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Abstract

Within the policy debate, there is a fear that large incumbent firms buy small firms' inventions to ensure that they are not used in the market. We show that such "acquisitions for sleep" can occur if and only if the quality of a process invention is small; otherwise, the entry profit will be higher than the entry-deterring value. We then show that the incentive for acquiring for the purpose of putting a patent to sleep decreases when the intellectual property law is stricter because the profit for the entrant then increases more than the entry-deterring value does.

JEL Classification: G24, L1, L2, M13, O3

Keywords: Acquisitions, Innovation, Sleeping patents, IP law, ownership

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Acquisition for Sleep*

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Within the policy debate, there is a fear that large incumbent firms buy small firms' inventions to ensure that they are not used in the market. We show that such "acquisitions for sleep" can occur if and only if the quality of a process invention is small; otherwise, the entry profit will be higher than the entry-deterring value. We then show that the incentive for acquiring for the purpose of putting a patent to sleep decreases when the intellectual property law is stricter because the profit for the entrant then increases more than the entry-deterring value does.

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1. Introduction

There is a concern in policy debate that incumbent firms in the market buy patents mainly to protect their market.[1] Incumbents may not even use the patents in their businesses — instead, they put the patents to sleep.[2] Torrisi et al. (2016) employ data from a large-scale survey (InnoS&T) of inventors in Europe, the USA, and Japan who were listed in patent applications filed at the European Patent Office (EPO) with priority years between 2003 and 2005. They find that a substantial share of patents are neither used internally nor used for market transactions, which confirms the importance of strategic patenting and inefficiency in the management of intellectual property. Cunningham et al. (2019) examine the acquisitions and detailed project-level development histories of more than 35,000 drug projects and find that approximately 6 % of all acquisitions in their sample are acquisitions for the purpose of closing down projects.

This raises the issue of when incumbents will acquire entrepreneurial firms to protect their markets and put the acquired patent to sleep. To this end, we construct a theoretical model with the following features. Initially, an entrepreneur could either enter a product market with a patented process invention or sell it to one of many incumbent firms that compete to acquire the invention. Then, if the acquirer wants to commercialize the invention, it faces a commercialization cost. Finally, firms compete in an oligopoly to generate profits.

We label an invention that reduces variable costs substantially as a high-quality invention, whereas an invention that only has a limited impact on variable costs is referred to as a low-quality invention.[3] We then show that *acquisition for sleep* takes place if and only if the quality of the invention is low. The value of using the invention for the market-entering entrepreneur is low when the quality is low. However, the value of entry deterrence is high for the incumbents, even though they will not commercialize the invention, because a rival is blocked from entering the market. When the quality of the invention increases, the entry-profit value will increase more than the entry-deterrence value and this will instead lead to entry. At even higher quality levels, the invention will be of direct use to the incumbent, and a sale will again but the patent will not be put to sleep.

Next, we investigate the effects of a stricter intellectual property (IP) law that aims to stimulate innovations by securing rents to the possessor of the innovation. We assume that the stricter the IP law is, the lower the cost reduction spillover to non-possessors is. We show that

[1] See, for instance, Boldrin and Levine (2013) and the references therein, Gotts and Sher (2012), and Hovenkamp and Hovenkamp (2017).

[2] Cunningham et al. (2019) describe a "killer acquisition" case, where the pharmaceutical firm Questcor, which employed adrenocorticotropic hormone (ACTH) drugs in its product Acthar, acquired the U.S. development rights for Synacthen, a potential rival drug in 2013 from a rival firm. Questcor did not develop Synacthen after the acquisition.

[3] Thus, our model is not a model of vertical quality differentiation.

the incentive for acquisition for sleeps decreases when the IP law becomes stricter because the profit for the entrant then exceeds the acquisition for sleep value. The key for this result is that the stricter IP law will not directly benefit the acquirer because the acquirer will not use the invention.

