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Forecasting technological discontinuities in the ICT industry

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ABSTRACT

Building on the existing literature on evolutionary innovation and technological change, this paper aims to identify potential signals of technological discontinuities and to obtain assessments of experts to what extent these signals help them to predict discontinuities. Furthermore, we analyze whether internal experts (experts employed with firms) and external experts (e.g., consultants) differ in the importance they attribute to signals as predictors of technological discontinuities. The empirical analysis is based on a unique dataset obtained from a conjoint analysis conducted with 29 experts in the ICT industry. The conjoint approach allows for a simulation of the forecasting process and considers utility trade-offs. The results show that for both types of experts the perceived benefit of users most highly contributes to predicting technological discontinuities. Internal experts assign more importance to legal frameworks (e.g., standards) as signals helping them to predict technological discontinuities than external experts. The latter, in turn, assign more importance to profit margins and the recombination potential of technologies than their internal counterparts. Our results add important insights to the literature on R&D and innovation management.

1. Introduction

Firms that are active in industries characterized by frequent and rapid technological changes may suddenly be confronted by technological discontinuities (Bourgeois and Eisenhardt, 1988). If overlooked, discontinuities can threaten a firm's competitive position or even its survival. If perceived in due time, technological discontinuities can provide an opportunity to catch up or strengthen a firm's position in the market (Hill and Utterback, 1980; Hill and Rothaermel, 2003).

Following Anderson and Tushman (1990: 604), technological discontinuities are defined as "innovations that dramatically advance an industry's price vs. performance frontier". This definition does not necessarily require the emergence of a completely new technology. It is also in line with understanding innovation as a process that critically relies on the recombination of existing ideas and artifacts to create something new (Nelson and Winter, 1982; Fleming, 2001). Examples of technological discontinuities in information and communication technology (ICT) include touch screen technology[1] for smart phones and tablet PCs, which displaced traditional displays or the development of Voice over IP[2], which posed a severe challenge to standard telephone systems by reducing the price of a telephone call to almost zero. Both technologies had been known for decades. Nevertheless, their application in ICT triggered technological discontinuities.

To anticipate technological discontinuities, organizations have developed sophisticated forecasting and planning tools. Nevertheless, firms are not shielded from 'surprises'. Instead, they consistently encounter technological discontinuities. Established firms often overlook signs of technological discontinuities because they try to compensate for imperfect knowledge and uncertainty by extrapolating their experiences to the future (Danneels, 2004). For instance, a switch from non-cellular to cellular technology in the

[1] The touch screen was developed in the early 1970s by Bent Stumpe, an engineer at the European Organization for Nuclear Research (CERN) (see http://cdsweb.cern.ch/record/1248908, accessed on May 16, 2012).

[2] The basic technology underlying Voice over IP, the Network Voice Protocol (NVP), a computer network protocol that allows human speech to be transferred over communications networks, had already been developed in the early 1970s by computer networking researcher Danny Cohen, who worked for the Information Sciences Institute at the University of Southern California (see ftp://128.9.176.20/isi-pubs/rr-81-90.pdf, accessed on May 16, 2012).

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mobile telephone market led to a shake-out, i.e. most established firms left the market (Elirnberg and Sjoberg, 1995). To minimize the potential for surprise, Ansoff (1975) proposes that companies should listen to "weak signals", i.e. "imprecise early indicators about impending significant events" (Könnölä et al., 2007: 611). Listening to weak signals cannot only safeguard organizations against surprises but can also enable them to influence the environment to force competitors to respond (Chakravarthy, 1982).

Although the literature has provided substantial evidence of the occurrence and the consequences of technological discontinuities (e.g., Chandler, 1977; Tushman and Anderson, 1986; Barley, 1986; Henderson and Clark, 1990), it provides scant information about possible signals of these discontinuities. Literature on technology foresight proposes to use broad indicator-based concepts to forecast changes–it, however, remains silent about concrete frameworks of those broad concepts. Instead, the literature offers management tools (Martin, 2001; Reger, 2001).

Building on the existing literature on evolutionary innovation and technological change, this paper aims to identify signals of technological discontinuities and to analyze the importance experts[3] assign to these signals to help them predict technological discontinuities. As an extension to the analysis, we investigate whether the valuations of signals of discontinuities of experts employed with firms (internal experts) differ from those of external parties like consultants or venture capitalists. Wulf et al. (2010), who propose a scenario approach of strategic planning, for instance, argue that consulting with external parties might be a good way of preventing so-called "blind spots", i.e. indications of change that willingly or unwillingly would have been overlooked by "internal experts".

