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Creating technology candidates for disruptive innovation: Generally applicable R&D strategies

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ABSTRACT

In this paper, we first examined the importance of technology creation in technological disruptive innovations (DIs), and found both academic scholars and industrial practitioners have underestimated the challenging nature and importance of technology at least in technological DI. We then moved upstream to study empirically how technology candidates could be created purposefully for potential technological DI. Four generally applicable R&D strategies were abstracted from intensive studies on 37 technological DIs, by applying the central thoughts of principal component analysis which transforms many correlated variables into a small number of uncorrelated ones. The four R&D strategies abstracted are miniaturization, simplification, augmentation and exploitation for another application. Their creation of DI was examined, postulated and then demonstrated by means of the Delphi method. The frequencies of their utilization were also compiled and the implications discussed. This study has further advanced the knowledge at the front-end of R&D, i.e. the technology perspective of DI. It hopes to facilitate more purposeful creation of technology candidates for potential technological DI in future.

1. Introduction

Ever since the popularization of the *disruptive innovation theory*, enlightened incumbents have learnt the importance of disruptive innovation (DI) and are better prepared to exploit potential DI to avoid potential dethronements from below (Christensen and Raynor, 2003; Lindsay and Hopkins, 2010). Furthermore, the new market created by DI could grow to become very significant and be worthwhile by itself (Govindarajan and Kopalle, 2006; Utterback and Acee, 2005; Linton, 2009). Creating potential DI has thus been increasingly regarded as a promising strategy to fend off potential disruptors or to simply seek new growth.

The literature so far has assumed that a particular technology would emerge from R&D laboratories once in a while. Such a technology candidate would facilitate the commercialization and innovation path of a DI. The research focus to-date has therefore correctly addressed the subsequent management challenges of exploiting the technology candidate for successful DI (Yu and Hang, 2010). Little research has been done on the front end, i.e., the creation of technology candidates for potential DI purposefully rather than leaving it to chance.

In this paper, we have moved upstream to study empirically how one may purposefully create technologies for potential DI in R&D laboratories. Hence, the research scope is within technological DI (e.g., digital camera and electric bicycles), rather than pure business model DI (e.g., budget airlines and online education). At the beginning, the case of transistor radio was briefly reviewed to explain the importance of technologies in technological DI. The literature on the purposeful creation of DI from a technology perspective was then reviewed. To date, the findings of most papers could not be applied as they did not address the initially "inferior performance" of DI; thus the explicit identification of R&D strategies specific to the creation of technologies for potential DI has remained as a research gap.

Our research aims to address this gap. By generating generally applicable R&D strategies (hereafter calls the R&D strategies), we extend the research on the technology aspect of DI, complementing the existing literature on DI. It is also hoped that the findings of this research will be helpful to R&D managers in pursuing the strategic intent of creating disruptive technology candidates to enhance the technology options of the firm (Rouse and Boff, 2004).

The research begins with the literature review on the technological dimension of DI in Section 2. It is followed by a 4-step research design in Section 3. Section 4 first presents the abstraction

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process of the R&D strategies, and then explains each strategy in detail with 2 cases; finally, it discusses the application frequency and implications of the strategies in the future. Section 5 summarizes the findings, policy implications, limitations and avenues for future research.

2. Literature review on the technological dimension of DI

Although Christensen (1997) has first coined the term disruptive technology, he and other scholars have subsequently focused on management challenges in DI, assuming that suitable technologies are available. Technological uncertainty was not considered as a major issue, unlike radical technology/innovation (Leifer et al., 2000). In fact, the original term ''disruptive technology'' covers innovation not only in technology, but also in product, process and service. In subsequent studies, the term *disruptive technology* has been replaced by *disruptive innovation* (Christensen and Raynor, 2003). Furthermore, finer categorization has been proposed, i.e., DI includes both technological DI and business model DI (Markides, 2006).

In addition to insufficient attention to technology uncertainty, there is a good understanding that the initial performance of DI is inferior when compared to existing technology/product which sustains the mainstream market. Both of these factors have contributed to the general perception that it is sufficient to be vigilant and be quick to spot the opportunity when a technology for technological DI first emerges sometime in the future. Another general perception is that since it is relatively inferior, technology candidate for DI may not be a worthwhile R&D goal in universities and industrial R&D laboratories, which in turn reinforces the current pattern that technological DI only occurs by chance or only occasionally.