The existing literature on strategic patenting has shown that patents may remain unused for strategic reasons, such as to prevent the entry of new competitors or to prevent business stealing (Choi and Gerlach, 2017; Gilbert and Newbery, 1983; Morton and Shapiro, 2014; Ziedonis, 2004). In their seminal paper, Gilbert and Newbery (1983) showed that an incumbent firm may have an incentive to develop an entry-deterring non-used patent ("sleeping patents") to protect its market. Cunningham et al. (2019) show that acquired drug projects are less likely to be continued in the development process when the acquired project overlaps with the acquirer's development pipeline and when the acquirer has strong incentives to protect its market power. We add to this literature by showing that acquisition for sleep of process innovation patents can occur—but only when the quality of the patented invention is sufficiently low.

There is also a strand of literature studying how mergers affect innovation incentives. Gans, Hsu, and Stern (2002), Gans and Stern (2003), Norbäck and Persson (2012); and Norbäck, Persson and Svensson (2016) show that the incentive for entrepreneurial innovation increases when the entrepreneurial firm can be acquired by competing incumbents. A recent literature study post-merger innovation effects. Federico et al. (2017, 2018), Motta and Tarantino (2017), and Gilbert (2018) finds that merging parties may have diminished innovation incentives after the merger. Analogous to Cunningham et al. (2019), we examine how mergers affect the incentive to implement existing inventions, and we add to the literature by showing that merged firms have an incentive to implement process inventions unless the quality of the invention is low.

The existing literature has shown that IP law facilitates technology transfer between market firms for ideas and thereby increases the commercialization of entrepreneurial inventions (Arora, 1995; Arora et al., 2001; Gans et al., 2008). Gans and Persson (2013) show that stronger intellectual property protection and stricter competition policy can act as complements for stimulating entrepreneurial innovation. We add to the literature by showing that IP law can reduce the risk of killler acquisitions because a stricter IP law increases the entrant's commercial value of its patent more than it increases an incumbent's destructive value of the patent.

2. The model

Consider an entry-stable oligopoly industry served by $n \geq 2$ symmetric incumbent firms. Initially outside the market, there is is also an entrepreneur who recently made an invention and patented it. The entrepreneur contemplates selling the invention to one of the incumbents, or keeping the invention in order to enter into the market. The interaction is as follows.

Stage 1: In the first stage, the ultimate ownership of the invention is determined. The entrepreneur faces a choice between keeping the invention for herself and entering the market facing a fixed entry cost G, or selling the invention in an auction, where the n incumbents are the bidders.

Stage 2: In the second stage, if an incumbent is the possessor of the invention, she may decide to implement the invention in its own production technology. Since implementation comes with a fixed cost I, the incumbent may decide not to use the invention. We make the simplifying assumption that the entrepreneur does not face an implementation cost.

Stage 3: Finally, in the third stage, firms compete in an oligopoly.

It should be noted that the entrepreneur cannot first enter and then sell the invention. In this perfect information setting allowing for this option would not change the mechanisms in play. The reason is that there is no value for the entrepreneur to undertake such a strategy since she will then lose the amount G compared to selling directly. In an asymmetric information setting, this issue might, however, become more involved. We leave such an exercise to future research.

2.1. Stage 3: Product-market equilibrium

To encapsulate all of the different market structures that may arise in the product market interaction based on the previous interactions in Stage 1 and Stage 2, let the set of potential firms in the industry be $\mathcal{J} = e \cup \mathcal{I}$, where e is the entrepreneur and $\mathcal{I} = \{i_1, i_2 ... i_n\}$ is the set of incumbent firms. Denote the owner of the entrepreneur's invention, k, as $l \in \mathcal{J}$.

Symmetry of incumbents implies that we need only to keep track of three types of different ownership structures: the one where the *entrepreneur keeps the invention* ($l = e$), the one where an *incumbent acquires the invention and implements it* ($l = i$), and the one where an *incumbent acquires the invention but never implements it* ($l = 0$). Symmetry also implies that there are only three types of firms that can be active in the product market, denoted $h = \{E; A; N\}$: the *entrepreneurial firm* (E), an *acquiring incumbent* (A), and *non-acquiring incumbents* (N).

Firms sell a homogeneous good in the product market. The inverse aggregate demand is linear:

$$P(l) = a - Q(l), \tag{2.1}$$

where $P(l)$ is the product market price under ownership l, $a > 0$ is a demand parameter and $Q(l)$ is the aggregate output under ownership l.

