Research Policy 44 (2015) 1555–1565

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Disruption in the US machine tool industry: The role of inhouse users and pre-disruption component experience in firm response

Raja Roy[a,*], Susan K. Cohen[b]

[a] Management and Marketing Department, College of Business and Management, Northeastern Illinois University, 5500 N. St. Louis Ave., Chicago, IL 60625 USA
[b] Katz Graduate School of Business, University of Pittsburgh, USA

ARTICLE INFO

Article history:
Received 19 July 2014
Received in revised form
12 November 2014
Accepted 11 January 2015
Available online 23 June 2015

Keywords:
Disruptive technological change
User innovation
Product innovation

ABSTRACT

We investigated how incumbent differences affect their response to a disruptive change and found that incumbents with access to inhouse knowledge that helps them understand "what to develop and design" and "how to do it," are likely to be the leaders in matching the performance features in a disruptive product. We used the advent of machine tools with disruptive Computer Numerical Control (CNC) technology as the context and concentrated on the transition period when the machine tool demand was shifting from customized machine tools with mechanical controls to standardized machine tools with CNCs. We found that incumbents with access to inhouse users and broad pre-disruption component experience were the leaders in matching the agility of the disruptive products. Our findings suggest that the boundary conditions for the theory of disruption is more nuanced than what the literature predicts.

1. Introduction

By suggesting that new technologies, which are initially unable to meet the needs of mainstream customers but introduce new performance features, can eventually displace mainstream technologies, Christensen's (1997) research and subsequent studies by Danneels (2006), Henderson (2006), and others have shed new lights on how managers and scholars approach technological innovation. Researchers acknowledge that "innovator's dilemma" prevents a large manufacturer, such as RCA or DEC, from responding to the disruptive threat. These manufacturers either do not introduce disruptive new products or are late in introducing products that match the performance features of the disruptive products (Christensen and Overdorf, 2000). Despite the impact of Christensen's theory on both academia and practise, researchers (e.g., Tripsas, 1997; see also Christensen et al., 2011) have also provided evidence that large manufacturers, e.g., Mergenthaler Linotype, Sony, and others, often successfully respond to disruptive technological changes. Such evidence led Henderson (2006, p.5) to observe that Christensen's (1997) focus "on the dynamics of decision making in the senior team as the dominant explanation for why established firms so often miss disruptive innovations" obscures the critical role of firm-level competencies "in shaping the ways firms respond to disruptive innovations."

Henderson's critique implies that understanding how firm differences affect incumbents' responses to disruptive innovation may help clarify the boundary conditions of the theory of disruption (Dubin, 1978) and potentially benefit both managers and academics. To explore the boundary conditions of the theory of disruption, we build on innovation literature (e.g., Chen et al., 2012), which reports that incumbents' capabilities play a vital role in their efforts to adapt to a technological change. More specifically, we investigate if firm-level factors such as access to inhouse users and prior technological experience (von Hippel, 1994; Cattani, 2006) constitute the boundaries of the theory of disruption. Intuitively, the co-location of inhouse users of disruptive products (henceforth referred to as "inhouse users") and prior experience in the components required to manufacture the disruptive products would help firms to understand "what to develop and design" and "how to do it" (Teece, 1992, p.10), respectively, which should be beneficial to a firm during a technological change, including disruption. The research question that we seek to answer in this paper is, "how does access to inhouse users and prior experience in the components needed to manufacture products with the disruptive technology help firms match the performance of the disruptive product?"

The context of our study is the introduction of disruptive Computer Numerical Control (CNC) technology in the 1970s in the US machine tool (MT) industry. Unlike Christensen's (1997) assertion,

* Corresponding author. Tel.: +1 504 296 5223.
E-mail addresses: rroyneiu@gmail.com (R. Roy), suecohen@katz.pitt.edu (S.K. Cohen).

http://dx.doi.org/10.1016/j.respol.2015.01.004
0048-7333/

we find that the major mainstream (or pre-disruption) MT manufacturers did not suffer from "innovator's dilemma" and competed to match the critical performance feature of the disruptive product. We define the period from 1975 – when Fanuc of Japan introduced the CNC 2000 and 3000 series of MTs and developed DC servo motors; critical milestones in the emergence of the CNC technology till 1980, when CNC MTs had only about 3% of the US market share of MTs, as the "pre-disruption" period. US manufacturers' consumption of the disruptive CNC MTs grew precipitously in the 1980s – from 34 percent of the total MT consumption in 1983 to more than 50 percent in 1987—and culminated with the US government imposing the voluntary restraint agreement (VRA) against the Japanese manufacturers in 1987. Accordingly, we treat the period 1981–1987 as the "disruption period."

Traditionally, the US auto manufacturers, the largest buyers of MTs, relied on transfer machine system for mass production. These "systems" included mechanically controlled MTs (MC MTs) – customized products that were designed to produce the same component year after year (Carlsson, 1996, p.86; Carlsson, 1989a, p. 256). The demand conditions of MTs in Japan were considerably different from that in the US, and in the 1970s, the Japanese auto producers started to rely on batch production system. This system, also known as the Toyota system of production (Helper, 1995; p.12), was started by Taiichi Ohno and adopted by most of the Japanese automakers in the 1970s. However, the US auto manufacturers, who traditionally relied on mass production, adopted the batch production system in the 1980s (Alexander, 1990; p. 33). Whereas mass production aimed at "achieving efficiency at high volume" by keeping the "line moving," the aim of Toyota's system was to achieve efficiency at low batch production volumes by using the agile CNC MTs with high "throughput" (Carlsson, 1984a; p. 104).

