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A real options framework for R&D planning in technology-based firms

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ABSTRACT

The increasing uncertainty in technology and market trends makes it difficult for technology firms to capture emerging opportunities. This paper develops an R&D planning framework based on the real options analysis to identify, develop and evaluate technological opportunities. The developed methodology can encourage R&D organizations to proactively explore uncertainties and to identify managerial options to capture emerging opportunities. Furthermore, the developed real options model integrated with the Bass diffusion model can help R&D managers evaluate and select optimal investment decisions to maximize market payoff under different demand structures. The case of a biochip R&D project is studied.

Introduction

Since technology is an important asset for many firms in sustaining growth and retaining competitive advantage, R&D often plays a significant role in determining a firm's technology position. Basically, technology underpins future products and the manufacturing processes that support these products for a technology-reliant firm. It is very important for such a firm to clearly understand what technologies are available to them and how to select and exploit appropriate technologies that provide their products or services with a competitive edge. Although the importance of technology planning is

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well understood, most technology-based firms make their R&D decisions either based on group discussion or some strategic planning tools, such as technology roadmapping (Petrick and Echols, 2004). With increasing complexities of analyzing uncertainty in technology development and market trends (Thorn et al., 2011), R&D decision making has become more difficult for technology-based firms seeking to enhance their competitive position and drive their sustainable profitable growth (Pich et al., 2002; Song et al., 2007). The presence of tremendous uncertainty has led to many failures in their R&D investments. Therefore, determining the optimal R&D decisions for capturing emerging technological opportunities over time has become the major challenges for hi-tech industries (Scott, 2001).

In the fast changing industrial environment, all forecasts can be expected to err in significant ways. Technology-based firms, therefore, should incorporate more managerial flexibility into their R&D processes in order to allow them to reassess and adjust their decisions in a timely manner according to the impact of environmental changes (Hunt et al., 2004). Building flexibility into R&D processes, however, always incurs costs, because it involves redundant capabilities by making smaller investments that may miss out on economies of scale, or it may cause delays that reduce benefits (Verganti, 1999). The management challenge is to properly choose and implement different forms of flexibility in the R&D process and to analyze the cost–benefit tradeoff for maximizing potential market payoffs, while minimizing downside risks.

This paper presents a real-options-based methodology that identifies potential opportunities, develops R&D plans with managerial flexibility to capture opportunities and avoid risks, and then evaluates the value of these opportunities. The proposed methodology is developed based on the concept of technology roadmapping (Farrukh et al., 2003), together with the real options model by Huchzermeier and Loch (2001) to manage technological opportunities for maximizing market payoff, while minimizing downside losses. Since the market value of a technological opportunity is affected by its diffusion pattern, this paper extends Huchzermeier and Loch's real options model (Huchzermeier and Loch, 2001) with the Bass innovation diffusion method (Bass, 1969; Mahajan et al., 1995) to allow decision makers to evaluate and select optimal managerial options to maximize market payoffs under different demand structures. The proposed methodology is illustrated with a case study of a biochip R&D project. Taguchi's robust design method (Phadke, 1989) was applied to evaluate and select the decision that is more robust to market uncertainty.

This paper is organized as follows: the following section provides a literature review: the proposed real options-based R&D planning framework is developed in section "A Real Options Methodology for R&D planning"; A case study of a biochip R&D project is illustrated in Section "Case Study of a biochip R&D project" and experimental results and managerial implications are also discussed as well; Section "Conclusions" concludes the paper.

Literature review

This paper reviews three popular approaches in the literature for R&D planning: strategic planning tools, decision analysis approaches, and benefit measurement methods.

Strategic planning tools

In strategic planning tools, technology roadmapping is a comprehensive approach for the integration of technology development into product development and business strategies. It was developed in the late 1970s and has been widely applied in industry and academia for developing technology strategies, identifying gaps and opportunities in technology development, and resource allocation planning (Farrukh et al., 2003; Petrick and Echols, 2004; Phaal et al., 2004). Farrukh et al. (2003) proposed a fast-start technology roadmapping approach (T-Plan) for product planning by practitioners, and several possible extensions, such as the exploration of new opportunities, have been presented. Walsh (2004) modified the traditional roadmapping approach, generating a disruptive technology roadmapping process. As products become more complex, the expertise needed to successfully develop a new product often lies in more than one firm. Thus, Petrick and Echols (2004) suggested that firms should extend and share their technology roadmaps with their supply chain partners to make more sustainable new product development decisions. Although technology