Our study adds important insights to the discussion about signals of technological discontinuities using a unique dataset obtained from a conjoint analysis. The conjoint approach allows for a simulation of the forecasting process and an experimental variation of the predictors as well as the consideration of utility trade-offs (Franke et al., 2008). Our study also provides practical implications for R&D and innovation management.

The results show that the expected increase in the benefit of users caused by further development of a technology is considered the most important signal to help experts forecast technological discontinuities. Human restrictions are deemed to make the lowest contribution. Whereas internal and external experts agree about the perceived least important signals, internal experts attach more importance to legal frameworks like standards for helping them to predict whether discontinuities occur than external experts. External experts assign more importance to signals that are related to margins and the possibility to recombine technology with innovations from other technical fields.

The remainder of the paper is structured as follows. Section 2 provides a brief discussion of the conceptual framework of our analysis. Section 3 presents the methodology and provides descriptive statistics. The results are discussed in Section 4. Section 5 concludes the paper.

2. Theoretical background

Although technological discontinuities can be externally determined, i.e. by a crisis or regulatory changes induced by governments or standard setting bodies, most discontinuities are endogenous, i.e. are determined by economic forces and thereby influenced by the organizations that are active in a particular industry. Consequently, it is not only possible to adapt to technological discontinuities but also to influence or anticipate them (Bronzen, 1953). The identification of technological discontinuities is the focus of this paper. Technological discontinuities are defined as "innovations that dramatically advance an industry's price vs. performance frontier" (: 604). This definition is in line with Schumpeter (1942), who argues that technological discontinuities have the potential to create a considerable cost or quality advantage over competitors.

Henderson and Clark (1990), in their seminal work, distinguish between innovations that change the core design of technology concepts and innovations that only change the relationship between technology concepts. Whereas *incremental innovations* leave both, core concepts and linkages between core concepts unchanged (e.g., new screen size of televisions), *modular innovations* change the core concept but maintain linkages between concepts (e.g., replacement of an analog with a digital telephone). *Architectural innovations* change linkages between core concepts but maintain the concepts themselves (e.g., the Walkman as a miniaturized radio) and, finally, *radical innovations* change both, core concepts and linkages (e.g., move from CDs to MP3 files). Given the definitions above, technological discontinuities can be clearly classified as radical innovations and possibly also as modular innovations. Both types of innovation result in a change of the technology. It is important to note that technological discontinuities do not necessarily require the emergence of a completely new technology. A recombination of existing ideas and artifacts (Nelson and Winter, 1982; Fleming, 2001) may also result in discontinuities. Hence, discontinuities may also be triggered by changes in technologies that allow a (re-) combination with the actual technology. Innovation activities in related technological fields may thus depict a signal for technological discontinuities in a particular technology.

According to the evolutionary innovation literature, technological discontinuities depict the beginning of a new technology cycle. They lead to a period of technical experimentation, and are terminated by the emergence of the dominant design. The dominant design is then followed by a period of incremental change, in turn terminated by the subsequent technological discontinuity (Abernathy and Utterback, 1978; Sahal, 1981; Anderson and Tushman, 1990; Tushman and Nelson, 1990). Discontinuities are often initiated in niche markets, since niches provide an incubator, which shields radical innovations from market selection (Geels, 2002; Schot, 1998). An example for such a niche is the army, which enabled the development of the digital computer or the radar (Geels, 2002). Technology life cycles that draw to an end – which can be identified by the consecution of increasingly incremental changes in a technology – may be another signal of coming technological discontinuities.

Since technology forecasting is an art rather than a science (Jantsch, 1967), institutionalized technology monitoring or forecasting systems in organizations are often supplemented by the views of other, independent technology experts (Porter et al., 2011; Yoon and Park, 2007). These experts could either be consulted directly or indirectly through their publications (Ehrnberg and Jacobsson, 1997). Combining the views from different sources often results in 'better' decisions than those based on the knowledge or experience of a single member of a group (Jeppesen and Lakhani, 2010). This is also in line with what Surowiecki (2005) refers to as the "wisdom of crowds". Hence, judgments from independent experts may also form a signal of technological discontinuities.

Whereas radical innovations typically start new technology cycles, modular innovations – even though they have the potential to start new technology cycles – often lead to standardization allowing an increase in product variations rather than tipping new technology life cycles (Henderson and Clark, 1990; Garcia, 2010). Anticipated changes in standards and other legal frameworks like, e.g., legal texts or EU-Directives, in itself, could trigger technological

[3] Experts are defined as persons "with a high degree of skill in or knowledge of a certain subject", see http://www.thefreedictionary.com/expert, accessed on March 25, 2014.