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Thinking about technology: Applying a cognitive lens to technical change

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ABSTRACT

We apply a cognitive lens to understanding technology trajectories across the life cycle by developing a co-evolutionary model of technological frames and technology. Applying that model to each stage of the technology life cycle, we identify conditions under which a cognitive lens might change the expected technological outcome predicted by purely economic or organizational models. We also show that interactions of producers, users and institutions shape the development of collective frames around the meaning of new technologies. We thus deepen our understanding of sources of variation in the era of ferment, conditions under which a dominant design may be achieved, the underlying architecture of the era of incremental change and the dynamics associated with discontinuities.

1. Introduction

Evolutionary models of technical change invoke a life cycle metaphor to depict technological progress in an industry over time. Within this literature, the basic model posits that early on, following a technological discontinuity, high levels of technical variation characterize an era of ferment. Next, selection among competing technologies leads to the retention of a dominant design – a set of technologies and associated problem-solving heuristics embodied in a particular product design. Convergence on a dominant design is followed by a period of incremental progress that is ultimately disrupted by another technological discontinuity as the cycle repeats itself in a highly path-dependent process. Associated with each stage of this cycle are technical outcomes that the literature has addressed: Where does technical variation originate? Under what conditions does a dominant design emerge (or not)? What determines which design will become "dominant?" What drives the rate and direction of technological change during periods of incremental progress? When does a technological discontinuity occur? A long-standing research tradition grounded in both economics (Dosi, 1984; Nelson and Winter, 1982; Sahal, 1981) and organizations (Tushman and Anderson, 1986; Tushman and Rosenkopf, 1992; Utterback, 1974) has examined these questions. For the most part, however, the technology life cycle literature, including such recent papers as Murmann and Frenken (2006) and Suarez (2004), has neglected cognitive factors, factors that we argue are essential to understanding the dynamics of technology evolution.

Given the inherent unpredictability and equivocality of technologies (Nightingale, 2004; Weick, 1990), one might expect that cognitive processes should shape their evolution. Neither the nature of a new technology nor its trajectory is obvious *ex ante*. When a technology first emerges, actors – be they producers, users or institutions – are unsure about what it is or how it will perform. In such ambiguous circumstances, actors need to make sense of the situation before they can act (Weick, 1995), implying

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that cognitive explanations should be central to understanding technology evolution. Yet, while cognition has received increasing attention in the broader field of organizational theory (DiMaggio, 1997; Huff, 1990; Lant, 2002; Walsh, 1995), research on the technology life cycle has been largely silent about cognition's role. One view of innovation has underscored the cognitive underpinnings for translating scientific discoveries into technologies within organizations (Nightingale, 1998), and in this paper we extend these types of insights by developing a model of technology evolution that explicitly considers the role of cognitive dynamics across organizations.

The model we develop focuses on how the technological frames (Acha, 2004; Orlikowski and Gash, 1994) of a wide array of actors shape the technological trajectory over the life cycle. We propose that diverse technological frames are a source of variation in the era of ferment, that framing activities help drive the achievement of a dominant design when one emerges, and that the intertwining of technological frames and organizational architecture in the era of incremental change can explain why transitions are so difficult.

We use the word "technology" in the tradition of the technology life cycle literature, to mean technology as applied in a particular product context and as embodied in a physical artifact. So technology is not just the knowledge from which products are elaborated, but also includes the physical manifestation of that knowledge within a product. For instance, empirical studies of the technology life cycle have examined products such as automobiles, typewriters, television sets, and calculators (Suarez and Utterback, 1995).

Our theoretical exploration of the relationships among technology, technological frames and actors' interpretive processes leads to two important contributions to the literature on technological change. We first use cognitive factors to refine our understanding of why technologies evolve along a particular path over the course of the life cycle. For each stage of the technology life cycle, we identify conditions under which applying a cognitive lens might change the expected technological outcome predicted by purely economic or organizational models. Because cognitive dynamics may not be fully aligned with the kinds of economic or behavioral forces previously identified in the technology life cycle literature, we argue that models of technological progress that ignore cognitive factors may result in spurious conclusions. Even when economic, organizational and cognitive factors all work in the same direction, our model provides an alternative explanation for commonly observed phenomena, improving our depth of understanding.

Second, applying such a cognitive lens to technological change foregrounds the importance of interactions among the frames of multiple sets of actors in the process. We suggest that the technological frames of producers, users, and institutional actors all need to be considered in understanding technology evolution. Because their frames are likely to be diverse, interactions among these actors may be conflictual. Actors may therefore act purposefully to shape which frame comes to predominate in the field. Thus, we argue that the emergence of a collective technological frame is a contested process. Such diversity and contestation amongst frames can help explain why (and which) alternatives appear during the era of ferment. It also shows why dominant designs are not always achieved. Only when this process culminates in a predominant collective frame can a dominant design emerge. A collective technological frame is an essential dimension of the dominant design, and it structures further developments in the field. This model thus provides a co-evolutionary perspective on the interpretive dynamics that contribute to the direction a technology takes.

In the following sections, we first develop our cognitive model of technology trajectories, building upon prior research in the area of managerial cognition. We then apply the model to each stage of the technology life cycle. We examine how the mechanisms at work and the expected outcomes might differ from previously established economic or organizational arguments. We conclude with implications for research and practice suggested by this cognitive model of technical change.

2. A cognitive model of technology trajectories

2.1. The underpinnings of a cognitive model of technology trajectories: technological frames and interpretive processes

The examination of cognition in the managerial arena goes back at least to March and Simon (1958), who argued that everyone in an organization brings a certain cognitive foundation, a set of givens, to any management decision – assumptions about the future, knowledge about alternatives and a view of the consequences of pursuing each alternative. Confronted with a highly complex and uncertain environment that does not transmit clear and easily recognizable signals, actors use these givens, or frames, to form simplified representations of the information environment. By frame, we mean the lens through which actors reduce the complexity of the environment in order to be able to focus on particular features, make context-specific interpretations, decide, and act (Goffman, 1974).

In the context of understanding technology evolution, we focus on what Orlikowski and Gash (1994, p. 178) call a "technological frame," which captures how actors make sense of a technology (see also, Acha, 2004). Specifically, technological frames shape how actors categorize a technology relative to other technologies and which performance criteria they use to evaluate the technology. Said differently, a technological frame guides the actor's interpretation of what a technology is and whether it does anything useful.

Actors' technological frames do not spring up randomly, but rather are the encoding of their prior history, including both idiosyncratic organizational experiences and industry affiliations. Within an organization, the common experiences of members create a shared understanding of technology – an understanding that is unique to the firm given its distinctive history (Prahalad and Bettis, 1986). This shared logic is rooted in experience with existing products and technologies. Even startup firms with no history have founders whose unique perspectives become imprinted in