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Optimal licensing in a differentiated Bertrand market under uncertain R & D outcomes and technology spillover☆

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ABSTRACT

This paper studies the licensing behavior in a differentiated Bertrand duopoly market in which the innovative firm engages in a cost-reducing R & D with uncertain outcomes. We also assume that there will be technology spillover if R & D ends in success. The results show that, in the case of a non-drastic innovation with uncertain outcomes, (i) the optimal licensing contract in terms of fixed-fee and royalty licensing is fixed-fee licensing when product substitution and technology spillover are both small, while it is royalty licensing otherwise; and (ii) if two-part tariff licensing is available, it is superior (equivalent) to royalty licensing when technology spillover is small (large), but always better than fixed-fee licensing for any degree of product substitution and technology spillover. Moreover, the results also indicate that the probability of R & D success in each licensing method plays an important role in determining the innovative firm's optimal licensing strategy.

1. Introduction

In recent years, along with the instant development of world globalization, social economic environment has changed enormously. In the face of a market characterized by diversified demands and fierce competition, firms are more willing to gain a position of market dominance through technology innovation, instead of relying solely on the possession of scarce resources as before. According to Griliches (1992), technology innovation enjoys an average annual yield of more than 40%, which is higher than the 8% gained by other methods. Due to its relatively high returns, a major issue faced by firms in the process of innovation is that how to apply the improved (or new) technology obtained from innovation to generate profits. Technology licensing is viewed as one of the most quick and effective ways to achieve this goal. On the one hand, for the innovative firm, it doesn't transfer the ownership of the licensed technology but merely gives the licensee only the right to use the technology. This retaining ownership enables the innovator to have impacts on the licensees in terms of output (price) and profits by some strategic behaviors, which in turn can help the licensor to improve its technical capabilities and thus gain a market competitive advantage. On the other hand, for the firms with weak R & D abilities or insufficient funds to engage in innovation, technology licensing is a practical approach to acquire the new technology, which is mainly used to reduce technology gap and improve their own competitiveness.

Along with the rapid development of technology and increasing degrees of product complexity, technology licensing has being widely used to commercialize firms' achievements of innovations, especially in such the industries as electrics and electronics, chemicals and pharmaceuticals, and computer and telecommunications, where technology licensing occurs more frequently (Kabiraj and Kabiraj 2017). For example, QUALCOMM Incorporated is one of the most influential hi-tech enterprises in telecom industry. By agreeing licenses on the use of CDMA air interface technology with more than 135 companies worldwide, it received a total of $7.878 billion in licensing revenues in 2013, accounted for nearly 69% of the total pre-tax profit.[1] According to the World Development Indicators database, the licensing fee paid by Chinese firms to foreign firms had an annual growth rate of over 34 percent between 1998 and 2009 (Nguyen et al., 2016). These tremendous licensing incomes enable the innovative firm to not only recover the early investment needed for R & D projects, but also realize a real growth in profit. Hence, technology licensing has been regarded by managers as a core strategy for the firm's long-term development. This is also supported by Grindley and Teece (2008), who argue that the use

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of licensing is treated as an important part of the business for high-tech firms such as IBM, Texas Instruments, Hewlet-Packard.

Due to its importance to most industries, the issue of technology licensing has attracted the attention of a lot of researchers. Since the seminal work carried out by Arrow (1962), there has been a vast literature studying on different aspects of technology licensing, which constitutes an important area of modern industrial economics.[2] In general, these studies can be broadly divided into two main categories by considering the innovator's market position. The first is the outsider's optimal licensing strategy. In this case, the innovator stands outside the market and doesn't produce any product.[3] Hence, all of its profit come from the licensing revenue. An important finding shows that the optimal licensing strategy is either a fixed-fee or to auction a certain number of licenses, which often allows the outside innovator to extract the maximum surplus from a cost-reducing innovation (Kamien and Tauman 1986; Kamien et al. 1992; Sen and Tauman 2007). However, other studies have also shown the presence of a per-unit royalty in the outside innovator's licensing contract (Chang et al., 2013; Bagchi and Mukherjee, 2014; Fang et al., 2015; Kim and Lee, 2016). The second is the insider's optimal licensing strategy. Different from the outsider, the inside innovator (the incumbent firm) cares not only about the licensing revenue but also the influence of licensing on its market position. With respect to this issue, it has been well studied in the previous literature (Wang, 1998, 2002; Li and Yanagawa, 2011; Kishimoto and Muto, 2012; Wang et al., 2013; Chang et al., 2015). The results show that under some circumstances using a per-unit royalty allows the inside innovator to enjoy a cost advantage over rivals, which makes itself more aggressive and thus enjoys more total profit as compared to using a fixed-fee.