In a recent exploratory study (Yu and Hang, 2008), it was found that the creation of certain technological DI could indeed be extremely challenging, especially if it was based on a new scientific discovery. The introduction of the world's first transistor radio by Sony clearly demonstrated such a challenge. The deeper investigation of the technological dimension has provided the following important perspectives: (i) the R&D leading to the creation of technologies for DI may indeed be extremely challenging and is hence suitable as an agenda for use-inspired upstream research in companies as well as in universities and (ii) by creating technology candidates for DI ahead of competitors, the firm could command a substantial lead in exploiting them for subsequent DIs and building unique core competences. The challenging nature of technology in some technological DI is also found by Schmidt and Druehl (2008) who argued that some opportunities of new market disruption (which they named as detached market low-end encroachment) were often very risky and technologically challenging.

Although important and challenging, the creation of technology candidates for potential DI from purposeful R&D was rare and will need to be promoted (Linton, 2004; Walsh, 2004). There were several recent attempts in the literature to propose a systematic approach to create technologies for DI. Unfortunately, most of them were not applicable to the creation of technological DI with initially inferior performance. For example, Kostoff et al. (2004) proposed a systematic approach to create technologies for DI through the first stage of literature text-mining to create suitable ideas, followed by the second stage of special workshops and roadmapping exercise. They interpreted DI as innovation that could provide dramatic improvements and were more efficient with higher unit performance. This is not the same as Christensen's definition of DI that are initially inferior relative to the existing technologies in primary attributes. The explicit generation of R&D strategies specific to the creation of technology for DI on purpose has remained as a research gap. Although there are indeed insightful studies on the technology dimension of DI (e.g., Bower and Christensen, 1995; Paap and Katz, 2004), they focused on the stage of technology identification for potential DI when a group of new technologies were available in the R&D laboratories. However, our research is on the creation of such technology options, which is the prior stage that has not been well studied.

3. Research design

The qualitative method using multiple case studies is adopted in this research because it is more appropriate for research in nascent stage while the quantitative method is used in mature theory testing (Edmondson and McManus, 2004). Furthermore, case studies allow investigators to retain the holistic and meaningful characteristics of real-life events, and multiple case studies are generally considered more robust than single case study (Eisenhardt and Graebner, 2007).

We applied a sequential research design with four steps, as shown in Table 1.

Step 1: Identification of technological DI cases. We began our case studies by collecting successful technological DI across a wide range of industries and the unit of analysis is technology. Collectively, as a pool of raw data, these cases were carefully filtered by Govindarajan and Kopalle's four criteria of DI: (i) inferior on the attributes that mainstream customers value; (ii) offer new value propositions (NVPs) to attract a new customer segment or the more price sensitive mainstream market; (iii) sold at a lower price and (iv) the market penetration goes from niche to mainstream. Since the *disruptive innovation theory* only became popular and being widely studied for one decade, there are not many examples being studied and well documented. Furthermore, some DI were pure business model innovation rather than technological innovation (e.g., budget airlines), and are thus outside our research scope. In addition, some technological innovations were claimed to be disruptive but in fact did not satisfy the definition of Christensen (1997) or Govindarajan and Kopalle (2006). Nevertheless, we finally identified 37 qualified cases with sufficient data support. The 37 cases were classified into 5 technological categories (e.g., ''Industrial/Commercial Computer Hardware and Software'') for further study. For case sampling, the research aim is to provide normative recommendations to create disruptive technologies, i.e. the inquiry of knowing ''how'' rather than testing ''how'' or ''why''. As failure cases did not observe the insights-oriented sampling criteria (Eisenhardt and Graebner, 2007; Keupp et al., 2009), they were not selected.

Step 2: Abstraction of generally applicable R&D strategies. We applied the central thoughts of principal component analysis (PCA) as the systematic method (Fukuda and Watanabe, 2008) to abstract R&D strategies common to the 37 cases. Principal component analysis (PCA) is a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components (Jolliffe, 2002). Each principal component accounts for as much of the variability in the data as possible. It is a systematic process to boil multiple variables/factors down into several key variables/factors. The process of abstracting R&D strategies by PCA is as follows: (i) we studied the features, performance levels, cost and market to justify the cases as technological DI. (ii) Second, the focus was to understand what NVPs were offered between disruptor and disruptee products. (iii) The large number of value propositions (also considered as all correlated variables) will boil down to several categories of NVPs by identifying NVPs