitioners who make decisions in the present are subject to a number of biases (Bercovitz, Figueiredo, & Teece, chapter 13, this volume). Even if it did matter, human judgment is limited at best and biased as well. These limits and biases apply all the more so to situations involving complex decisions, as is usually the case with technological choices. These limits and biases result in technological choices that are viewed as foresights or oversights only in hindsight.

Given these challenges, it appears that Barney's coin-flipping analogy

may be too generous a metaphor when it comes to describing outcomes of technological innovations. In other words, innovations are not just "chancy," but are constrained by the past as well, even as humans with their limited cognitive resources make complex decisions in a changing contextualized world. If we were to flip an unbiased coin, we might have a 50/50 chance of success. Outcomes from technological innovation appear to be bleaker. Under these conditions, only hindsight is 20/20.

Beating the odds: Towards a theory of technological innovation

To construct a theory of technological innovation, we must suggest how it is possible to enhance the slim odds of technological success, which can be known only in the future, by adopting practices in the present, given (and despite) our pasts. Specifically, we must identify ways to deal with the complexities associated with technological choices to systematically influence outcomes. We must demonstrate how it is possible for us to escape our past in order to create a new future. Moreover, we must establish that practitioners actively try to tailor a fit between their "external" environments and "internal" competencies.

Learning to flip coins

Chapters in the next section address the challenge arising from uncertainty. The section begins with Barney's chapter, which suggests that technological foresights and oversights are simply lucky outcomes of a random process. One way to address this challenge is to aggregate outcomes across units and time, to learn from each "experiment" so that the odds of success may increase across units and time. This is what we (Garud, Nayyar, and Shapira) propose in chapter 3. Dosi and Lovallo (chapter 4) suggest that even if learning does not occur, individual experiments create alternatives to choose from (see also Levinthal, chapter 10, this volume).

Tailoring fits

The third section addresses the contingent nature of outcomes. Beginning with a chapter by Langlois (chapter 5) that articulates the problem, the section continues with a chapter by Brown (chapter 6) that suggests why and how fits can be tailored by firms as they enact their realties. Similar to Weick's (1979) notion of enactment and March's (1991) notions of exploration, Brown suggests that "Our jobs is to be there as markets evolve, to learn to recognize them even before they recognize themselves, because we can't afford to wait for the clarity of hindsight as we construct linkages between emerging markets and emerging technologies. We allow technologies to shape markets and the markets to shape the technologies." Amabile and

Conti's chapter (chapter 7) also explores this issue, but by examining the context for fostering creativity within organizations. They argue that many of the downsizing efforts currently underway in organizations can adversely affect employee motivations to engage in innovative activities. Amabile and Conti then offer several suggestions as to how this negative facet of downsizing may be overcome.

Remembering to forget

Chapters in the fourth section explore how it might be possible to attenuate the links with the past to reduce its constraining effects. The challenge is articulated by Porac (chapter 8) who argues that technological trajectories are "sticky" in the sense that past actions and choices constrain the present and the future. Henderson (chapter 9), too, offers insights on how past beliefs about the potentials of a technology might constrain its limits. Reflecting on similar issues, Levinthal (chapter 10) points out that the codification of past experiences, considered as "wisdom" in stable environments, acts as inertial forces in changing environments. Consequently, Levinthal argues that unlearning may be required for "discovery." Jelinek (chapter 11) too is mindful of the need to create new initiatives in mature industries. She suggests that substantial entrepreneurship is required on the part of members who perform organizationally "unnatural" and "illegitimate" acts. She suggests that such "unnatural" and "illegitimate" acts can be cultivated through the pervasive sharing of managerial tasks and responsibilities, mindful alertness to anomalies, and ambiguity absorption by means of mutual support. Eliashberg, Lilien, and Rao (chapter 12) point out that the use of many market research tools may accentuate the problems of the past when technology practitioners extrapolate from them. These authors offer tools that are appropriate to probe the future rather than the past

(S)top management and culture

The fifth section addresses the role of top management in dealing with complexity. Bercovitz, Figueiredo, and Teece (chapter 13) articulate the challenge of complexity. Specifically, they highlight the biases inherent in making decisions on complex issues. Murmann and Tushman (chapter 14) illustrate how the collective mobilization of innovation intelligence through the presence of a diversity of perspectives in top-management teams is fundamental to dealing with the complexities associated with innovation. Van de Ven and Grazman (chapter 15) have a similar message. They suggest that it is important to put in place dialectical processes to overcome the potential myopia that might develop during technological innovations. However, Fischhoff, Lanir, and Johnson (chapter 16) and Kunda (chapter 17) caution that top-management intervention can create unintended side effects. Specifically, top-management intervention may decrease the possibility of

autonomous innovation (Fischhoff, Lanir & Johnson, chapter 16, this volume), or might create a subtle cultural context in which innovating members "burn" themselves out in the quest of a task that by its very nature can never be completed (Kunda, chapter 17, this volume).[2]

In sum, the challenges to a theory of innovation stem from the fact that technological outcomes are uncertain and contingent upon a match between firms' internal capabilities and external environments, even as technological activities are complex and constrained. These are powerful ideas. The underpinnings to a theory of technological innovation lie in an equally enticing set of ideas. Specifically, technological outcomes can be systematically enacted to overcome constraints of the past by managing complexity in the present.