Under incumbent ownership, $l = \{i, 0\}$, we have $Q(l) = q_A(l) + (n-1)q_N(l)$, where $q_A(l)$ is the output of the acquiring incumbent and $q_N(l)$ is the output of the $n-1$ non-acquiring incumbents. Under entry by the entrepreneur, $l = e$, we have $Q(e) = q_E(e) + nq_N(e)$, where $q_E(e)$ is the output of the entrepreneur and $q_N(e)$ is the output of the n non-acquiring incumbents.

Let $c_h(l)$ be the marginal cost of a firm of type h under ownership l. The direct profit is then

$$\pi_h(l) = [P(l) - c_h(l)]\, q_h, \tag{2.2}$$

The Cournot-Nash-output for a firm of type h under ownership l, $q_h^*(l)$, can be solved from the first-order conditions:

$$\frac{d\pi_h(l)}{dq_h} = P^*(l) - c_h(l) - q_h^*(l) = 0. \tag{2.3}$$

Using the direct profit in (2.2) and first-order conditions in (2.3), the reduced-form profit for a firm of type h under ownership l, is simply

$$\pi_h^*(l) = [q_h^*(l)]^2\,. \tag{2.4}$$

Let us now explore the reduced-form product market profits $\pi_h^*(l)$ in more detail.

2.1.1. Incumbent ownership

Suppose that an incumbent has acquired the invention in stage 1. Assume that the invention reduces the possessor's marginal cost. Let $c_A(l)$ be the acquiring incumbent's marginal cost, and let $c_N(l)$ be the marginal cost of a non-acquiring incumbent. Since the acquiring incumbent's marginal cost depends on whether it has invested in implementing the entrepreneur's invention with its technology in stage 2, we have

$$c_A(l) = \begin{cases} c_A(i) = c - k, \\ c_A(0) = c, \end{cases} \quad , \qquad c_N(l) = c, \tag{2.5}$$

where $c - k > 0$ will be assumed.

From (2.3)-(2.5), when the acquiring incumbent implements the invention ($l = i$), we obtain

$$\pi_A(i) = \left(\frac{\Lambda + nk}{n+1}\right)^2, \quad \pi_N(i) = \left(\frac{\Lambda - k}{n+1}\right)^2, \tag{2.6}$$

where $\Lambda = a - c$.

From (2.3)-(2.5), when the acquiring incumbent does not implement the invention ($l = 0$), we obtain

$$\pi_A(0) = \left(\frac{\Lambda}{n+1}\right)^2 = \pi_N(0). \tag{2.7}$$

2.1.2. Entry by entrepreneur

Suppose instead that the entrepreneur kept the invention in stage 1 and entered the product market. Let $c_E(e)$ be the entrant's marginal cost, and let $c_N(e)$ be the marginal cost of a non-acquiring incumbent. With the invention reducing marginal cost, we now have

$$c_E(e) = c - k, \qquad c_N(e) = c. \tag{2.8}$$

From (2.3)-(2.4) and (2.8), we obtain firms' reduced-form profits under entry by the entrepreneur

$$\pi_E(e) = \left(\frac{\Lambda + (n+1)\,k}{n+2}\right)^2, \ \pi_N(e) = \left(\frac{\Lambda - k}{n+2}\right)^2. \tag{2.9}$$

To proceed, we assume the following:

Assumption 1 *(i) The market is entry-stable:* $\pi_E(0) = \left(\frac{\Lambda}{n+2}\right)^2 \leq G$. *(ii) The market is exit-stable:* $k \in [0, \Lambda)$

Assumption 1(i) implies that the entrepreneur cannot enter the market without ownership of the innovation. Assumption 1(ii) implies that the quality of the innovation is sufficiently low, such that it does not cause the exit of incumbent firms (i.e., the innovation is not drastic). Thus, under entry, there are $n+1$ firms competing in the market, and under acquisition, there are n firms competing in the market.

