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Cost-Reducing Innovation and the Role of Patent Intermediaries in Increasing Market Efficiency

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Patent intermediaries have gained importance as non-practicing entities in the innovation domain, buying innovations from an external provider and then licensing them to practicing firms. In this study, we analyze the competition between two identical incumbent firms and a patent intermediary for the acquisition and licensing of a cost-reducing innovation developed by an external innovator. We show that the outcome of the IP acquisition and licensing game critically depends on the degree of the cost-reducing innovation. Patent intermediaries win IP rights in patent markets if the innovation is incremental. They also win the IP rights when the innovation is moderate or radical, providing they have significant efficiency advantages over incumbent firms and the uncertainty about the degree of innovation is low. We also show that patent intermediaries serve to make markets more efficient. When the innovation is incremental or moderate, they help ensure a lower cost of production and a lower price for customers, and when the innovation is radical, they help increase the profits of the incumbent firms.

Key words: patent intermediary; cost-reducing innovation; degree of innovation; Cournot competition; innovation management
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1. Introduction

The ownership and licensing of patents have been discussed in the literature primarily from the perspective of the innovator (licensor) and firms who operate in the product market (licensees). However, with the increasing specialization of roles of firms within the innovation ecosystem, patents are evolving from exclusionary instruments that give firms the rights to be the sole user of innovations to "assets that play a part in a business strategy and have value as transactional goods" (Monk 2009). Today, an increasing number of companies treat the IP from patents as a central business asset that is managed strategically, and valued and leveraged with a view to generating returns through active licensing (Monk 2009). This phenomenon of patent use as part of a business strategy has given rise to a new breed of firms known as patent intermediaries. These firms acquire and monetize patents, achieving markedly superior scale and wielding significant influence in the patent market within relevant technology sectors. They are generally referred to as patent intermediaries because they are neither IP creators nor IP consumers (e.g., licensees and purchasers). At times they are also referred to as non-producing or non-practicing entities (NPEs). A category of such firms relies primarily on generating revenue streams through "enforcing patents against infringers," and are known as patent trolls (Fischer and Henkel 2011).

One reason for the success of patent intermediaries is their role as market mediators; individual inventors, that are small companies or universities, traditionally have had a hard time finding buyers or licensees for the innovations they own (Hagiu and Yoffie 2013). Since patents are illiquid instruments with a high degree of uncertainty in valuation (Lemley and Shapiro 2005), there exist opportunities for intermediaries to make their markets more efficient by providing inventors with access to buyers of their intellectual property (Graham and Sichelman 2008). Patent intermediaries also act as patent distributors, as patents function as information goods that can be shared, allowing parties to benefit from arrangements like non-exclusive use through licenses to other parties (Wang 2010). However, the business model and the role of patent intermediaries in fostering innovation have evoked mixed reactions in the literature. On the positive side, Geradin et al. (2012) find that patent intermediaries have a nuanced role to play in the pursuit of innovation, and they can increase competition by licensing to multiple players, lowering downstream prices, and enhancing consumer choice. Similarly, Reitzig et al. (2010) find that patent intermediaries exploit information asymmetries in technology markets, in order to gain patent-based competitive advantages, and have sustainable business models. Nell and Lichtenthaler (2011) summarize the role played by patent intermediaries from the perspective of technological knowledge characteristics, and differences between product markets and technology markets. They show that intermediaries play an important role in technology transfer, as transferring technologies is more complex than transferring products.

In contrast, Bessen et al. (2011) find that non-practicing entities (NPEs) who rely on litigation (patent trolls) have caused high litigation and damage costs to technology companies and reduced innovation incentives. Reitzig et al. (2007) also find that patent trolls can only operate when the courts have an unrealistic consideration of the trade-offs faced by firms using the technologies for which related patents are owned by the intermediary. We do not consider the business model of patent trolls in our study. We focus on patent intermediaries whose primary business model revolves around generating revenues through licensing patents to multiple practicing firms, and who perform one or more services that connect the IP creators and the IP consumers (Millien and Laurie 2008).

Patent intermediaries focus on connecting parties that wish to monetize existing patent rights, which helps rights holders in exploiting their patents. Such patent intermediaries can be divided into four broad groups: (i) brokers, who play a bridging or market-making role for producers and consumers of intellectual property, (ii) defensive aggregators, who acquire patents and license them to their subscribers, providing subscribers with freedom of operation and safety from litigation, (iii) offensive aggregators, who develop and acquire patents to realize revenue through licensing, and (iv) IP advisory, IP consulting, IP management, or technology transfer firms (Millien and Laurie 2008, Wang 2010). An example of a patent aggregator is RPX Corporation; its business model revolves around charging its clients an annual subscription fee, in exchange for which it identifies patents that might be threatening to subscribers, acquires them (or the right to grant sub-licenses) in the open market from individual or corporate inventors and provides its subscribers with licenses to those patents. RPX makes decisions on which patents to acquire and uses its own capital to acquire them. Importantly, RPX Corporation has committed not to use litigation as a means of asserting its IP rights. Retailers such as Barnes & Noble and Best Buy, technology firms such as Cisco, IBM, Intel, McAfee, Microsoft, and NEC and communication firms such as Nokia, Research In Motion, Samsung, Sony, and Verizon pay RPX annual subscription fees ranging from \$65,000 to \$6.9 million (Hagiu and Yoffie 2013). Allied Security Trust (AST) is another prominent patent intermediary. Other firms in this space that act as defensive aggregators and participate in the market as brokers and in advisory roles can be found in Hagiu and Yoffie (2013).

In this paper, we study the role of a non-troll patent intermediary on the equilibrium outcome when two ex-ante identical incumbent firms, that subsequently engage in Cournot competition,[1] compete with the patent intermediary to acquire a cost-reducing innovation. More formally, we develop a model of a patent market where the external innovator who owns the innovation does not know the value of the cost-reducing innovation it has developed. The innovation directly impacts the unit production cost of two identical incumbent firms in the product market. The patent intermediary can also bid for the innovation and subsequently, license the innovation to one or both of the incumbent firms. The external innovator sells the innovation in an auction to the highest bidder among the incumbent firms and the patent intermediary. If the patent intermediary wins the innovation, it can choose to either license to a single incumbent firm or both incumbent firms, and if one of the incumbent firms wins the innovation, it can choose to license it to its competitor. After the licensing decisions are made and announced, both incumbent firms compete in a Cournot framework and experience a lower production cost if they have acquired or licensed the innovation; otherwise, they have a higher unit production cost. We identify the optimal bid prices of the incumbent firms and the patent intermediary for the innovation, and show that the licensing and bidding strategy critically depends upon the degree of the cost-reducing innovation.

Interestingly, we show that if the innovation is incremental, then patent intermediaries always win the innovation (IP rights) and subsequently license the innovation to both incumbent firms, thereby maximizing production efficiency. In contrast, when the innovation is moderate or radical, the patent intermediary will win the innovation only if it has significant efficiency advantages in patenting over incumbent firms, and if the uncertainty about the degree of innovation is low. Additionally, patent intermediaries serve to increase consumer welfare by lowering the price of the product for consumers. This can occur when patent intermediaries win the innovation if it is incremental or moderate. If the innovation is radical, patent intermediaries serve to share the overall gains in the system due to their efficiency in the patenting process with incumbent firms, thereby increasing their profits. Hence, patent intermediaries serve to make markets more efficient in the following manner (i) when the innovation is incremental or moderate, they license the innovation to both firms, resulting in a low cost of production and a lower price for customers, (ii) when the innovation is radical, they effectively increase the profits of the incumbent firms.

An important finding of this study is that patent intermediaries acquire incremental innovations, and these are licensed to both incumbent firms. Empirical evidence suggests that patent intermediaries primarily own incremental patents (Graham and Mowery 2003, Hedlund 2007, Reitzig et al. 2007). Our study provides a theoretical justification for the ownership of incremental patents by patent intermediaries, and provides an important basis for forming testable hypotheses.

2. Literature Review

There is a substantial stream of research that investigates the interaction of the innovation markets and IP rights and market mechanisms used by firms. Our study is similar to this stream of research, as we study the impact of the degree of innovation on the existence of patent intermediaries in innovation markets. Gupta (2008) studies the impact of knowledge spillovers from manufacturer investments in cost-reducing innovation on the channel structure. Arora and Ceccagnoli (2006) study the relationship between patent protection effectiveness and technology licensing and find that high patent protection effectiveness increases technology licensing if the firms lack complementary assets to exploit new technologies, while firms that have complementary assets are less likely to license technologies. Fosfuri (2006) finds that the rate of technology licensing displays an inverted U-shaped relationship with the number of technology suppliers and is higher for licensors with smaller market shares. Ceccagnoli (2009) finds that the effect of preemptive patenting is stronger when incumbents have high market power and a high threat of entry, and is lower when R&D competition is characterized by radical innovations. Ziedonis (2004) examines the role of fragmented ownership of patents in technology industries and finds that firms patent aggressively to avoid being curtailed in their use of innovation.

The literature on cost-reducing innovation has considered various factors like process improvement investments, experience or learning curves, the sources of the technology, and the characteristics of market and technology. In a monopolistic environment, Bernstein and Kok (2009) investigate the impact of procurement approaches on the dynamics of supplier investments in cost reduction when a buyer purchases components from several suppliers, while Rust et al. (2002) consider the impact of cost-reducing and demand-enhancing innovations on profitability. Sinclair et al. (2000) study the impact of process R&D on experience or learning curves in reducing the unit cost of production. In contrast, we examine the efficacy of cost-reducing innovations that are acquired externally in a competitive environment.

In addition to the literature on motivating cost-reducing innovations, the extant research has also studied the phenomenon of partnering in the supply chain on innovations. Geffen and Rothenberg (2000) find that strong partnerships with providers and adequate incentive systems result in better innovations that reduce cost. Kim (2000) studies the coordination of a manufacturer and a supplier on the supplier's effort at the innovation, and finds that the incentive of the supplier for investing in innovation is critically dependent on the increased demand from the lower retail price charged by the manufacturer since the product is produced at a lower unit variable cost. Similarly, Lou (2007) finds that the impact of cost-reducing innovations in the market is vitally dependent on the excess demand generated by the innovation. Chao and Kavadias (2008) study conditions under which firms develop radical (drastic) and incremental innovations, and show that there is a trade-off between environmental complexity and environmental instability. There has also been a substantial amount of research on the structure of innovation markets and the incentives of firms to invest in innovation, and the mechanisms of offering products to consumers, as well as demand-enhancing services (Bhaskaran and Gilbert 2009, Gupta 2008, Gupta and Loulou 1998, Terwiesch and Xu 2008, Xia and Gilbert 2007). Erat and Krishnan (2012) also study the problem of designing award structures to external agents for incentivizing innovation in the form of contests. We contribute to this stream of literature by studying the role of patent intermediaries in innovation markets: under what conditions of cost-reducing innovation do patent intermediaries participate in innovation markets?