Learning makes the difference

By themselves, the terms technological oversights and foresights focus attention on innovation as outcomes. Such a focus creates a roadblock to the construction of a theory of technological innovation. Focusing on outcomes alone can result in "functional" thinking, wherein we begin rationalizing how and why oversights and foresights may have occurred only in hindsight.

To gain potency, oversights and foresights as outcomes have to be part of a larger process. Indeed, learning is a key process that distinguishes technological innovation as a game of chance from one that is a game that involves skill as well. Without learning (or unlearning as the case might be) technological choices are indeed just "coin flips." With the introduction of learning, however, technological innovation becomes an activity that possess the potential to be systematic, enacted, unconstrained, and manageable.

Indeed, each chapter in this book has several implications for the notion of learning as applied to technological choices over a period of time, though their meanings and applications differ. For instance, the notion of learning, associated with the organizing theme in the second section, results from repeated choices that are made possible by aggregating across time and entities. In contrast, the notion of learning implicit in the theme of the third section has to do with the recognition and creation of a match between an external environment (that is not fully in a firm's control) and internal capabilities (that create a certain cognitive mind-set). Most interestingly, the notion of learning is inextricably intertwined with notions of unlearning for chapters in the fourth section. Learning results in the creation of a stock of knowledge that might need to be abandoned to create a "launching ground" for new learning in an attempt to accumulate contemporary useful knowledge. Learning, from the perspective of the fifth section, has to do with a combination of the above approaches as practitioners attempt to manage technological innovations in a complex and messy world.

Each chapter is a richer mosaic of ideas about learning and unlearning

than we have attributed to them. The important point to note is that if we have to create a useful theory of technological innovation, the notion of learning, in its various forms, is fundamental. We (Garud, Nayyar, and Shapira) return to these issues once again in the conclusion of the book (chapter 18) in which we provide our readers a way to integrate the various themes in this book. In doing so, we take the first steps towards creating a theory of technological innovation that entertains the proposition that it is possible to "beat the odds."

Acknowledgments

We acknowledge financial and organizational support from the Center for Entrepreneurial Studies, Stem School of Business, New York University. We thank Sanjay Jain and Arun Kumaraswamy for their comments on an earlier version of this chapter.

Notes

1 See Utterback (1994), he uses the metaphor of innovation as a game of "chutes and ladders" to suggest that oversights and foresights are inevitable.
2 These chapters are richer than the conceptual "boxes" that we have put them into. Indeed, it is important to note that these boxes emerged inductively as we experimented with various combinations and approaches to the organization of the book. When we first conceptualized this book, we had the various contributors organized by disciplines (technology, marketing, decision making, organizational processes, and strategy). We found that such an organizing scheme created artificial disciplinary barriers to a phenomenon that is truly interdisciplinary. We then tried to organize the book by "levels" of analyses. We soon discovered that many chapters cut across levels. The current scheme, although committing a "procrustean transformation" of its own, nevertheless represents elements of a theory of technological innovation.

References

Alster, N. (1987). How Intel and Motorola missed the Sun rise. *Electronic Business*, 13(21), 32–34.
Arthur, B. (1988). Self-reinforcing mechanisms in economics. in P. Anderson et al., *The Economy as an Evolving Complex System*. Reading, MA: Addison-Wesley.
Cooper, R. G. and Kleinschmidt, E. J. (1990). New product success factors: A comparison of "kills" versus successes and failures. *R&D Management*, 20, 1, 47–63.
David, P. (1985). Clio and the economics of QWERTY, *Economic History*, 75: 227–332.
Dosi, G (1982). Technological paradigms and technological trajectories. *Research Policy*, 11: 147–162.
Garud, R. and Rappa, M. (1994). A socio-cognitive model of technology evolution. *Organization Science* 5, 3: 344–362.
Hughes, T. P. (1989). *American Genesis: A Century of Invention and Technological Enthusiasm, 1870–1970*. New York: Viking.

Levitt, B. and March, J. G. (1988). Organizational learning. *Annual Review of Sociology*, 14, 319–340.

Mansfield, E. (1981). How economists see R&D. *Harvard Business Review*, November–December, 98–106.

March, J. G. and Sproull, L. S. (1990). Technology, management, and competitive advantage. In P. S. Goodman, L. S. Sproull, and Associates (eds.), *Technology and Organizations*. San Francisco: Jossey-Bass, 144–173.

March, J. G. (1991). Exploration and exploitation in organizational learning. *Organization Science*, 2(l), 71–87.

Nayak, P. and Ketteringharn, J. (1986). *Breakthroughs*. New York: Rawson Associates.

Powell, W. W. (1991). Expanding the scope of institutional analysis. In W. W.Powell and P. J. DiMaggio (eds.), *The New Institutionalism in Organizational Analysis*. Chicago: University of Chicago Press, 183–203.

Rosenberg, N. (1994). *Exploring the Black Box: Technology, Economics, and History*. New York: Cambridge University Press.

Smith, D. and Alexander, R. (1988). *Fumbling the Future: How Xerox Invented, Then Ignored, the First Personal Computer*. New York:William Morrow.

Utterback, J. M. (1994). *Mastering the Dynamics of Innovation*. Boston: Harvard Business School Press.

Van de Ven, A. H. (1986). Central problems in the management of innovation. *Management Science*, 32(5), 590–607.

Weick, K. (1979). *The Social Psychology of Organizing*. Reading, MA: Addison-Wesley.

Wilson, T. L. and Hiavacek, J. D. (1984). Don't let good ideas sit on the shelf. *Research Management*, 27 (3), 27–34.