A common feature of most literature on technology licensing (including all the above-mentioned studies) is that the outcome of an innovative firm's R & D is naturally regarded as successful while the possibility of failure in the R & D endeavors is completely ignored. In others words, the influence of uncertain R & D outcomes on an innovative firm's licensing strategy has not been considered. A possible reason for this peculiar assumption is that in the real world innovation is always viewed as a risky activity, in which "dry holes" and "blind alleys" are the rule, not the exception (Miyagiwa and Ohno, 2002).[4] In fact, a technology innovation with high returns is usually accompanied by a high risk of failure, and this often puts the innovative firms into a dilemma. On the one hand, firms are driven to innovate constantly by the huge profits resulted from a successful R & D. On the other hand, the failure in R & D will also cause a certain loss to firms and thus reduce their enthusiasms on innovation. Hence, being aware of this uncertainty, firms are usually cautious about the actual investment in R & D, and this will inevitably have an impact on their other business activities, in particular on the aspect of technology licensing. Furthermore, technology spillover is unavoidable. As most technologies usually have some public good aspects, it provides a possibility for other firms to access and copy the new technology by some formal or informal methods. This makes the innovator unable to enjoy the full benefits from an innovation but bear all the cost of R & D. Therefore, when a firm engages in R & D and then intends to license its new technology to the rivals, it has to face the above-described situation.

Recently, Zhang et al. (2016) analyze the innovator's optimal licensing in a differentiated Stackelberg duopoly model with uncertain R & D outcomes. However, like most of the previous research, the results in this study are concluded on the base of quantity competition model with differentiated goods, in which both parties take their respective outputs as the decision variables and the price only plays a role of market clearing. Then, what will happen when a firm engages in R & D with uncertain outcomes and compete in other ways, such as price? In reality, due to the influence and restriction of many factors such as production capacity, product complexity and funding, it's infeasible for a firm to adjust its output in a short time. However, the adjustment of price is easier to realize due to its lower cost. Hence, price competition among firms is very common in the market. In addition, different from the fact that outputs are strategic substitutes in quantity competition, in price competition, one firm's higher price can lead other competitors to make a higher price as well (Bulow et al., 1985). Then, what kind of licensing strategy will a stochastic R & D firm choose to optimize its total profit under this strategic complement effect? By all appearances, it is a valuable research issue.

Based on the above analysis, this paper extends the study of technology licensing under uncertain R & D outcomes and technology spillover to the case of a differentiated Bertrand competition. The main purpose is to explore the following two issues. First, whether the innovative firm is willing to license its innovation when it faces a stochastic R & D in price competition. Second, if it is possible, what kind of licensing strategy is optimal for the innovative firm and whether it will be influenced the probability of R & D success, technology spillover and even product differentiation?

The main contribution of this paper is that it is the first time to consider licensing schemes under uncertain R & D outcomes in the context of price competition. Wang and Yang's (1999) is the first to consider technology licensing for an inside innovator in a Bertrand-type set-up and finds that fixed-fee licensing is preferred when product substitution is small while royalty licensing is preferred otherwise. Following their seminal work, quite a significant amount of work has been conducted about licensing schemes in price competition (see e.g., Faulí-Oller and Sandonís, 2002; Erkal, 2005; Lu and Poddar, 2014; Colombo and Filippini, 2015; Ghosh and Saha 2015).[5] However, to the best of our knowledge, there has been no attention paid on the uncertainty of R & D outcomes so far. Hence, this paper can fill this gap. Moreover, besides the classic discussion of whether a pure fixed-fee licensing is better or worse than a pure royalty licensing for the inside innovator, we also contribute to examine two-part tariff licensing that don't delve deeply enough by many previous studies. And the main results about the optimal licensing contract can provide valuable insights in formulating strategic investment and licensing decisions for the stochastic R & D firms.

The remainder of this study is organized as follows. Section 2 sets up the basic model and analyze the case where technology licensing is absent. Sections 3 and 4 separately investigate fixed-fee and royalty licensing contract. In Section 5, we explore the insider's optimal choice between these two above-mentioned means of licensing. Section 6 extends to two-part tariff licensing and analyzes its optimality relative to the previous licensing methods. And in Section 7, we conclude the whole study. All of the proofs are provided in the Appendix A and B.

[2] Arrow (1962) separately investigates royalty licensing in a perfectly competitive market and in a monopoly market, and concludes that the licensing revenue that the innovator obtains in the former is higher than that in the latter.

[3] The main body of outside innovators may be such as universities, independent research institutions or upstream enterprises. These organizations usually do not participate in the competition of their downstream product market.

[4] The buzz word "dry hole" is originally used in oil exploration to describe a well where no significant reserves of oil are found. This term is now often used to describe any fruitless commercial initiative, meaning a business venture that ends up being a loss. Read for more details: http://www.investopedia.com/terms/d/dry-hole.asp.

[5] Faulí-Oller and Sandonís (2002) analyze the insider's licensing behaviors in a situation where the innovation is licensed to a Bertrand rival via two-part tariff contracts. Erkal (2005) considers the licensing of cost-reducing innovations between horizontal firms in a differentiated Bertrand market. Lu and Poddar (2014) examine the insider patentee's licensing problem under spatial competitions when firms compete in prices. Colombo and Filippini (2015) analyze the two-part licensing mechanism in a differentiated Bertrand duopoly where royalty can be ad valorem or per-unit. Ghosh and Saha (2015), on the other hand, study how the optimal trade policy is affected by the possibility of technology licensing in a differentiated duopoly with price competition.