In the literature on the licensing contracts to be used, Kulatilaka and Lin (2006) study the optimal contract design problem from the perspective of an incumbent firm engaging in R&D, and find that when firms can license innovations to competitors, royalty contracts are optimal if the firm has no external funding constraint, and royalty contracts with fixed fees are optimal in the presence of budget constraints. The analysis of the licensing of patents is not limited to the technology domain. Kumar and Turnbull (2008) study the role of characteristics of financial innovations on the decision to patent and license innovations, and find that for certain sets of characteristics, it is optimal not to patent and license innovations even if the option is available. Our study contributes to this stream of literature by considering the impact of the nature of the innovation and the business model of the licensor on the licensing strategy of the licensor. When an external innovator owns the innovation, Kamien et al. (1992) find that fixed-fee licenses dominate quantity-dependent licenses from the perspective of the innovator. Kamien and Tauman (1986) find that when the external innovator is a Stackelberg leader, fixed-fee contracts dominate quantity-dependent contracts. Sen and Tauman (2007) find that for external innovators, the optimal licensing policy is quantity-dependent for relatively significant innovations. Kabiraj (2004) shows that if the innovator is external, quantity-dependent licensing contracts dominate fixed-fee and auction contracts for non-drastic innovations, and auctions are optimal for drastic innovations. Xiao and Xu (2012) explore how royalty revisions affect the incentives and profits in a R&D and marketing alliance between a marketer and an innovator and find that the alliance structure affects the royalty rate. In a similar vein, Savva and Scholtes (2014) study contractual arrangements for joint new product development between an innovator and a technology firm, and explore how an option to opt out of the contract can mitigate some disadvantages of traditional licensing arrangements. Erat and Kavadias (2006) study the competitive aspects of the market for new technology by exploring the scenario when a technology supplier wishes to license the technology to competing downstream buyers. We add to this stream of literature by considering the impact of patent intermediaries in the supply chain structure for innovation. In this study, the optimal licensing contracts are based on fixed-fees only, as monitoring costs for royalty-based contracts can be high (Leffler and Rucker 1991).

In the literature on the impact of the degree of innovation on the licensing strategy, Katz and Shapiro (1985) find that if incumbent firms engage in R&D activity, any resulting radical innovations will not be licensed, and incumbent firms find it optimal to license incremental innovations to their competitors using fixed-fee licensing schemes. Kamien et al. (1992) model the innovator as an external firm (as in this paper), but assume that the innovator knows the value of the innovation. They investigate the optimal number of licenses to be offered by such an innovator, along with the price at which the licenses should be offered. They characterize the optimal number of licenses, and differentiate innovations to be either drastic or non-drastic. In contrast to this stream of literature, our focus is on the role of patent intermediaries. Therefore, we study the case in which external innovators do not know the value of the cost-reducing innovation to the incumbent firms. Hence, the innovator does not have the intent or ability to use contracts to license the innovation and focuses on selling the innovation to the highest bidder, who can then license the innovation to other firms.

Finally, when academic units form NPEs, scholars have examined the role of university R&D and their patenting and technology licensing strategies (Colyvas et al. 2002, Mowery et al. 2002, Sine et al. 2003). Belderbos et al. (2004) classify the net outcome of degree of innovation depending on the parties involved, and find that cooperation with suppliers typically results in incremental innovation, while firms cooperating with universities make radical innovations. Firms cooperating with their competitors may either make radical or incremental innovations. We contribute to this stream of research by examining the patenting and licensing strategies of for-profit NPEs, and characterize the domains where such NPEs have viable business models.

The rest of the study is organized as follows. In section 3, we describe the model and state our assumptions formally. Section 4 contains the formulation, analysis, and results of the model and the main contributions of the study. Section 5 concludes the study with a discussion of the findings.

3. Model Description and Assumptions

In this section, we describe the formal mathematical model in detail and state our assumptions. We consider an industry that has two identical firms who are producing the same good, where the initial per unit cost of production for both firms is c. A cost-reducing innovation is developed by a innovator firm who is engaged in innovation only, and does not know the value of the innovation to the two competing firms. The innovation reduces the marginal cost of production for the two firms to θc, where $\theta < 1$. After the incumbent, firms choose their mode of production (if they own the patent or license the innovation, their unit production cost is θc, otherwise it is c), they engage in Cournot competition and face a downward sloping inverse demand function. A patent intermediary also exists in the innovation market. We model the problem as a four-stage game between the innovator, the two identical firms and the patent intermediary. In the first stage, the innovator announces the development of the innovation. In the second stage, the two firms and the patent intermediary offer their respective bids to the innovator for owning the innovation, and the innovator awards the innovation to the firm with the highest bid, who then obtains a patent for the innovation. At the time of bidding for the innovation, the value of θ is uncertain. Once the innovation is acquired and patented, the value of θ is realized. The distribution and the realized value of θ, before and after patenting (respectively), are common knowledge for the incumbent firms and the patent intermediary. In the third stage, if the winner of the patent is one of the two incumbent firms, it can choose to either use the patent itself exclusively, or it can choose to license the patent to its competitor. If the winner of the patent is the patent intermediary, it can choose to either license the patent to one of the incumbent firms only, or license the innovation to both firms. In the fourth stage, the set of licensees becomes common knowledge, and the two firms simultaneously determine their production levels. The two identical incumbent firms are referred to as firms 1 and 2, and the patent intermediary is referred to as PI. Figure 1 depicts the timeline of the four-stage model.

We make the following assumptions about the model parameters

A1. The price charged by the two firms in the market is given by $p(Q) = a - bQ$, where Q_1 and Q_2 are the quantity decisions of the two firms, and $Q = Q_1 + Q_2$.

A2. The innovation leads to a lower marginal cost of production θc for the two incumbent firms. The innovator does not know the value of θ to the incumbent firms.

A3. The value of θ is not known to the firms at the time of bidding (Stage 2) with certainty, but the incumbents and the PI have a common distribution on the value of θ, with a pdf of $f(\cdot)$, mean of $\bar{\theta}$ and a standard deviation of σ. The value of θ is known to the incumbent firms and the PI with certainty after the patent for the innovation has been obtained (Stage 3).

A4. The innovator does not have the intent or ability to license the innovation directly to the incumbent firms or the PI, and sells the innovation to one of the incumbents or the PI.

A5. The PI has a cost of k_p for obtaining the patent based on the innovation, while the two incumbent firms have a cost of k_i for obtaining the patent. Since the core competence of the PI is its knowledge of the patenting process, we assume that $k_p < k_i$ (Wang 1998).

A6. The innovator auctions the IP rights to the innovation to the firm that offers it the highest price. In case of a tie, the innovator arbitrarily allocates the IP rights to one of the firms.

A7. To ensure that the linear price-quantity relationship gives us meaningful results, we assume that $c < a$.

A8. The transaction monitoring costs of quantity-dependent contracts are high, hence, royalty-based contracts cannot be enforced (Leffler and Rucker 1991).

4. Model Formulation and Analysis

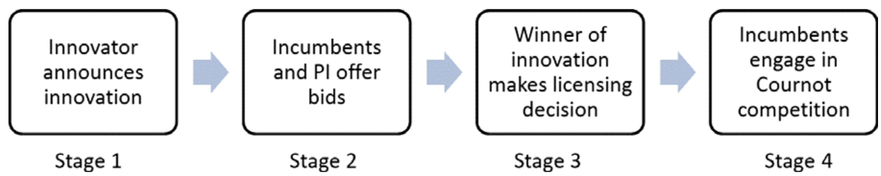
In this section, we derive the bids made by the two incumbent firms and the PI to purchase the patent from the innovator. Our analysis here provides insights on the factors that support the existence of patent intermediaries. As described earlier, we model a four-stage game, and therefore we begin our analysis by looking at the Cournot subgame between the two incumbent firms in the fourth stage.

4.1. Cournot Subgame in Fourth Stage

In the fourth stage, the two incumbent firms engage in Cournot competition with their respective unit costs of production c_1 and c_2. If either firm has the right to use the patent, then its unit cost of production is θc, and if it does not have access to the patent, then its unit cost of production is c.

Since the inverse demand function is $p(Q) = a - bQ$, it can be easily shown that in the fourth-stage Cournot subgame, the following results hold, by using first-order conditions. Without loss of generality, let us assume that $c_1 \geq c_2$ that is, $c_1 = c$, and $c_2 = \theta c$. The profit functions of firms 1 and 2 then are

Figure 1 Time Line of the Model



$$\Pi_1 = (a - b(Q_1 + Q_2) - c)Q_1,$$
$$\Pi_2 = (a - b(Q_1 + Q_2) - \theta c)Q_2.$$
$$Q_1 = \begin{cases} \frac{a-2c+\theta c}{3b} & \text{if } a - 2c + \theta c \geq 0 \\ 0 & \text{if } a - 2c + \theta c < 0, \end{cases}$$
$$Q_2 = \begin{cases} \frac{a-2\theta c+c}{3b} & \text{if } a - 2c + \theta c \geq 0 \\ \frac{a-\theta c}{2b} & \text{if } a - 2c + \theta c < 0. \end{cases}$$

The equilibrium profits are

$$\Pi_1(c_1, c_2) = \begin{cases} \frac{(a-2c+\theta c)^2}{9b} & \text{if } a - 2c + \theta c \geq 0 \\ 0 & \text{if } a - 2c + \theta c < 0, \end{cases}$$
$$\Pi_2(c_2, c_1) = \begin{cases} \frac{(a-2\theta c+c)^2}{9b} & \text{if } a - 2c + \theta c \geq 0 \\ \frac{(a-\theta c)^2}{4b} & \text{if } a - 2c + \theta c < 0. \end{cases}$$

We now present the results of the analysis of the prices offered by the incumbent firms and the PI to the innovator for the rights to acquire the patent, and the subsequent winner of the rights to the patent, when the incumbent firms strategically signal that they will consider licensing the innovation to their competitor. For our analysis, we delineate the prices offered for the patent, the winner of the patent, and the licensing strategy used by it based on the degree of innovation. The degree of innovation is defined as incremental if both incumbent firms use the innovation in the fourth stage (if the PI owns the innovation, it licenses the innovation to both incumbents, and if one of the two incumbents win the innovation, it licenses the innovation to the other incumbent). The innovation is termed as moderate if on winning the innovation, the PI licenses it to both firms, but if one of the incumbents wins the innovation, it does not license it to the other firm. Finally the innovation is termed as radical if only one firm operates with the innovation in the fourth stage, and the other firm exits the market. We show that the existence of the PI in the market critically depends on the degree of innovation, and we characterize the above three regions (incremental, moderate, and radical) based on the model analysis shown below.

4.2. Licensing Strategy

We start the analysis by finding the optimal licensing strategy of the PI if it wins the patent. To find the optimal licensing strategy of the PI if it wins the IP rights, assume that it offers a licensing fee T to firms 1 and 2, and the incumbent firms make their choices to license from the PI based on this fee. The following matrix presents the payoff of firms 1 and 2 if both the incumbent firms are operating in the market in the fourth stage (based on the analysis presented in section 4.1, note that at this stage, the value of θ is realized and known by the incumbent firms and the PI).