Consistent with Christensen's (1997) predictions, the diffusion of the CNC MT technology in the US started with the demand from the small job shops that supplied components to the larger aerospace and auto manufacturers. As we discuss in details in Supplementary material Appendix 1, for the US auto manufacturers, the transformation from mass production to batch production was a disruptive one because it affected their value systems (Carlsson, 1984b; working paper, p.24; Kalafsky, 2006, p. 189; Alexander, 1990; p.26) and manufacturing processes (Helper, 1995; p. 12; Mazzoleni, 1997; p.424)—the critical sources of innovators' dilemma that Christensen and Overdorf (2000) identified. Consequently, although the CNC MTs were commercialized in 1975, these standardized cheaper products had a market share of just about 3% in the US in number of units sold in 1980 (Mazzoleni, 1997; p. 408).

Although the US users of MTs had ignored the CNC MTs in the pre-disruption period, during the disruption period, however, those users, such as General Motors (GM) and Ford, started demanding MTs with CNC. During this time period, we found that – unlike Christensen and Overdorf's (2000; p.8) predictions that "no company has routine process for handling" disruptive innovations and therefore established manufacturers "never introduce" (p. 7) the disruptive products – the US MT manufacturers not only introduced the disruptive products but also tried to match the agility – or the speed with which a MT can process raw materials (Carlsson, 1989b; p. 191) – of the disruptive Japanese CNC MTs.[1]

[1] The innovation and operations literatures treat agility as an integral part of MT's flexibility and define agility as the MT's capacity to quickly respond to changes in customer demand (Upton, 1995, p.206; Wadhwa and Rao, 2003, p.114). This definition, which equates agility with the speed of response, is consistent with O'Connor's (1994; pp. 54–55) observation that agile MTs helped Pratt and Whitney perform metal cutting operations in one third the time it took using manual methods and Sheridan's (1993, p.30) observation that agile MTs help with rapid introduction of new or modified products. Cho and Hsu (1997) and Mehrabi et al. (2000), and others have made similar observations.

We examine the responses of 45 US MT manufacturers who had made MTs with the pre-disruptive MC technology and subsequently adopted the disruptive CNC technology in the late 1970s. We posit that firms that possess the knowledge of "what to develop and design" and "how to do it" during disruption, are likely to have the value systems and processes (Christensen and Overdorf, 2000) that are conducive to matching the agility of the disruptive products. Our results suggest that, unlike Christensen's (1997) proposition, whether established firms will be the innovation leaders with the disruptive new technology or not, depends on firm-level factors, such as access to inhouse users and prior experience using components.

2. Theory and hypotheses

Researchers generally agree that firms that listen too closely to their customers are likely to be inertial in their response to a disruptive new technology (Christensen, 1997, 2006; Christensen and Overdorf, 2000; Adner 2002; Henderson, 2006; Wessel and Christensen, 2012). Researchers also agree that disruption is associated with both demand and technological uncertainty. For an established manufacturer facing a disruptive change, the demand uncertainty is driven by the fact that, ex-ante, firms are uncertain about which performance features the mainstream customers are likely to value. The demand uncertainty affects firms' value systems—the "standards by which. . ..[a firm judges]. . .if a new product is attractive or not" (Christensen and Overdorf, 2000; p. 4) and prevents the allocation of resources to the disruptive new technology. The technological uncertainty, on the other hand, is driven by the fact that, ex-ante, firms find it almost impossible to predict if, and when, the product made with the disruptive new technology will be able to meet the requirements of the mainstream customers and how to design those products. The genesis of technological uncertainty is therefore rooted in the lack of understanding of the processes and capabilities that may be required to manufacture the disruptive new product.

Given these uncertainties, developing new products in response to disruption is akin to searching for solutions to a problem that the firm faces (Helfat, 1994; Katila, 2002) and a pertinent literature for our theory building is the organizational learning literature. Scholars in this tradition have observed that, while searching for solutions to existing problems, prior experience accumulated by a firm helps it to learn (Argote and Todorova, 2007). This stream of literature reports that, under uncertainty, firms are more likely to learn vicariously (Bandura, 1977) from the "fashion leaders" or "trend setters" (Bikhchandani et al., 1992; Srinivasan et al., 2007; Semadeni and Anderson, 2010). Consistent with the prediction of this stream of research, Argyres et al. (2015, p. 219) highlighted that matching the performance of market leader's products is a viable strategic response for the follower firm because imitation "diminishes or neutralizes potential advantages that otherwise might accrue to the innovator." Extending this argument to the realm of disruption, we expect that vicarious learning from the disruptor, about the agility of their products, can help a firm cope with the uncertainties associated with disruption. Consistent with Teece's (1992; p.10) insights, it seems plausible that, in the context of disruption, vicarious learning will help a firm understand "what to design?" (i.e., which performance features create value for the customers) and "how to design the product?" (i.e., which components to use in the design of the disruptive new products to deliver those performance features), thereby helping it to adapt to the change. Extending these arguments to the context of disruption, we expect an incumbent that is facing demand and technological uncertainties associated with disruption, to match the performance features of the disruptor's products.