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Price competition and technology licensing in a dynamic duopoly

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ABSTRACT

Decisions regarding product innovations are inherently dynamic because for consumers to perceive constant improvement in product innovation, innovation must be current and continuously updated. Moreover, firms' price and innovation decisions interact over time, adding to their dynamic nature. In this study, we examine price and innovation decisions in a dynamic duopoly of an innovating firm and a non-innovating firm. The innovating firm competes with the non-innovating firm on price and determines the innovation level that improves its consumers' product valuation. The non-innovating firm lacks the technology to innovate but can obtain innovation by licensing. Consumer perceptions of product innovations evolve over time. In our study, we derive and characterize firms' subgame-perfect Nash equilibrium decisions and profits. Additionally, we analyze the effects of technology licensing on firms' instantaneous and steady-state equilibrium behaviors and on consumer perceptions of innovation. The analysis shows that firms' myopia leads to a low innovation level and severe price competition, thereby reducing firm profits. Licensing is effective in mitigating the intensity of price competition and is beneficial for the innovating firm but not always for the non-innovating firm. Consumer perceptions of product similarity and capability to utilize technology stimulate the non-innovating firm to accept licensing.

1. Introduction

In the current highly competitive business environment, it is challenging for firms to capture market share and increase profitability. Approximately 94.5% of firms identify the development of innovations as a prerequisite for satisfying consumer expectations and increasing demand (Hana, 2013). The Organisation for Economic Co-operation and Development (OECD, 2005) defined four types of innovations that encompass many activities: product innovation, process innovation, organizational innovation, and marketing innovation. Product innovation is a predominant strategy because it directly affects consumers' purchasing behavior and has a sizeable impact on profitability. Product innovation is generally defined as the development of new products or major changes (e.g., changes in design, quality improvements, and the use of new materials or components) to existing products. A key driver of product innovation is the need to signal firms' ability to apply knowledge and technology to improve existing products or develop new products (Evanschitzky, Eisend, Calantone, & Jiang, 2012; OECD, 2005). Due to economic factors or limitations that affect research and development (R&D), many companies acquire technological innovations through licensing agreements with other firms, including their competitors. For example, Sun Microsystems provided technological knowledge to its rivals to change competitive dynamics and fundamentally transform the market of the networking systems industry (Garud & Kumaraswamy, 1993). Similarly, in 1997, Ford Motor Co. began licensing its passenger-side air bag deactivation switch technology to its competitors. The benefits Ford received included earning licensing royalties, lowering production costs through economies of scale, and setting the industry standard for the deactivation switch system (Fradkin, 2014). Recently, Ford Motor Co. announced that it will license more than 400 electric vehicle patents to accelerate the growth of electric vehicle technology (Dearborn, 2015). In addition, Toyota Motor Co. licensed its hybrid technologies to competitors Nissan, Ford, Mazda, and Subaru for long-term perspectives on developing standardization of hybrid cars and achieving economies of scale (News, 2010; Stoll & Zachary, 2004). Because of such interactions, insights can be gained by examining the competitive dynamics between firms and the effect of those dynamics on pricing decisions and technology licensing.

Although considerable research (e.g., Arora & Ceccagnoli, 2006; Crama, De Reyck, & Degraeve, 2013; Kulatilaka & Lin, 2006; Sun, Xie, & Cao, 2004) has addressed technology licensing and innovation over the last decade, much of this research considers firms' interactions in static models or focuses on the designs of licensing schemes. However, a consumer's purchasing behavior is influenced by his current perception of product innovations in relation to his

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memory of previous product innovations. Therefore, his perception of product innovations evolves over time. As a result, decisions regarding product innovations are dynamic because in order to satisfy consumer demands, the development of product innovations must be current and continually updated. Additionally, technology licensing is a long-term strategy, and not taking future returns into account may lead to a misinterpretation of firms' interactions and equilibrium behavior. Furthermore, decisions regarding price and product innovations interact dynamically. This study furthers current research by simultaneously examining price competition and technology licensing in a dynamic duopolistic supply chain and the effects of competition and licensing on decisions regarding product innovations.

Specifically, we formulate a differential game consisting of an innovating firm and a non-innovating firm and demonstrate that firms compete in price over time and that market demand can be increased through product innovations. First, we formulate the competitive interaction between two firms in a continuous dynamic environment in the absence and presence of licensing. Second, we derive the firms' subgame perfect Nash equilibrium (SPNE) and steady-state equilibrium decisions. Finally, we conduct analyses to obtain insights regarding (1) firms' SPNE behaviors, (2) variations in the equilibrium results over time, (3) steady-state equilibrium behaviors, and (4) parametric impacts on licensing performances.