In an online Appendix, we prove a number of results on how $\pi_h(l)$ is related to the quality of the invention:

Lemma 1. *Firms' reduced-form profits* $\pi_h(l)$ *are affected by the quality of the invention* k*:*
(i). $\frac{d\pi_A(i)}{dk} > 0$, $\frac{d\pi_E(e)}{dk} > 0$.
(ii). $\frac{d\pi_N(i)}{dk} < 0$, $\frac{d\pi_N(e)}{dk} < 0$.
(iii). $\frac{d\pi_h(0)}{dk} = 0$, *where* $h = A, E, N$.
(iv). $\frac{d\pi_A(i)}{dk} > \left|\frac{d\pi_N(l)}{dk}\right|$ *and* $\frac{d\pi_E(e)}{dk} > \left|\frac{d\pi_N(l)}{dk}\right|$, *where* $l = i, e$.

First, the profit of the possessor—the acquiring incumbent, or the entrepreneur—increases in invention quality, k. As is well known, the possessor's profit increases for two distinct reasons: There is a direct cost-saving effect from higher invention quality as the possessor obtains a lower marginal cost. However, the possessor also gains from a strategic effect—as the possessing firm obtains a lower marginal cost, it can also commit to producing a higher output. This induces its rivals to cut back on production to limit the reduction in output price.

Second, regardless of whether the entrepreneur or a rival incumbent has possession, a non-acquiring incumbent will see its profits decline upon facing a more efficient owner of the invention. Again, this occurs from the strategic effect where the lower marginal cost of the possessing firm enables it to commit to a higher output that induces non-acquiring incumbents to reduce their sales, leading to lower profits.

Third, we have the trivial property, wherein invention quality cannot affect reduced-form profits if the invention is not brought into the market. Thus, if the acquiring incumbent has not implemented the invention ($l = 0$), invention quality has no effect, and $\frac{d\pi_A(0)}{dk} = \frac{d\pi_N(0)}{dk} = 0$.

Finally, the "negative externality" on rivals' profits from an increase in invention quality is smaller than the increase in the profit of the possessor.

2.2. Stage 2: Implementation

If an incumbent has acquired the invention in stage 1, she can, in stage 2, implement the invention at a fixed cost I. From (2.5), it follows that implementation allows the incumbent to reduce her marginal cost from c to $c-k$. From (2.6) and (2.7), the acquirer's gain in profits from implementing the new technology, Δ_A, is

$$\Delta_A(k) = \pi_A\,(i) - \pi_A\,(0) > 0. \tag{2.10}$$

where we note that the acquisition price paid for the invention in Stage 1 is sunk in at this stage and thus does not affect the implementation decision.

To proceed, let $\Delta_A^{\max}$ be the maximum gain from implementation, i.e., let $\Delta_A^{\max} = \pi_A\,(i)|_{k=\Lambda} - \pi_A\,(0)$. The following result is then immediate:

Lemma 2. *Suppose that an incumbent acquires the invention in stage 1. Then, if the implementation cost is limited in size, $I \in (0, \Delta_A^{\max})$, there exists a unique invention quality, k^I, defined from $\Delta_A(k^I) = I$ such that for $k \in [0, k^I)$, the acquiring incumbent will not implement the invention, whereas for $k \in [k^I, \Lambda)$, the acquiring incumbent implements the invention.*

From Lemma 1 and (2.10), we have

$$\frac{d\Delta_A}{dk} = \underset{(>0)}{\frac{d\pi_A\,(i)}{dk}} - \underset{(=0)}{\frac{d\pi_A\,(0)}{dk}} > 0 \tag{2.11}$$

With the gain to implementation Δ_A strictly increasing in invention quality, there must exist a unique invention quality k^I at which the acquiring firm is indifferent between implementing the invention or not implementing it. Thus, if the invention quality is lower than k^I, it never uses post-acquisition — i.e., the invention is "put to sleep". However, an invention with a quality higher than k^I will be implemented in the acquirer's technology.