We now identify if the PI should license the innovation (if it wins the patent) to both firms or only to one firm. Let T_1^{PI} be the maximum licensing fee that the PI can charge to ensure that only one of the two firms enters into a licensing agreement with it. For only one of the incumbent firms to license the innovation, from Figure 2, the conditions for a Nash equilibrium imply that T_1^{PI} has to satisfy are

$$\frac{(a - 2c + \theta c)^2}{9b} \geq \frac{(a - \theta c)^2}{9b} - T_1^{PI},$$
$$\frac{(a - 2\theta c + c)^2}{9b} - T_1^{PI} \geq \frac{(a - c)^2}{9b}.$$

Hence, the maximum licensing fee that the PI can charge from one firm is the maximum value of T_1^{PI} that satisfies the above inequalities. Therefore,

$$T_1^{PI} = \frac{4(a - \theta c)(c - \theta c)}{9b}.$$

Similarly, let T_2^{PI} be the maximum licensing fee that firm PI can charge to ensure that both firms enter into a licensing agreement with it. For both the incumbent firms to license the innovation, from Figure 2, the conditions for a Nash equilibrium imply that T_2^{PI} has to satisfy

$$\frac{(a - 2c + \theta c)^2}{9b} \leq \frac{(a - \theta c)^2}{9b} - T_2^{PI},$$
$$\frac{(a - 2\theta c + c)^2}{9b} - T_2^{PI} \geq \frac{(a - c)^2}{9b}.$$

Figure 2 Incumbent Payoff Matrix for Both Incumbents in the Market

		Firm 1: License	Firm 1: Do Not License
Firm 2	License	$\Pi_1 = (a - \theta c)^2/9b - T$ $\Pi_2 = (a - \theta c)^2/9b - T$	$\Pi_1 = (a - 2c + \theta c)^2/9b$ $\Pi_2 = (a - 2\theta c + c)^2/9b - T$
	Do Not License	$\Pi_1 = (a - 2\theta c + c)^2/9b - T$ $\Pi_2 = (a - 2c + \theta c)^2/9b$	$\Pi_1 = (a - c)^2/9b$ $\Pi_2 = (a - c)^2/9b$

Hence,

$$T_2^{PI} = \frac{4(a-c)(c-\theta c)}{9b}.$$

Note that if the PI wins the patent, it will earn $2T_2^{PI}$ from licensing the patent to both firms, and $2T_2^{PI} - T_1^{PI} = 4(c - \theta c)(a - 2c + \theta c)/9b \geq 0$. Therefore, if the PI wins the IP rights, the equilibrium of the licensing subgame will be such that the PI will set the licensing fee to T_2^{PI} and its payoff from licensing the patent to both incumbent firms will be $\frac{8(a-c)(c-\theta c)}{9b}$. Both firms 1 and 2 in this case will earn a payoff of $(a - \theta c)^2/9b - T_2^{PI} = (a - 2c + \theta c)^2/9b$.

We now focus on the licensing strategy of the incumbent firms, if one of them wins the innovation. If firm 1 (2) wins the IP rights and decides to license, its payoff will be $(a - \theta c)^2/9b + T^i$, where T^i is the licensing fee charged from firm 2 (1). Firm 2's (1's) profit will be $(a - \theta c)^2/9b - T^i$. Since firm 2 (1) will earn a profit of $(a - 2c + \theta c)^2/9b$ if it does not accept the licensing offer, therefore, $T^i = (a - \theta c)^2/9b - (a - 2c + \theta c)^2/9b$. Hence, licensing to the competitor yields a profit of $2(a - \theta c)^2/9b - (a - 2c + \theta c)^2/9b$ for firm 1 (2). If the incumbent firm winning the IP rights does not license to the competitor, it gets a payoff of $(a - 2\theta c + c)^2/9b$. If $\theta \geq 5/3 - 2a/3c$, then licensing to the competitor yields a higher payoff than the payoff without licensing, hence, we classify the innovation as *incremental* if $\theta \geq 5/3 - 2a/3c$. Labeling such an innovation as incremental is intuitive for another reason: the innovation does not reduce the cost of production for the incumbents substantially, as $5/3 - 2a/3c \leq \theta \leq 1$. Therefore, if the innovation is incremental, if one of the incumbent firms wins the patent, it will choose to license the innovation to the other incumbent firm. If the innovation is not incremental, then the incumbent winning the IP rights will not license the innovation to its competitor. Proposition 1 formalizes this intuition.

PROPOSITION 1. *If the cost-reducing innovation is incremental* ($5/3 - 2a/3c \leq \theta < 1$), *then if one of the incumbent firms wins the patent, it will license the patent to the other incumbent firm. If the PI wins the patent, it will license the innovation to both incumbent firms.*

Proposition 1 indicates that if the innovation is incremental, then both incumbent firms will operate in the market in the fourth stage with a lower unit cost of production. Since the innovation is incremental, if one of the incumbent firms wins the IP rights, it will license the innovation to the other firm, as it finds it profitable to acquire licensing fees from its competitor and operate with the lower unit production cost from the innovation in a competitive environment compared to having an advantage in the unit production cost. Both the incumbent firms do not attain any benefits from using the innovation exclusively in this case, as the benefits of exclusive use of the innovation are outweighed by the higher fee under licensing that the incumbent firm has to pay in equilibrium. If the PI wins the innovation, while it can charge a higher licensing fee from one of the incumbent firms, it prefers to get a lower licensing fee from both incumbent firms, as twice the lower licensing fee gives it a higher revenue than the revenues from licensing to one of the incumbent firms alone. Therefore, if the innovation is incremental, production efficiency will be maximized, as both incumbent firms have the lowest unit cost of production.

As shown in Proposition 1, if $\theta \geq 5/3 - 2a/3c$, if one of the incumbent firms wins the innovation, licensing to the competitor yields a higher payoff for the winner than the payoff without licensing $((a - 2\theta c + c)^2/9b)$. If $\theta < 5/3 - 2a/3c$, licensing to the competitor yields a lower payoff to the winning incumbent firm, hence, if $\theta < 5/3 - 2a/3c$, if one of the incumbent firms wins the innovation, it will use the innovation exclusively. This gives us one of the boundaries for classifying a *moderate* innovation ($\theta < 5/3 - 2a/3c$); the lower boundary for classifying a moderate innovation is found as follows. Since only one firm operates with the innovation in the fourth stage of the game, the other firm with higher unit production cost of c will operate in the market only when its production quantity (and hence, profits) in the Cournot game is positive, otherwise it will exit the market. The condition for this is obtained from the equilibrium quantities of the Cournot game in section 4.1 (if $a - 2c_1 + c_2 < 0$ where $c_1 = c, c_2 = \theta c$, then $Q_1 = 0$). This condition yields that $\theta > 2 - \frac{a}{c}$. Hence, the innovation is labeled moderate when $2 - a/c < \theta < 5/3 - 2a/3c$. Again, the classification of a moderate innovation is intuitive, as it defines a region where the unit cost of production is reduced moderately by the innovation. The payoff matrix in this case is still represented by Figure 2. We characterize the licensing strategy of the incumbent firms and the PI if they win the IP rights in Proposition 2. In what follows, for ease of exposition, we adopt the following notation: Incremental Innovation $\equiv\{\theta^i \leq \theta < 1\}$, where $\theta^i = \frac{5}{3} - \frac{2a}{3c}$, Moderate Innovation $\equiv\{\theta^m < \theta < \theta^i\}$ where $\theta^m = 2 - a/c$, and *Radical* Innovation $\equiv\{0 < \theta \leq \theta^m\}$.

PROPOSITION 2. *If the cost-reducing innovation is moderate* ($\theta^m < \theta < \theta^i$), *then if the PI wins the IP rights, it licenses the innovation to both incumbent firms, while if one of the incumbent firms wins the IP rights, it* *exclusively uses the cost-reducing innovation. Both the incumbent firms operate in the market.*

Proposition 2 highlights that when the innovation is moderate, both the incumbent firms compete in a Cournot duopoly after the licensing game. However, compared to the case of incremental innovation, there is an important difference when the innovation is moderate. If one of the incumbent firms wins the innovation, it will exclusively use the innovation, and not license the innovation to its competitor, hence, only one firm uses the innovation in the Cournot subgame. In this case, the winning incumbent firm finds that the benefit from the lower unit production cost from exclusive use of the innovation is substantial, and higher than the benefit from the licensing fee it can charge its competitor and then operate in a symmetric Cournot subgame with the same unit production cost.

When the innovation is radical ($0 < \theta \leq \theta^m$), note that the payoff matrix for the two incumbent firms in the Cournot subgame is different, as the quantities produced under equilibrium are not non-zero always (please refer to section 4.1). Figure 3 presents the payoff matrix of both firms 1 and 2 when the innovation is radical.

As before, we identify the optimal licensing strategies and the associated payoffs for the PI and the incumbent firms, and subsequently identify their bid prices for the patent. Proposition 3 summarizes the outcome of the licensing game when the innovation is radical.

PROPOSITION 3. *If the cost-reducing innovation is radical ($0 < \theta \leq \theta^m$), then if the PI wins the innovation, it will license the innovation exclusively to one incumbent. If one of the incumbent firms wins the patent it will exclusively use the cost-reducing innovation, hence, the eventual market structure of the Cournot game is a monopoly, as the other incumbent firm exits the market.*

If the incumbent wins the innovation, Proposition 3 highlights that if the innovation is radical, then the winner of the innovation will not license the innovation to its competitor, and operate in a monopoly. The benefit from a lower unit production cost from a radical innovation is so high that the winning firm prefers to use the innovation exclusively, as the other firm's quantity is driven to zero and it is forced to exit the market. This result for radical innovations has also been shown in the literature when the external innovator licenses the innovation to incumbent firms directly (Kamien and Tauman 1986, Kamien et al. 1992, Katz and Shapiro 1985). Finally, if the PI wins the innovation, then it will license it to only one of the incumbent firms.

4.3. Bidding Strategy

In this section, we derive the bidding strategies of the two incumbent firms and the PI, and identify the conditions under which each of the firms wins the innovation based on their bids. Note that the actual value of the degree of innovation θ is not known with certainty to the firms at this stage, but the distribution of θ is common knowledge. For ease of exposition, we assume that the support of the distribution of θ is within the same domain as the mean, $\bar{\theta}$. Hence, if $\bar{\theta}$ is within the incremental region, the support of the distribution is also within the incremental region, the same assumption holds for the other two regions. This assumption is made for tractability, and it is reasonable to assume that the realized outcomes for θ can be predicted to be within the same domain as $\bar{\theta}$. This assumption essentially captures the notion that once a innovation is known, the incumbent firms and PI will have some credible prior knowledge of its value and hence the realized value of the degree of the innovation will be in the neighborhood of the expected value, $\bar{\theta}$. We relax this assumption in section 4.5. Note that the winner of the innovation will incur the cost of patenting (k_i or k_p), and hence all parties will rationally account for this cost to determine their bidding strategy.

4.3.1. Incremental Innovation. If the innovation is incremental and the PI wins the IP rights to the innovation, then it follows from the analysis in section 4.2 that it wins a profit of $E[\frac{8(a-c)(c-\theta c)}{9b}]$ from the innovation by licensing the innovation to both the incumbent firms. Similarly, if one of the incumbent firms

Figure 3 Incumbent Payoff Matrix for Radical Innovations

		Firm 1	
		License	Do Not License
Firm 2	License	$\Pi_1 = (a-\theta c)^2/9b - T$ $\Pi_2 = (a-\theta c)^2/9b - T$	$\Pi_1 = 0$ $\Pi_2 = (a-\theta c)^2/4b - T$
	Do Not License	$\Pi_1 = (a-\theta c)^2/4b - T$ $\Pi_2 = 0$	$\Pi_1 = (a-c)^2/9b$ $\Pi_2 = (a-c)^2/9b$

wins the IP rights, its total profits are given by the sum of its own profits and the licensing fees that it obtains from licensing the innovation to the other incumbent firm (from Proposition 1, the winning incumbent firm will license the innovation to their competitor if the innovation is incremental). Proposition 4 summarizes the bids of the three firms and characterizes the winner of the IP rights when the innovation is incremental.