A brief summary of the findings is as follows: (1) Regarding firms' SPNE behaviors, we find that product differentiation is a critical driver for the innovating firm to invest in innovation. Technology licensing for a licensor (innovating firm) is both a way to obtain economic benefits from a licensee (non-innovating firm) and a competitive strategy used to affect the decisions of licensees and change the competitive dynamics of market demand. Thus, even when licensing is free to the licensee, the licensor will still choose to invest in innovation. (2) The length of licensing will affect the non-innovating firm's decision of whether to adopt or not adopt technology licensing. However, the length of licensing is not a critical issue to licensors. (3) When firms take a more myopic view, they will compete on price by decreasing innovation investment, thereby decreasing both firms' profits. However, licensing is effective to mitigate the intensity of price competition such that sales margins of both the licensor and the licensee can be increased. Moreover, consumer perceptions of product similarity are always harmful to the innovating firm but can motivate the non-innovating firm to accept licensing. (4) Licensing is beneficial to both firms and consumers when two factors—consumer perceptions of product similarity and consumer acknowledge of the innovation development—are controlled at moderate levels. As the dynamic interaction between firms lasts longer, licensing will be more effective; i.e., licensing is not advised if firms or consumers are shortsighted. In terms of the profitability of licensing to the licensee, the licensee should improve its capability to utilize the technology transferred rather than striving for a greater degree of technology transfer.

The remainder of this paper is organized as follows. Section 2 surveys the related literature while comparing these studies with our work. In Section 3, we develop the demands for firms from consumer utility, and build the dynamics of consumer perceptions of innovation and their relationship with firms' endogenous innovation level. Then, we derive firms' SPNE decisions in the absence and presence of technology licensing. In Section 4, we analyze firms' instantaneous and steady-state equilibrium behavior, and then investigate the performance of licensing for the profitabilities and consumer perceptions of innovation. The final section concludes the study with a brief summary and suggests potential future research directions.

2. Literature review

The predominant strategy used to improve a firm's level of innovation is technology licensing. Thus, topics related to technology licensing have frequently been examined in the field of operational management (e.g., Allain, Henry, & Kyle, 2015; Arora & Ceccagnoli, 2006; Bagchi & Mukherjee, 2014; Borah & Tellis, 2014; Crama et al., 2013; Hong, Govindan, Xu, & Du, 2017; Kulatilaka & Lin, 2006; Pun & Ghamat, 2016; Sen & Stamatopoulos, 2016). Arora and Ceccagnoli (2006) investigated the relationship between patent protection and technology licensing through a structural model based on empirical data and discovered that complementary assets are a key factor, i.e., the effectiveness of patent protection increases the propensity of technology licensing when specialized complementary assets are lacking, and however, the contrary result is true when specialized complementary assets are possessed. Moreover, their findings provide a better understanding of when technology specialists are formed in a long-term industry configuration and when innovators must battle with incumbents. Kulatilaka and Lin (2006) examined technology licensing in a duopolistic model under demand uncertainty in which an entrant chooses between licensing technology or developing its own technology and an established firm determines its investment timing based on licensing agreements. They found that technology licensing can dissuade a competitor from developing its own technology. Additionally, the wait-to-invest strategy is predominant under high demand uncertainty except when the innovation will set industry standards.

Bagchi and Mukherjee (2014) studied two licensing schemes—royalty per unit and fixed-fee licensing—used by an innovator and multiple licensees and determined the effect of these schemes on product differentiation under Bertrand and Cournot competition. They found that when there are many licensees, the benefits to both the innovator and the consumer are greater under royalty-based licensing than under fixed-fee licensing. Additionally, they showed that royalty-based licensing is usually profitable to the innovator under Bertrand competition and thus is common in practice. Following this finding and common practice, we consider technology licensing with a pure royalty policy. Sen and Stamatopoulos (2016) characterized cost-reducing technology licensing under more general cost and demand models and found that upfront fees are unnecessary in licensing contracts under additive and subadditive cost functions. In their work, they concluded that a drastic technology will be licensed when technology leads to increasing returns to scale and a non drastic technology will be licensed if the gain from the technology is higher than the marginal gain for the licensee. When technology leads to decreasing returns to scale, the licensing fee may be waived. Pun and Ghamat (2016) considered technology transfer through an R&D joint venture between two competing firms to improve the component quality and demonstrated that the R&D joint venture may intensify competition but is nonetheless beneficial to the firms. Hong et al. (2017) examined technology licensing in the context of a closed-loop supply chain in which a manufacturer competes with a remanufacturer on quantity and collection and simultaneously licenses technology to the remanufacturer under royalty-based and fixed-fee licensing schemes to recover the investment costs of the patented products. They also found that, for the manufacturer, fixed-fee licensing is superior to royalty-based licensing. The aforementioned studies focused on licensing schemes using static models. However, technology licensing and product innovations are long-term activities that result in dynamic interactions between firms. Therefore, to explore the instantaneous and long-term equilibrium behavior of firms regarding decisions to license technology and the choice of licensing schemes, examining the interaction between the firms using a dynamic model is beneficial.

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