2.3. Stage 1: The acquisition-entry game

Having solved for the implementation choice under an incumbent acquisition, we now turn to solving for the equilibrium ownership of the invention. We model the acquisition-entry process as an auction, where each incumbent announces a bid, b_i, for the invention. $\mathbf{b} = (b_1, ..b_i.., b_I) \in R^I$ is the vector of these bids. Following the announcement of b, the invention may be sold to one of the incumbents at the bid price, or remain in the ownership of the entrepreneur e. The acquisition is solved for Nash equilibria in undominated pure strategies.

There are three different valuations that need to be considered:

First, v_e is the *entry value* for the entrepreneur of keeping an innovation with quality k and entering the market at the fixed cost G

$$v_e = \pi_E(e) - G. \tag{2.12}$$

Second, v_{ie} is an incumbent's *entry-deterring valuation.* It is the value for an incumbent of obtaining the innovation, when the entrepreneur would otherwise enter the market

$$v_{ie} = \begin{cases} \pi_A(0) - \pi_N(e) > 0, \ k \in [0, k^I), \\ \underbrace{[\pi_A(i) - I - \pi_A(0)]}_{=\Delta_A - I \geq 0} + \underbrace{[\pi_A(0) - \pi_N(e)]}_{(>0)} > 0, \ k \in [k^I, \Lambda) \end{cases} \tag{2.13}$$

The upper line in (2.13) represents the entry-deterring value if the invention has a quality below the threshold necessary for profitable implementation, $k < k^I$. The entry-deterring value is strictly positive even if the invention is not implemented. To see this, note that the first term is the profit when possessing the innovation, $\pi_A(0)$, while the second term is the profit when the entrepreneur enters the market the invention, $\pi_N(e)$. The latter profit must be smaller than the former, $\pi_A(0) > \pi_N(e)$, since not only does entry increase competition by increasing the number of firms present in the market, but through the possession of the invention k the entrepreneur is also a more efficient competitor.[4] The lower line in (2.13) shows the entry-deterring valuation when the invention quality is high enough for the acquiring incumbent to invest in implementation. From (2.7), we write the entry-deterring value as the sum of the gain the acquirer obtains from implementing the new technology (i.e., $\Delta_A - I \geq 0$) and the gain from preventing entry (i.e., $\pi_A(0) - \pi_N(e) > 0$).

Third, v_{ii} in (2.14) is an incumbent's *preemptive valuation.* It represents the value for an incumbent of obtaining an innovation when a rival incumbent would otherwise obtain it

$$v_{ii} = \begin{cases} \pi_A(0) - \pi_N(0) = 0, \ k \in [0, k^I), \\ \underbrace{[\pi_A(i) - I - \pi_A(0)]}_{=\Delta_A - I \geq 0} + \underbrace{[\pi_A(0) - \pi_N(i)]}_{(>0)} > 0, \ k \in [k^I, \Lambda). \end{cases} \tag{2.14}$$

The upper line in (2.14) shows the preemptive value when the invention has a quality below the threshold necessary for profitable implementation, $k < k^I$. The first term shows the profit when possessing the innovation, $\pi_A(0)$. The second term shows the profit if a rival incumbent obtains the innovation, $\pi_N(0)$. It then follows from (2.7) that the preemptive valuation must zero when the acquiring incumbent has no incentive to invest in implementation. The lower line in (2.14) shows the preemptive valuation when the invention quality is high enough for the acquiring incumbent to invest in implementation. Using (2.7), we can again write the preemptive value as the sum of two terms: the gain the acquirer obtains from implementing the new technology (i.e., $\Delta_A - I \geq 0$) and the gain in profit from preventing a rival incumbent acquiring and implementing the technology (i.e., $\pi_A(0) - \pi_N(i) > 0$).

Equations 2.6 and 2.9 reveal that the profit to the non-acquirer will be lower under entry than under a rival acquisition due to the stronger competition under entry, $\pi_N(e) < \pi_N(i)$. It

[4] See Equation 2.7 and Equation 2.9.

follows that the entry-deterring valuation will always exceed the preemptive valuation

$$v_{ie} > v_{ii}. \tag{2.15}$$

We can now proceed to solve for the Equilibrium Ownership Structure (EOS). From (2.15), the valuations v_{ii}, v_{ie} and v_e can be ordered in three different ways, as shown in Table 2.1. These inequalities are useful for solving the model and illustrating the results. The following lemma can be stated:

Lemma 3. *Equilibrium ownership l^*, acquisition price S^* and entrepreneurial reward R_E are described in table 2.1:*

Proof. See Norbäck and Persson (2012). ■

Table 2.1: The equilibrium ownership structure (EOS), the acquisition price and the reward to the entrepreneur.