PROPOSITION 4. *If the cost-reducing innovation is incremental ($\theta^i \leq \theta < 1$), the two incumbent firms will bid $\frac{8}{9b}(a - c)(c - \bar{\theta}c) - k_i$ for the IP rights, and the PI will bid $\frac{8}{9b}(a - c)(c - \bar{\theta}c) - k_i + \epsilon$, $\epsilon \to 0^+$ for the IP rights. The PI will win the innovation and license the innovation to both incumbent firms.*

Proposition 4 shows that patent intermediaries win the IP rights to the innovation if the innovation is incremental. Here, the PI's expected profit is $k_i - k_p - \epsilon > 0$. In practice as well, patent intermediaries have been observed to have patents to incremental innovations rather than original or radical innovations in their portfolio (Economist 2011, Graham and Mowery 2003, Hedlund 2007). While the extant literature has considered the existence of patent intermediaries for reasons like making markets more efficient, providing liquidity, and the market mediation role as in Hagiu and Yoffie (2013) and Wang (2010), we show that a critical condition for the participation of patent intermediaries in patent markets is the degree of innovation (incremental).

4.3.2. Moderate Innovation. If the innovation is moderate, again the PI will license the innovation to both incumbent firms, and win a profit of $E[\frac{8(a-c)(c-\theta c)}{9b}]$ from their licensing fees. However, in this case, if one of the incumbent firms wins the innovation, it will not license the innovation to their competitor, but would prefer to use the innovation exclusively. Proposition 5 summarizes the bids of the three firms and characterizes the winner of the IP rights when the innovation is moderate.

PROPOSITION 5. *If the cost-reducing innovation is moderate ($\theta^m < \theta < \theta^i$), then:*

(i) if $\frac{(c-\bar{\theta}c)(5c-3\bar{\theta}c-2a)+3\sigma^2c^2}{9b} + k_p - k_i > 0$, the two incumbent firms will bid $\frac{1}{3b}[(c - \bar{\theta}c)(2a - c - \bar{\theta}c) + \sigma^2c^2] - k_i$ for the IP rights, and the PI will bid $\frac{8}{9b}(a - c)(c - \bar{\theta}c) - k_P$ for the IP rights. One of the two incumbent firms will win the innovation and use the innovation exclusively.

(ii) if $\frac{(c-\bar{\theta}c)(5c-3\bar{\theta}c-2a)+3\sigma^2c^2}{9b} + k_p - k_i < 0$, the two incumbent firms will bid $\frac{1}{3b}[(c - \bar{\theta}c)(2a - c - \bar{\theta}c) + \sigma^2c^2] - k_i$ for the IP rights, and the PI will bid $\frac{1}{3b}[(c - \bar{\theta}c)(2a - c - \bar{\theta}c) + \sigma^2c^2] - k_i + \epsilon$, $\epsilon \to 0^+$ for the IP rights. The PI will win the innovation and license the innovation to both incumbent firms.

Proposition 5 details several interesting features about patent ownership when the innovation is moderate. First, note that an increase in the uncertainty in the knowledge of the degree of innovation (σ^2) leads to a higher likelihood of one of the two incumbent firms winning the IP rights, and lowers the ability of the PI to win the innovation. The intuition behind this result is that the uncertainty in the knowledge of the degree of the innovation leads to a higher upside for the two incumbent firms in their profits in the fourth stage (Cournot competition), while it does not affect the expected profits of the PI. This increased upside is reflected in a higher bid by the two incumbent firms than that of the PI, compared to the case where the degree of innovation is known with certainty. Second, the two incumbent firms have a higher chance of winning the IP rights if the innovation is moderate compared to the case when the innovation is incremental. This can be deduced from the fact that the gap between the patenting costs of the PI and the incumbent firms ($k_i - k_p$) has to be higher for the PI to win the IP rights, compared to the case when the innovation is incremental. If the PI wins the innovation (case (*ii*) of Proposition 5), its expected profit is $k_i - k_p - \frac{(c-\bar{\theta}c)(5c-3\bar{\theta}c-2a)+3\sigma^2c^2}{9b} - \epsilon > 0$.

4.3.3. Radical Innovation. If the innovation is radical, the PI will license the innovation to only one of the incumbent firms, and win a profit of $E[(a - \theta c)^2/4b - (a - c)^2/9b]$ from their licensing fees. If one of the incumbent firms wins the innovation, it will also not license the innovation to their competitor, but prefer to use the innovation exclusively. Proposition 6 summarizes the bids of the three firms and characterizes the winner of the IP rights when the innovation is radical.

PROPOSITION 6. *If the cost-reducing innovation is radical ($0 < \theta \leq \theta^m$), then*

(i) if $\frac{(a-c)^2}{9b} + k_p - k_i > 0$, the two incumbent firms will bid $\frac{1}{4b}[(a - \bar{\theta}c)^2 + \sigma^2c^2] - k_i$ for the IP rights, and the PI will bid $\frac{1}{4b}[(a - \bar{\theta}c)^2 + \sigma^2c^2] - \frac{1}{9b}(a - c)^2 - k_P$ for the IP rights. One of the two incumbent firms will win the innovation and use the innovation exclusively.

(ii) if $\frac{(a-c)^2}{9b} + k_p - k_i < 0$, the two incumbent firms will bid $\frac{1}{4b}[(a - \bar{\theta}c)^2 + \sigma^2c^2] - k_i$ for the IP rights, and the PI will bid $\frac{1}{4b}[(a - \bar{\theta}c)^2 + \sigma^2c^2] - k_i + \epsilon$,

$\epsilon \to 0^+$ for the innovation. The PI will win the innovation and license the innovation to one of the two incumbent firms.

Proposition 6 highlights the impact of a high degree of innovation (radical) on the bidding policies of the PI and the incumbent firms. First, while the uncertainty in the value of the degree of innovation at the bidding stage increases the bids of the incumbent firms as well as the PI, since only one of the incumbent firms will operate in the fourth stage of Cournot competition with the radical innovation, both incumbent firms and the PI increase their bids by the same amount to benefit from the upside of the innovation. Hence, the uncertainty (represented by a non-zero variance) has no role to play in deciding whether the PI or one of the incumbent firms wins the innovation. Second, the two incumbent firms have the highest chance of winning the IP rights if the innovation is radical compared to the cases where the innovation is incremental or moderate. This can be deduced from the fact that the gap between the patenting costs of the PI and the incumbent firms $(k_i - k_p)$ has to be the highest for the PI to win the IP rights, compared to the cases when the innovation is incremental or moderate. If the PI wins the innovation (case (*ii*) of Proposition 6), its expected profit is $k_i - k_p - \frac{(a-c)^2}{9b} - \epsilon > 0$.

4.4. Impact of Patent Intermediary on Prices and Profits

We now analyze the impact of the presence of the PI on the prices offered in the market and the profits of the two incumbent firms and the innovator. For this purpose, we compare the prices offered in the market and the profits of the two incumbent firms and the innovator in the absence of the PI in Proposition 7.

PROPOSITION 7. *The absence of the PI has the following effects on the prices and profits of the incumbent firms:*

(i) if the innovation is incremental, the prices and profits of the incumbent firms are the same as in the presence of the PI.
(ii) if the innovation is moderate, then the profits of the incumbent firms are the same as in the presence of the PI, but the price of the product charged from the consumers is either the same or higher.
(iii) if the innovation is radical, the price of the product is the same, but the profits of the incumbent firms are lower than those in the presence of the PI.

Proposition 7 explores the case when the PI is absent. If the innovation is incremental, then since both firms prefer to license to the competitor over exclusive use of the innovation, therefore both firms will use the innovation in equilibrium. Hence, the price in the market will be the same as in the case with the PI. Note that both firms will offer the same bid to the innovator and will have the same profits as they would have in the presence of the PI in the market (so their profits would be $E[(a - 2c + \theta c)^2/9b]$, from Proposition 4).

If the innovation is moderate, then only one of the incumbents will use the innovation in equilibrium. This is because the incumbent winning the IP rights prefers to use the innovation exclusively, and the other incumbent will have a higher unit production cost. This leads to a lower total quantity produced, and hence, in the Cournot equilibrium, the price that consumers will pay for the product in equilibrium is higher than if the PI was present in the market. Hence, an important result that we find is that patent intermediaries increase consumer welfare when the innovation is moderate. When a PI is present, it prefers to license the product to both incumbent firms, thereby decreasing the unit production cost of both firms, and consequently the total quantity produced is higher. This reduces the price the products are offered at, and consumer welfare increases. Note that both firms will make their highest bids for the IP rights, and will therefore again have the same profits in equilibrium as they would have in the presence of the PI in the market (so their profits would be $E[(a - 2c + \theta c)^2/9b]$, from Proposition 5(*i*)).

If the innovation is radical, then in the Cournot equilibrium, only one incumbent uses the innovation, and the other incumbent exits the market. Hence, only one incumbent operates in the fourth stage in the market. This results in the same quantity and price outcome as in the presence of the PI. Hence, if the innovation is radical, prices do not change in the absence of the PI. However, note that in this case, the profits of the two incumbents are different: When the PI is not present, then both firms will always bid the same $\frac{1}{4b}[(a - \bar{\theta}c)^2 + \sigma^2 c^2] - k_i$, which is higher than what they would bid in the presence of the PI. Therefore each firm's expected profit in equilibrium is lower than that in the case with the PI. The intuition behind this result is as follows: in the absence of the PI, if the incumbent firm does not win the IP rights, it gets a profit of zero. If it wins the IP rights, at the bidding stage, it gets an expected profit of $\frac{1}{4b}[(a - \bar{\theta}c)^2 + \sigma^2 c^2] - k_i$ from winning the IP rights. Overall, when the innovation is radical, the PI lowers the degree of competition between the incumbents.

Finally, the innovator always Pareto-benefits from the existence of the intermediary, because if the PI is absent, the incumbents make the same bids as they do in the presence of the PI (they are identical competitors). However, if the PI wins the innovation, it makes a higher bid than the incumbents, resulting in a higher payoff for the innovator.

4.5. Comparative Statics: Effect of General Uncertainty in Degree of Innovation

In this section, we analyze the impact on the bidding strategies of the patent intermediary and the incumbent firms when the random variable θ has its support in [0,1], i.e., we relax the assumption made in section 4.3 that the support of the distribution of θ is within the same domain as the mean, $\bar{\theta}$. As before, in the fourth stage, we analyze the Cournot subgame between the two incumbent firms. Since the value of θ is already realized in the fourth stage, the profits of the incumbent firms and the patent intermediary from its licensing policy are the same as in section 4.3. However, the bidding process and the values bid by the incumbent firms and the patent intermediary are different from section 4.3, as θ can be in any of the three regions: incremental, moderate, and radical. Proposition 8 compares the outcome of the bidding process between the incumbent firms and the patent intermediary in this case.

PROPOSITION 8. *If the cost reduction* (θ) *can take any value in* [0,1] *in the bidding stage, then the PI wins the innovation if* $k_i - k_p \geq \frac{1}{9b}(a-c)^2 \int_0^{2-\frac{a}{c}} f(\theta)d\theta + \int_{2-\frac{a}{c}}^{\frac{5}{3}-\frac{2a}{3c}} \frac{(c-\theta c)(5c-3\theta c-2a)}{9b} f(\theta)d\theta$. *Else, one of the two incumbents firms wins the innovation.*

Proposition 8 shows that the assumption made in section 4.3 is not limiting, and the impact of the support of θ being in the region of [0,1] is a combination of the cases when the value of $\bar{\theta}$ is in the incremental, moderate, and radical regions. Note that, in section 4.3, when the innovation is incremental, the profits of the incumbent firms and the PI in the fourth stage of the game (Cournot competition) are the same, and the PI always wins the innovation as it is more efficient than the two incumbent firms ($k_p < k_i$). In the moderate and incremental regions, the PI wins the innovation if $\frac{(c-\theta c)(5c-3\theta c-2a)}{9b} + k_p - k_i > 0$ and if $\frac{(a-c)^2}{9b} + k_p - k_i > 0$ respectively. Proposition 8 shows that the bidding strategies of the firms are such that the bids of the incumbent firms and the PI are the differences between their profits from having the innovation or not having the innovation in the three regions, and the condition for winning the innovation is an expectation of the conditions of winning the innovation in the incremental, moderate and radical regions. Consistent with the insights provided in section 4.3, where we show that the PI exists when $k_i - k_p$ is high and/or the innovation is either incremental of moderate, in this case we find that the existence of the patent intermediary in equilibrium is supported by a high value of $k_i - k_p$ and/or a shift of the probability distribution, $f(\theta)$ toward the right side (shift of the mass toward the moderate/incremental region, since $\frac{1}{9b}(a-c)^2 \geq \frac{(c-\theta c)(5c-3\theta c-2a)}{9b} \geq 0$ for $2-\frac{a}{c} \leq \theta \leq \frac{5}{3}-\frac{2a}{3c}$). If the PI wins the innovation, its expected profit is $k_i - k_p - \frac{1}{9b}(a-c)^2 \int_0^{2-\frac{a}{c}} f(\theta)d\theta - \int_{2-\frac{a}{c}}^{\frac{5}{3}-\frac{2a}{3c}} \frac{(c-\theta c)(5c-3\theta c-2a)}{9b} f(\theta)d\theta \geq 0$.

4.6. When Incumbents Do Not Have Perfect Information about Availability of Innovation

Although in this study, we have assumed that the PI and both incumbent firms participate in the bidding process for the innovation, due to high search costs and/or information asymmetry in markets, it is plausible that not all incumbents may have perfect knowledge of the availability of the innovation at the bidding stage. In this section, we formalize that possibility and show, consistent with the expected intuition, that this case leads to higher expected profits for the PI. Interestingly, we find that the higher profits for the PI only occur when the degree of innovation lies in the radical region. The reason for these insights is as follows: in both the incremental and moderate regions, the final market equilibrium is a duopoly. In terms of expected profits, an incumbent firm that does not win the innovation is indifferent to whether is loses the innovation to the PI or to the other incumbent. Therefore, in these two regions, the PI does not have any additional chance of winning, and the expected profit of the PI is the same as our base model. However, the case with radical innovation leads to a monopoly. Moreover, it makes a difference to an incumbent whether it loses the inovation to the PI or the other incumbent. If the innovation is won by the PI, both incumbents, with a probability of 0.5, stand to make non-zero profits. This decreases the willingness to pay for the innovation for an incumbent if the other incumbent is absent from the bidding process. Therefore, the conditions for the existence of the PI are more relaxed and its expected profit is higher when compared to our base model.

To model this case, we assume that only one incumbent participates in the bidding process with a probability of η, and both the incumbent firms enter the bidding process with a probability of $1 - \eta$. We do not consider the case where none of the incumbents enter the bidding process as that yields to a trivial analysis and insights. We also assume that when bids for the innovation are being submitted, all parties participating in the bidding process have common knowledge of the number of participants (i.e., PI and one incumbent or PI and both incumbents). The following proposition summarizes our findings in this case.

PROPOSITION 9.

(i) *When only one incumbent enters the bidding process, the conditions that determine the existence of the PI firm remain unchanged for the case with incremental and moderate innovation (propositions 4 and 5); however, the condition for the radical innovation changes to* $\frac{(a-c)^2}{18b} + k_p - k_i < 0$.

(ii) *If the probability of one (resp., both) incumbent firm (s) of participating in the bidding process is* η *(resp.,* $1-\eta$*), then if the innovation is in the radical region: the PI firm wins the innovation if* $\frac{(a-c)^2}{9b} + k_p - k_i < 0$; *if* $\frac{(a-c)^2}{9b} + k_p - k_i > 0$ *and* $\frac{(a-c)^2}{18b} + k_p - k_i < 0$, *then the PI wins the innovation with a probability of* η; *if* $\frac{(a-c)^2}{18b} + k_p - k_i > 0$, *then the PI never wins the innovation. When the innovation is in the incremental and moderate regions, the conditions that determine whether the PI wins the innovation remain unchanged (Propositions 4 and 5).*

(iii) *If the probability of one (resp., both) incumbent firm (s) of participating in the bidding process is* η *(resp.,* $1-\eta$*), then the expected profit of the PI remains unchanged in the case with incremental and moderate innovation; however, the expected profit for the PI, conditional on winning the innovation, for the case with radical innovation increases to*

$$\eta\left[k_i - k_p - \frac{(a-c)^2}{18b} - \epsilon\right] + (1-\eta)\left[k_i - k_p - \frac{(a-c)^2}{9b} - \epsilon\right].$$

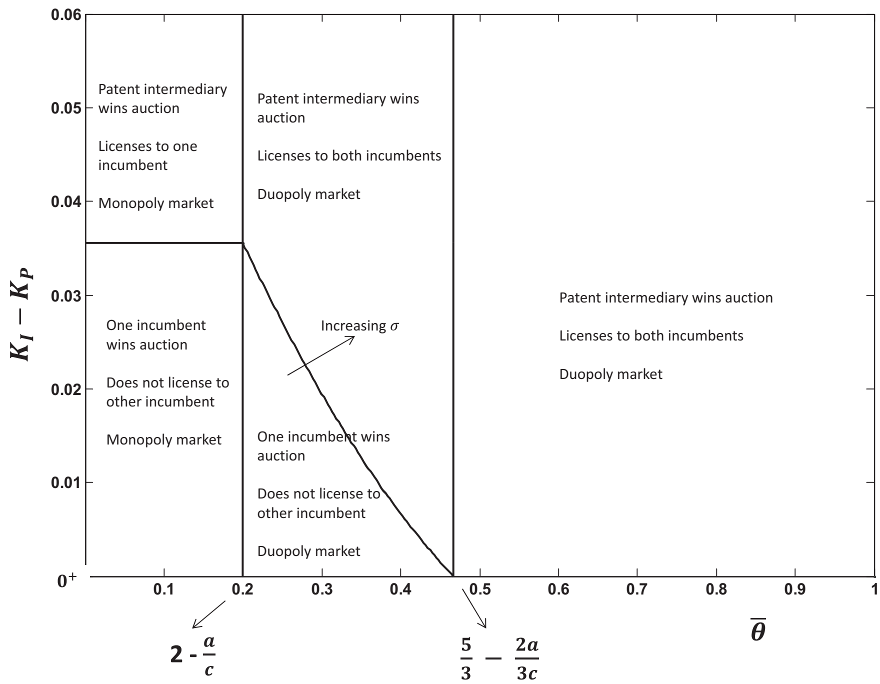
5. Conclusions and Future Research

In this study, we investigate the role of patent intermediaries in innovation. Specifically, we seek to understand under what conditions of innovation patent intermediaries play a role in innovation markets. We develop a model of the licensing of a cost-reducing innovation by a innovator who does not know the value of the patent to two incumbent firms who engage in Cournot competition in the market. We also model the existence of a PI and assume that the intermediary and the two incumbent firms have common priors on the value of the innovation to both firms. By analyzing the subsequent game between the different parties as a simultaneous game, we characterize: (i) the licensing fees offered by the two incumbent firms and the PI to the innovator, and (ii) based on the offered bids by the incumbents and the PI, the winner of the patent and its subsequent licensing policy. This enables us to characterize the conditions under which patent intermediaries exist in innovation markets. We have used a parsimonious model that provides novel insights on the relation between the existence of patent intermediaries and the degree of innovation.

Our findings are as follows. We find that the outcome of the IP acquisition and the subsequent licensing game critically depends on the degree of the cost-reducing innovation. For the licensing game, the following results hold: incumbent firms prefer to license the innovation to their competitors only when the degree of the innovation is incremental, meaning that the cost of producing the product based on the innovation is not substantially reduced. Under the same conditions for the degree of innovation, if the PI wins the patent, it licenses the innovation to both incumbent firms. Hence, incremental innovations result in perfectly efficient production. Incumbent firms will prefer not to license the innovation to their competitor if they win the IP rights and if the degree of innovation is above a threshold value. This threshold characterizes the higher boundary demarcating the region of moderate innovation. If the PI wins the IP rights, it prefers to license the innovation to both incumbent firms until a second lower threshold is reached, demarcating the lower boundary of the moderate innovation region. Both firms prefer to use the innovation exclusively and the PI licenses the innovation to one of the incumbent firms if the innovation is radical, meaning that the cost of producing the product based on the innovation is substantially reduced. For the IP acquisition game, the PI always wins the IP rights if the innovation is incremental. If the innovation is moderate, the PI wins the IP rights if the uncertainty of the innovation at the bidding stage is low, and if the efficiency of patenting of the PI (k_p) is moderately lower than that of the incumbent firms (k_i). If the above two conditions do not hold, one of the incumbent firms acquires the IP rights if the innovation is moderate. If the innovation is radical, the PI only wins the IP rights if it is significantly more efficient compared to the incumbent firms. Our results are summarized in Figure 4.

Our results have a number of implications. First, note that the PI always wins the IP rights when the innovation is incremental ($\theta^i \leq \theta < 1$). Empirical evidence suggests that patent intermediaries indeed own innovations of low quality (Graham and Mowery 2003, Hedlund 2007). However, patent intermediaries also own innovations of high quality (Fischer and Henkel 2011), showing that efficiency of patenting also plays an important role in the sustainable business model of patent intermediaries when the

Figure 4 Regions of Patent Intermediary Winning Innovation (a = 1.8, b = 2, c =1)



degree of innovation is high. When the innovation is moderate or radical, the PI wins the IP rights only when it is significantly more efficient at patenting than the incumbent firms and the uncertainty about the degree of innovation at the bidding stage is low. An extension of our base model shows that the PI firm's ability to win the innovation may be improved if there is some information asymmetry in the innovation market that may lead to only one incumbent participating in the bidding process. However, we find that this happens only in the case with radical innovation, where incumbent firms prefer losing the innovation to the PI compared to losing it to each other. Our analysis provides a theoretical explanation for the observation that NPEs who rely on licensing revenues for their business model take the degree of innovation into account.

Second, incumbent firms are willing to license the innovation to their competitor if they win the patent, but only when the degree of innovation is incremental. If they win the IP rights to moderate and radical innovation, they prefer to use the innovation exclusively. In contrast, patent intermediaries license the innovation to both firms when the innovation is incremental or moderate, and license the innovation exclusively to one firm only when the innovation is radical. A third implication of our results is that when the innovation is incremental, both incumbent firms will use the innovation and have a lower unit cost of production, irrespective of the identity of the firm that wins the patent. Fourth, patent intermediaries serve two useful functions for the prices that consumers pay and the profits of the incumbent firms. When the innovation is moderate, they lower the prices that consumers pay. When the innovation is radical, they increase the profits of the incumbents.

Our results contribute to the extant literature in a number of ways. First, to the best of our knowledge, this is the first modeling effort in the area of cost-reducing innovation that studies the impact of the degree of innovation upon the role of patent intermediaries. Second, we add to the literature on the licensing of cost-reducing innovations and show that in the presence of a PI, the winner of the rights to the patent and the subsequent market structure depends on the degree of innovation—incremental, moderate, and radical—in a more nuanced fashion than the extant literature which had focused on two classes of innovation—non-radical and radical.

Regarding the role of the innovator, although the innovator can replicate the role of the PI by seeking the patent itself and licensing the innovation to the incumbents, in practice, innovators may not do so, leaving that role to third parties. This may in part be explained by the fact that costs for obtaining the patent may be substantial for the innovator (may be higher than that for the incumbents). In addition, the innovator may want to focus on pure research and not assume the role of becoming a business partner in the industry. Finally, finding the right incumbents and the process of negotiating and writing legal contracts may impose additional costs and time constraints on the innovator.

A number of potential avenues for future research can be identified. First, the relationship between the degree of innovation and the existence of PI's can be empirically examined. Specifically, longitudinal data on PI's (number of firms) can be related to the degree of innovation in various industries. Our theoretical results posit that a higher density of PI firms may exist in innovation markets where the degree of innovation is low. Since, cost-reducing innovations are generally process-based innovations and hence incremental in nature, another hypothesis from our research is that PIs exist to a larger extent in process innovation markets. Next, future research can consider factors such as capital constraints and other sources of market inefficiency like information asymmetry, search costs, and litigation (which is the model adopted by PI firms that act as patent trolls) that may support patent intermediaries. Also, we have only considered the impact of formal knowledge structures in which the innovator does not know the value of the patent to the two incumbent firms and the market structure, but the firms and the PI have full information that is shared on the value of the patent and the market structure under competition. Future research should take these asymmetries of information into account. We conjecture that if the PI does not have full information (the assumption that the firms that operate in the market have full information is reasonable), then the PI will play a meaningful role only if innovations are extremely incremental, as they can perform the market assimilation role in a more restricted region. In addition, we assumed that there are only two identical firms for the sake of tractability. Future research can generalize the results to n incumbent firms; we expect that our results should be robust to this generalization in this case. Also, while our focus is on cost-reducing innovations, a useful future research avenue will be to map the approach/findings of this paper to feature enhancing innovations. Unlike our model, such a setting would involve more nuanced modeling of the end consumer demand function (as a function of the innovation) which may lead to newer insights. Finally, future research can consider generalized demand functions with the property that the revenue function is concave, and include other standard assumptions on price elasticity and demand.

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Appendix

Proof of Proposition 1. If the PI wins the patent, then in the licensing subgame, the PI will license the innovation to both incumbents as it earns $2T_2^{PI} = \frac{8(a-c)(c-\theta c)}{9b} > T_1^{PI} = \frac{4(a-\theta c)(c-\theta c)}{9b}$, which is the profit it would earn from licensing to one incumbent only. The condition for $2T_2^{PI} > T_1^{PI}$ is $\theta > 2 - \frac{a}{c}$, and is satisfied as when the innovation is incremental, $\theta \geq \theta^i$.

If one of the incumbent firms wins the patent, it will license to the competitor if $\frac{2(a-\theta c)^2}{9b} - \frac{(a-2c+\theta c)^2}{9b} \geq \frac{(a-2\theta c+c)^2}{9b}$. Simplifying this condition shows that it holds if $\theta \geq \frac{5}{3} - \frac{2a}{3c}$, or if the innovation is incremental. □

Proof of Proposition 2. If the PI wins the patent, the then the licensing subgame is identical to the case in Proposition 1, and the PI prefers to license the innovation to both incumbents if $\theta > \theta^m$.

If one the two incumbent firms wins the patent, it will prefer to use the innovation exclusively if its profit from exclusive use, $\frac{(a-2\theta c+c)^2}{9b}$ is greater than $\frac{2(a-\theta c)^2}{9b} - \frac{(a-2c+\theta c)^2}{9b}$, which is the profit the winning incumbent gets from licensing to its competitor. This condition reduces to $\theta < \frac{5}{3} - \frac{2a}{3c} = \theta^i$. □

Proof of Proposition 3. If the PI wins the innovation, for only one of the incumbent firms to license the innovation, from Figure 3, the conditions for a Nash equilibrium imply that T_1^{PI} has to satisfy

$$0 \geq \frac{(a-\theta c)^2}{9b} - T_1^{PI}$$

$$\frac{(a-\theta c)^2}{4b} - T_1^{PI} \geq \frac{(a-c)^2}{9b}$$

The maximum licensing fee that the PI can charge from one firm is the maximum value of T_1^{PI} that satisfies the above inequalities. Since $\frac{(a-\theta c)^2}{4b} - \frac{(a-c)^2}{9b} \geq \frac{(a-\theta c)^2}{9b}$ $(\frac{(a-c)^2}{9b} \leq \frac{(a-\theta c)^2}{9b})$,

$$T_1^{PI} = \frac{(a-\theta c)^2}{4b} - \frac{(a-c)^2}{9b}.$$

Similarly, let T_2^{PI} be the maximum licensing fee that firm PI can charge to ensure that both firms enter into a licensing agreement with it. For both the incumbent firms to license the innovation, from

Figure 3, the conditions for a Nash equilibrium imply that T_2^{PI} has to satisfy

$$0 \leq \frac{(a-\theta c)^2}{9b} - T_2^{PI} \frac{(a-\theta c)^2}{4b} - T_2^{PI} \geq \frac{(a-c)^2}{9b}$$

Hence, $T_2^{PI} = \frac{(a-\theta c)^2}{9b}$.

It is easy to see that $T_1^{PI} = \frac{(a-\theta c)^2}{4b} - \frac{(a-c)^2}{9b} \geq 2T_2^{PI} = \frac{2(a-\theta c)^2}{9b}$ if the innovation is radical. To show $\frac{(a-\theta c)^2}{4b} - \frac{(a-c)^2}{9b} \geq \frac{2(a-\theta c)^2}{9b}$, we need to show that $\frac{(a-\theta c)^2}{36b} \geq \frac{(a-c)^2}{9b}$, which reduces to the condition $\theta \leq 2 - \frac{a}{c}$, which is true if the innovation is radical.

If one of the firms wins the innovation, and decides to license the innovation to the competitor, its payoff will be $(a-\theta c)^2/9b + T^i$, where T^i is the licensing fee. Firm 2's (1's) profit will be $(a-\theta c)^2/9b - T^i$. Since firm 2 (1) will not exist in this case if firm 1 (2) does not license the innovation to it, $T^i = (a-\theta c)^2/9b$. Therefore, this licensing yields a profit of $2(a-\theta c)^2/9b$ for firm 1 (2) which is less than the monopolistic profit $(a-\theta c)^2/4b$. Therefore, if one of the incumbents wins the innovation, it will choose not to license to its competitor. □

PROOF OF PROPOSITION 4. When the innovation is incremental, the profits of an incumbent firm from winning the innovation and then licensing it to the other incumbent are given by $E[2(a-\theta c)^2/9b - (a-2c+\theta c)^2/9b]$, and the corresponding profit of the other incumbent firm is $E[(a-2c+\theta c)^2/9b]$. Therefore, the willingness to bid for the innovation for the two incumbents is given by: $E[2(a-\theta c)^2/9b - 2(a-2c+\theta c)^2/9b] - k_i = 8(a-c)(c-\bar{\theta}c)/9b - k_i$. If the PI wins the innovation, its net profits from licensing the innovation to the two incumbents minus its cost of patenting it are given by: $2E[T_2^{PI}] - k_p = 2E[(a-\theta c)^2/9b - (a-2c+\theta c)^2/9b] - k_p = 8(a-c)(c-\bar{\theta}c)6/9b - k_p$. Since $k_p < k_i$, the two incumbents will bid $8(a-c)(c-\bar{\theta}c)/9b - k_i$, and the PI will bid a marginally higher amount than the incumbent bid: $8(a-c)(c-\bar{\theta}c)/9b - k_i + \epsilon$, $\epsilon \to 0^+$, and win the innovation. □

PROOF OF PROPOSITION 5. When the innovation is moderate, the optimal licensing strategy of the incumbent firm is not to license the innovation to its competitor, and use the innovation exclusively. At the second (bidding) stage, the profits of an incumbent firm from winning the innovation and then using it exclusively are given by: $\Pi_i^W = E[(a-2\theta c+c)^2/9b] - k_i$. The profit of an incumbent that does not win the bid for the innovation is given by: $\Pi_i^L = E[(a-2c+\theta c)^2/9b]$. Therefore, the maximum willingness to bid for the innovation for the two incumbents is given by: $\Pi_i^W - \Pi_i^L$. We have,

$$\begin{aligned}
\Pi_i^W - \Pi_i^L = \\
&E[(a-2\theta c+c)^2/9b] - k_i - E[(a-2c+\theta c)^2/9b] \\
&= E[(a-2\theta c+c)^2/9b - (a-2c+\theta c)^2/9b] - k_i \\
&= \frac{1}{9b} E[3(c-\theta c)(2a-c-\theta c)] - k_i \\
&= \frac{1}{9b} E[3c^2\theta^2 - 3c^2 - 6ac\theta + 6ac] - k_i \\
&= \frac{1}{9b} \left(3c^2 E[\theta^2] - 3c^2 - 6acE[\theta] + 6ac\right) - k_i \\
&= \frac{1}{9b} \left(3c^2(\sigma^2 + \bar{\theta}^2) - 3c^2 - 6ac\bar{\theta} + 6ac\right) - k_i \\
&= \frac{3(c-\bar{\theta}c)(2a-c-\bar{\theta}c) + 3\sigma^2 c^2}{9b} - k_i.
\end{aligned}$$

Therefore, the maximum willingness to bid for the innovation for the two incumbents is given by: $\Pi_i^W - \Pi_i^L = \frac{3(c-\bar{\theta}c)(2a-c-\bar{\theta}c)+3\sigma^2c^2}{9b} - k_i$.

If the PI wins the innovation, its net profits from licensing the innovation to the two incumbents minus its cost of patenting it are given by: $\Pi_{PI} = 2E[(a-\theta c)^2/9b - (a-2c+\theta c)^2/9b] - k_p = 8(a-c)(c-\bar{\theta}c)/9b - k_p$.

Case 1: If $\Pi_i^W - \Pi_i^L = \frac{3(c-\bar{\theta}c)(2a-c-\bar{\theta}c)+3\sigma^2c^2}{9b} - k_i > \Pi_{PI} = 8(a-c)(c-\bar{\theta}c)/9b - k_p \Rightarrow \frac{(c-\bar{\theta}c)(5c-3\bar{\theta}c-2a)+3\sigma^2c^2}{9b} + k_p - k_i > 0$, then the two incumbent firms have to bid their maximum willingness to bid to ensure that they win the innovation, and their bid is given by $\frac{3(c-\bar{\theta}c)(2a-c-\bar{\theta}c)+3\sigma^2c^2}{9b} - k_i$. The PI also bids its maximum profit, and its bid is given by $8(a-c)(c-\bar{\theta}c)/9b - k_p$. One of the two incumbent firms wins the innovation in this case.

Case 2: If $\Pi_i^W - \Pi_i^L = \frac{3(c-\bar{\theta}c)(2a-c-\bar{\theta}c)+3\sigma^2c^2}{9b} - k_i < \Pi_{PI} = 8(a-c)(c-\bar{\theta}c)/9b - k_p \Rightarrow \frac{(c-\bar{\theta}c)(5c-3\bar{\theta}c-2a)+3\sigma^2c^2}{9b} + k_p - k_i < 0$, the two incumbent firms bid their maximum willingness to bid of $\frac{3(c-\bar{\theta}c)(2a-c-\bar{\theta}c)+3\sigma^2c^2}{9b} - k_i$. The PI bids a marginally higher amount of $\frac{3(c-\bar{\theta}c)(5c-2a-3\bar{\theta}c)+3\sigma^2c^2}{9b} - k_i + \epsilon$, $\epsilon \to 0^+$, and wins the innovation. □

PROOF OF PROPOSITION 6. When the innovation is radical, the optimal licensing strategy of the incumbent firm is not to license the innovation to its competitor, and use the innovation exclusively. At the second (bidding) stage, the profits of the two incumbent firms from winning the innovation and then using it exclusively are given by: $E[(a-\theta c)^2/4b] - k_i$. If the incumbent loses, its profit will be zero. Hence, the willingness to bid for the incumbents is $E[(a-\theta c)^2/4b]-k_i=\frac{1}{4b}[(a-\bar{\theta}c)^2+\sigma^2c^2]-k_i$. The PI's profits from winning the innovation are given by: $\Pi_{PI}=E[(a-\theta c)^2/4b-(a-c)^2/9b]-k_p=\frac{1}{4b}[(a-\bar{\theta}c)^2+\sigma^2c^2]-\frac{1}{9b}(a-c)^2-k_p$.

Case 1: If $\frac{1}{9b}(a-c)^2+k_p-k_i>0$, then the bids of the two incumbent firms is given by $\frac{1}{4b}[(a-\bar{\theta}c)^2+\sigma^2c^2]-k_i$. The PI also bids its maximum profit, and its bid is given by $\frac{1}{4b}[(a-\bar{\theta}c)^2+\sigma^2c^2]-\frac{1}{9b}(a-c)^2-k_p$. One of the two incumbent firms wins the innovation in this case.

Case 2: If $\frac{1}{9b}(a-c)^2+k_p-k_i<0$, then the two incumbent firms will bid $\frac{1}{4b}[(a-\bar{\theta}c)^2+\sigma^2c^2]-k_i$. The PI bids a marginally higher amount of $\frac{1}{4b}[(a-\bar{\theta}c)^2+\sigma^2c^2]-k_i+\epsilon$, $\epsilon\to 0^+$, and wins the innovation. □

PROOF OF PROPOSITION 7.

Case 1: If the innovation is incremental, in the absence of the PI, the two incumbents still submit their maximum rational bid of $8(a-c)(c-\bar{\theta}c)/9b-k_i$, hence their profits in equilibrium are $E[(a-2c+\theta c)^2/9b]$. The incumbent winning the innovation will license it to its competitor, hence, both the firms have a unit production cost of θc, and the price charged of consumers in equilibrium does not change.

Case 2: If the innovation is moderate, in the absence of the PI, the two incumbents will still submit their maximum rational bids of $\frac{3(c-\bar{\theta}c)(5c-2a-3\bar{\theta}c)+3\sigma^2c^2}{9b}-k_i$, and use the innovation exclusively, hence, their profits do not change (given by $E[(a-2c+\theta c)^2/9b]$). However, in this case, the incumbent winning the innovation uses it exclusively, hence, the other firm has a higher unit cost of c. This case is identical to the case in Proposition 5(*i*), when one of the incumbents wins the innovation.

However, in the presence of the PI, if $\frac{(c-\bar{\theta}c)(5c-3\bar{\theta}c-2a)+3\sigma^2c^2}{9b}+k_p-k_i<0$, the PI wins the innovation and licenses it to both incumbents. The profits of the incumbents are the same in this case ($E[(a-2c+\theta c)^2/9b]$), but the price charged of consumers is lower, as both firms have a unit production cost of θc.

Case 3: If the innovation is radical, then even in the absence of the PI, the optimal licensing strategy of the incumbent firm that wins the innovation is not to license the innovation to its competitor, and use the innovation exclusively, with its cost being θc. Therefore, the other firm exits the market, and the final structure is a monopoly. This is the same scenario as that in the presence of the PI, therefore, the price of the product remains the same. However, both the incumbents stand to earn a zero profit in this case as the firm that wins the innovation will do so by paying its maximum willing amount to the innovator. In the presence of the PI, both incumbents stand a chance to earn $(a-c)^2/9b>0$ (with a probability of $\frac{1}{2}$), if the PI wins the innovation (which will happen if k_p is significantly lower than k_i). □

PROOF OF PROPOSITION 8. For the incumbent firms, denote Π_i^W as the profit in the fourth stage if the firm wins the innovation, and Π_i^L if it loses the innovation to the other incumbent.

If the realized value of θ in the fourth stage is in the incremental region, then from Proposition 4, $\Pi_i^W=2(a-\theta c)^2/9b-(a-2c+\theta c)^2/9b-k_i$, $\Pi_i^L=(a-2c+\theta c)^2/9b$. Similarly, if the realized value of θ in the fourth stage is in the moderate region, then from Proposition 5, $\Pi_i^W=(a-2\theta c+c)^2/9b-k_i$, $\Pi_i^L=(a-2c+\theta c)^2/9b$ for the two incumbent firms. If the realized value of θ in the fourth stage is in the radical region, then from Proposition 6, $\Pi_i^W=(a-\theta c)^2/4b-k_i$, $\Pi_i^L=0$, for the two incumbent firms. In the incremental and moderate regions, $\Pi_{PI}=2[(a-\theta c)^2/4b-(a-c)^2/9b]-k_p$, and in the radical region, $\Pi_{PI}=(a-\theta c)^2/4b-(a-c)^2/9b-k_p$.

Denote $\hat{\Pi}_i^W$ as the expected profits of the incumbent firms from winning the innovation, and $\hat{\Pi}_i^L$ as the expected profits of the incumbent firms from losing the innovation to the other incumbent. Similarly, $\hat{\Pi}_{PI}^W$ is the expected profit of the PI from winning the innovation. Let B^i and B^{PI} denote the bids of the incumbent firms and the PI respectively.

For the incumbent's bid B^i, the following condition holds: $\hat{\Pi}_i^W-B^i-k_i\geq\hat{\Pi}_i^L$. For the patent intermediary's bid, $\hat{\Pi}_{PI}^W-B^{PI}-k_p\geq 0\Rightarrow B^{PI}\leq\hat{\Pi}_{PI}^W-k_p$.

Since the two incumbents are identical and competitive, their bidding equilibrium is at their maximum willingness to pay. Hence, $B^i=\hat{\Pi}_i^W-\hat{\Pi}_i^L-k_i$. For the patent intermediary to win the innovation,

$$max[B^{PI}]=\hat{\Pi}_{PI}^W-k_p\geq\hat{\Pi}_i^W-\hat{\Pi}_i^L-k_i.$$

Hence, $k_i-k_p\geq\hat{\Pi}_i^W-\hat{\Pi}_i^L-\hat{\Pi}_{PI}^W$.

$$\Rightarrow k_i - k_p \geq \int_{\frac{5}{3}-\frac{2a}{3c}}^{1} \left[\frac{2(a-\theta c)^2-(a-2c+\theta c)^2}{9b} - \frac{(a-2c+\theta c)^2}{9b} - \frac{2(a-\theta c)^2-2(a-2c+\theta c)^2}{9b} \right] f(\theta)d\theta$$

$$+ \int_{2-\frac{a}{c}}^{\frac{5}{3}-\frac{2a}{3c}} \left[\frac{(a-2\theta c+c)^2}{9b} - \frac{(a-2c+\theta c)^2}{9b} - \frac{2(a-\theta c)^2-2(a-2c+\theta c)^2}{9b} \right] f(\theta)d\theta$$

$$+ \int_{0}^{2-\frac{a}{c}} \left[\frac{(a-\theta c)^2}{4b} - \frac{(a-\theta c)^2}{4b} + \frac{(a-c)^2}{9b} \right] f(\theta)d\theta$$

Simplifying this equation gives us the result in the proposition. □

Proof of Proposition 9. (i) Here, we assume that only one of the incumbent firms participates in the bidding process. When the innovation is incremental, the profits of an incumbent firm from winning the innovation and then licensing it to the other incumbent are given by $E[2(a-\theta c)^2/9b - (a-2c+\theta c)^2/9b]$, and the profit of that incumbent firm is $E[(a-2c+\theta c)^2/9b]$ if the innovation is won by the PI. Therefore, the willingness to bid for the innovation for that incumbent is given by: $E[2(a-\theta c)^2/9b - 2(a-2c+\theta c)^2/9b] - k_i = 8(a-c)(c-\bar{\theta}c)/9b - k_i$. If the PI wins the innovation, its net profits from licensing the innovation to the two incumbents minus its cost of patenting it are given by: $2E[T_2^{PI}] - k_p = 2E[(a-\theta c)^2/9b - (a-2c+\theta c)^2/9b] - k_p = 8(a-c)(c-\bar{\theta}c)6/9b - k_p$. Since $k_p < k_i$, the participating incumbent will bid $8(a-c)(c-\bar{\theta}c)/9b - k_i$, and the PI will bid a marginally higher amount than the incumbent bid: $8(a-c)(c-\bar{\theta}c)/9b - k_i + \epsilon, \epsilon \to 0^+$, and win the innovation.

When the innovation is moderate, the optimal licensing strategy of the incumbent firm is not to license the innovation to its competitor, and use the innovation exclusively. At the second (bidding) stage, the profits of an incumbent firm from winning the innovation and then using it exclusively are given by: $\Pi_i^W = E[(a-2\theta c+c)^2/9b] - k_i$. The profit of that incumbent by losing the innovation to the PI firm is given by: $\Pi_i^{LPI} = E[(a-2c+\theta c)^2/9b]$. Therefore, the maximum willingness to bid for the innovation for the two incumbents is given by: $\Pi_i^W - \Pi_i^{LPI} = \frac{3(c-\bar{\theta}c)(2a-c-\bar{\theta}c)+3\sigma^2c^2}{9b} - k_i$. If the PI wins the innovation, its net profits from licensing the innovation to the two incumbents minus its cost of patenting it are given by: $\Pi_{PI} = 2E[(a-\theta c)^2/9b - (a-2c+\theta c)^2/9b] - k_p = 8(a-c)(c-\bar{\theta}c)/9b - k_p$. If $\Pi_i^W \quad -\Pi_i^{LPI} = \frac{3(c-\bar{\theta}c)(2a-c-\bar{\theta}c)+3\sigma^2c^2}{9b} - k_i > \Pi_{PI} = 8(a-c) \quad (c-\bar{\theta}c)/9b - k_p \Rightarrow (c-\bar{\theta}c)(5c - \frac{3\bar{\theta}c-2a)+3\sigma^2c^2}{9b+k_p-k_i > 0}$, then the incumbent firm will win the innovation by outbidding the PI. If $\Pi_i^W - \Pi_i^{LPI} = 3(c-\bar{\theta}c)(2a-c-\bar{\theta}c) + \frac{3\sigma^2c^2}{9b-k_i < \Pi_{PI} = 8(a-c)(c-\bar{\theta}c)/9b-k_p}$ $\Rightarrow \frac{(c-\bar{\theta}c)(5c-3\bar{\theta}c-2a)+3\sigma^2c^2}{9b} + k_p - k_i < 0$, the PI bids a marginally higher amount of $\frac{3(c-\bar{\theta}c)(5c-2a-3\bar{\theta}c)+3\sigma^2c^2}{9b} - k_i + \epsilon, \epsilon \to 0^+$, and wins the innovation.

When the innovation is radical, the optimal licensing strategy of the incumbent firm is not to license the innovation to its competitor, and use the innovation exclusively. At the second (bidding) stage, the profit of the incumbent firm from winning the innovation and then using it exclusively is given by: $E[(a-\theta c)^2/4b] - k_i$. If the PI wins the innovation, it will license the innovation to only one incumbent, yielding a profit equal to $\frac{(a-c)^2}{9b}$ for that firm. Therefore, the expected profit for the incumbent firm if it loses to the PI in the bidding process is $\frac{(a-c)^2}{18b}$. Hence, the willingness to bid for the incumbents is $E[(a-\theta c)^2/4b] - k_i - \frac{(a-c)^2}{18b} = \frac{1}{4b}[(a-\bar{\theta}c)^2 + \sigma^2c^2] - k_i - \frac{(a-c)^2}{18b}$. The PI's profits from winning the innovation are given by: $\Pi_{PI} = E[(a-\theta c)^2/4b - (a-c)^2/9b] - k_p = \frac{1}{4b}[(a-\bar{\theta}c)^2 + \sigma^2c^2] - \frac{1}{9b}(a-c)^2 - k_p$. If $\frac{1}{18b}(a-c)^2 + k_p - k_i > 0$, then the incumbent firm wins the innovation in this case. If $\frac{1}{18b}(a-c)^2 + k_p - k_i < 0$, then the incumbent firm will bid $\frac{1}{4b}[(a-\bar{\theta}c)^2 + \sigma^2c^2] - k_i - \frac{(a-c)^2}{18b}$. The PI bids a marginally higher amount of $\frac{1}{4b}[(a-\bar{\theta}c)^2 + \sigma^2c^2] - k_i - \frac{(a-c)^2}{18b} + \epsilon, \epsilon \to 0^+$, and wins the innovation.

(ii) The proof for this part of the proposition follows directly from the proof of part (*i*) above and from the proof of propositions 4 and 5.

(iii) If the probability of one (resp., both) incumbent firm(s) of participating in the bidding process is η (resp., $1-\eta$), then the expected profit of the PI, conditional on winning the innovation is:

$$\Pi_{PI} = k_i - k_p - \epsilon, \text{ incremental innovation}$$

$$= k_i - k_p - \frac{(c-\bar{\theta}c)(5c-3\bar{\theta}c-2a)+3\sigma^2c^2}{9b} - \epsilon,$$

moderate innovation

$$= \eta\left[k_i - k_p - \frac{(a-c)^2}{18b} - \epsilon\right] + (1-\eta)\left[k_i - k_p - \frac{(a-c)^2}{9b} - \epsilon\right],$$

radical innovation

It is easy to observe that for the case with radical innovation, the PI makes a higher expected profit when compared to the profit in section 4.3.3. □

Note

[1]As in Adner and Zemsky (2005), we use Cournot competition between the incumbent firms as it allows for the possibility of licensing the innovation to both incumbent firms.

References

Adner, R., P. Zemsky. 2005. Disruptive technologies and the emergence of competition. *RAND J. Econ.* **36**(2): 229–254.

Arora, A., M. Ceccagnoli. 2006. Patent protection, complementary assets, and firms' incentives for technology licensing. *Manage. Sci.* **52**(2): 293–308.

Belderbos, R., M. Carree, B. Lokshin. 2004. Cooperative R&D and firm performance. *Res. Policy* **33**(10): 1477–1492.

Bernstein, F., A. G. Kok. 2009. Dynamic cost reduction through process improvement in assembly networks. *Manage. Sci.* **55**(4): 552–567.

Bessen, J. E., M. J. Meurer, J. L. Ford. 2011. The private and social costs of patent trolls. Working paper, SSRN. Available at http://ssrn.com/abstract=1930272.

Bhaskaran, S. R., S. M. Gilbert. 2009. Implications of channel structure for leasing or selling durable goods. *Mark. Sci.* **28**(5): 918–934.

Ceccagnoli, M. 2009. Appropriability, preemption, and firm performance. *Strat. Manage. J.* **30**(1): 81–98.

Chao, R. O., S. Kavadias. 2008. A theoretical framework for managing the new product development portfolio: When and how to use strategic buckets. *Manage. Sci.* **54**(5): 907–921.

Colyvas, J., M. Crow, A. Gelijns, R. Mazzoleni, R. R. Nelson, N. Rosenberg, B. N. Sampat. 2002. How do university inventions get into practice? *Manage. Sci.* **48**(1): 61–72.

Economist. 2011. Intellectual property: Patents against prosperity. August 1.

Erat, S., S. Kavadias. 2006. Introduction of new technologies to competing industrial customers. *Manage. Sci.* **52**(11): 1675–1688.

Erat, S., V. Krishnan. 2012. Managing delegated search over design spaces. *Manage. Sci.* **58**(3): 606–623.

Fischer, T., J. Henkel. 2011. Patent trolls on markets for technology – An empirical analysis of trolls' patent acquisitions. SSRN Working Paper, http://ssrn.com/abstract=1523102.

Fosfuri, A. 2006. The licensing dilemma: Understanding the determinants of the rate of technology licensing. *Strat. Manage. J.* **27**(12): 1141–1158.

Geffen, C. A., S. Rothenberg. 2000. Suppliers and environmental innovation: The automotive paint process. *Int. J. Oper. Prod. Manag.* **20**(2): 166–186.

Geradin, D., A. Layne-Farrar, A. J. Padilla. 2012. Elves or trolls? The role of nonpracticing patent owners in the innovation economy. *Ind. Corp. Change* **21**(1): 73–94.

Graham, S. J. H., D. C. Mowery. 2003. Intellectual property protection in the US software industry. W. M. Cohen, S. A. Merrill, eds. *Patents in the Knowledge-based Economy*. National Academies Press, Washington, DC, 219–258.

Graham, S. J. H., Sichelman T. 2008. Why do start-ups patent? *Berkeley Technol. Law J.* **23**: 1064–1070.

Gupta, S. 2008. Research note – Channel structure with knowledge spillovers. *Mark. Sci.* **27**(2): 247–261.

Gupta, S., R. Loulou. 1998. Process innovation, product differentiation, and channel structure: Strategic incentives in a duopoly. *Mark. Sci.* **17**(4): 301–316.

Hagiu, A., Yoffie, D. 2013. The new patent intermediaries: Platforms, defensive aggregators, and super-aggregators. *J. Econ. Perspect.* **27**(1) 45–66.

Hedlund, J. A. 2007. Patents pending: Patent reform for the innovation economy. Information Technology and Innovation Foundation Report.

Kabiraj, T. 2004. Patent licensing in a leadership structure. *Manchester School* **72**(2): 188–205.

Kamien, M. I., Tauman, Y. 1986. Fees versus royalties and the private value of a patent. *Q. J. Econ.* **101**(3): 471–491.

Kamien, M. I., Oren, S. S., Tauman, Y. 1992. Optimal licensing of cost-reducing innovation. *J. Math. Econ.* **21**(5): 483–508.

Katz, M. L., Shapiro, C. 1985. On the licensing of innovations. *RAND J. Econ.* **16**(4): 504–520.

Kim, B. 2000. Coordinating an innovation in supply chain management. *Eur. J. Oper. Res.* **123**(3): 568–584.

Kulatilaka, N., L. Lin. 2006. Impact of licensing on investment and financing of technology development. *Manage. Sci.* **52**(12): 1824–1837.

Kumar, P., S. M. Turnbull. 2008. Optimal patenting and licensing of financial innovations. *Manage. Sci.* **54**(12): 2012–2023.

Leffler, K. B., Rucker, R. R. 1991. Transaction costs and the efficient organization of production: A study of timber-harvesting contracts. *J. Polit. Econ.* **99**(5): 1060–1087.

Lemley, M. A., Shapiro, C. 2005. Probabilistic patents. *J. Econ. Perspect.* **19**(2): 75–98.

Lou, G. X. 2007. Cost-reducing innovation collaboration in supply chain management. *Wirel. Comm. Netw. Mobile Comput.* 4934–4937. DOI: 10.1109/WICOM.2007.1209.

Millien, R., Laurie, B. 2008. Meet the middlemen. *Intellectual Asset Management*, Jan–Feb, 53–58.

Monk, A. H. B. 2009. The emerging market for intellectual property: Drivers, restrainers and implications. *J. Econ. Geogr.* **9**: 469–471.

Mowery, D. C., B. N. Sampat, A. A. Ziedonis. 2002. Learning to patent: Institutional experience, learning, and the characteristics of US university patents after the Bayh-Dole Act, 1981–1992. *Manage. Sci.* **48**(1): 73–89.

Nell, P. S. V., U. Lichtenthaler. 2011. The role of innovation intermediaries in the markets for technology. *Int. J. Technol. Intell Plann.* **7**(2): 128–139.

Reitzig, M., J. Henkel, C. Heath. 2007. On sharks, trolls, and their patent prey-unrealistic damage awards and firms' strategies of "being infringed". *Res. Policy* **36**(1): 134–154.

Reitzig, M., J. Henkel, F. Schneider. 2010. Collateral damage for R&D manufacturers: How patent sharks operate in markets for technology. *Ind. Corp. Change* **19**(3): 947–967.

Rust, R. T., C. Moorman, P. R. Dickson. 2002. Getting returns on quality: Revenue expansion, cost reduction, or both? *J. Mark.* **66**(4): 7–24.

Savva, N., S. Scholtes. 2014. Opt-out options in new product co-development partnerships. *Prod. Oper. Manag.* **23**(8): 1370–1386.

Sen, D., Tauman, Y. 2007. General licensing schemes for a cost-reducing innovation. *Games Econ. Behav.* **59**(1): 163–186.

Sinclair, G., S. Klepper, W. Cohen. 2000. What's experience got to do with it? Sources of cost reduction in a large specialty chemicals producer. *Manage. Sci.* **46**(1): 28–45.

Sine, W. D., S. Shane, D. D. Gregorio. 2003. The halo effect and technology licensing: The influence of institutional prestige on the licensing of university inventions. *Manage. Sci.* **49**(4): 478–496.

Terwiesch, C., Y. Xu. 2008. Innovation contests, open innovation, and multiagent problem solving. *Manage. Sci.* **54**(9): 1529–1543.

Wang, X. H. 1998. Fee versus royalty licensing in a Cournot duopoly model. *Econ. Lett.* **60**(1): 55–62.

Wang, A. W. 2010. Rise of the patent intermediaries. *Berkeley Technol. Law J.* **25**: 159–200.

Xia, Y., S. M. Gilbert. 2007. Strategic interaction between channel structure and demand enhancing services. *Eur. J. Oper. Res.* **181**(1): 252–265.

Xiao, W., Y. Xu. 2012. The impact of royalty contract revision in a multistage strategic R&D alliance. *Manage. Sci.* **58**(12): 2251–2271.

Ziedonis, R. H. 2004. Don't fence me in: Fragmented markets for technology and the patent acquisition strategies of firms. *Manage. Sci.* **50**(6): 804–820.