Inequality:	Definition:	Ownership l^*:	Acquisition price, S^*:
$I1:$	$v_{ie} \geq v_{ii} > v_e$	i	v_{ii}
$I2:$	$v_{ie} > v_e \geq v_{ii}$	i	v_e
$I3:$	$v_e \geq v_{ie} > v_{ii}$	e	.

Lemma 3 shows that when one of the inequalities $I1$ or $I2$ holds, the invention k is obtained by one of the incumbents. Under $I1$, the acquiring incumbent pays the acquisition price $S = v_{ii}$, and she pays $S = v_e$ under $I2$. When I_3 holds, the entrepreneur retains the invention and enters the market.

2.3.1. Invention quality and acquisitions for sleep

How does invention quality impact the type of equilibrium owner, and when is the invention used in the market? To proceed, we use the following definitions:

Definition 1. *Let k_1^{ED} be defined from $v_{ie}|_{k<k^I} = v_e$, let k_2^{ED} be defined from $v_{ie}|_{k>k^I} = v_e$ and let k^{PE} be defined from $v_{ii}|_{k>k^I} = v_e$.*

For expositional reasons, we explore a benchmark case in which the entrepreneur's entry cost, consistent with entry-stability, exactly matches the implementation cost of the incumbents.

Assumption 2 $I = G = \pi_E(0)$.

We can then derive the following proposition with proofs given in an online Appendix:

Proposition 1. *Suppose that Assumptions 1 and 2 hold. Then:*

(i) *An incumbent acquisition without implementation, $k^* = 0$ ("acquisition for sleep"), takes place at sales price $S^* = v_e$ if the invention quality is sufficiently low, $k \in (0, k_1^{ED})$*, where $k_1^{ED} < k^I$.

(ii) *Entry with the invention, $k^* = k$, takes place if the invention quality is medium-low, $k \in [k_1^{ED}, k_2^{ED})$*, where $k_2^{ED} > k^I$.

(iii) *An acquisition with implementation, $k^* = k$, occurs at the sales price $S^* = v_e$ if the invention quality is medium-high, $k \in [k_2^{ED}, k^{PE})$.*

(iv) *An acquisition with implementation, $k^* = k$, occurs at sales price $S^* = v_{ii}$ if the invention quality is sufficiently high, $k \in [k^{PE}, \Lambda)$.*

Proposition 1 is illustrated in Figure 2.1. Panel (i) shows the acquiring incumbent's decision to implement the entrepreneur's technology. Panel (ii) illustrates the acquisition auction, while panel (iii) summarizes the outcome depicting the Equilibrium Ownership Structure (EOS).

Low invention quality and acquisitions for sleep From entry-stability (Assumption 1), the entry value is zero when the invention lacks quality, i.e., $v_e = 0$ for $k = 0$. In the region with low invention quality, $k \in [0, k^I)$, incumbents never implement the invention, as shown in panel (i) of Figure 2.1. Hence, the preemptive valuation is zero, $v_{ii} = 0$, as shown in (2.14). From (2.12) and Lemma 1, the reservation price of the entrepreneur, v_e is an increasing function of invention quality k.

$$\frac{dv_e}{dk} = \frac{d\pi_E(e)}{dk} > 0. \tag{2.16}$$

From (2.13), however, incumbents always value an acquisition that deters entry, $v_{ie} > 0$. As shown in panel (ii), we then have $v_{ie} > v_e > v_{ii} = 0$ at $k = \varepsilon$, where $\varepsilon > 0$ is small. An incumbent will now bid the reservation price v_e, a bid that will be accepted by the entrepreneur. Since the invention is not implemented, $k^* = 0$, it will not be worthwhile for rival incumbents to challenge or preempt the acquisition.

What happens when invention quality increases? From (2.13) and Lemma 1, the entry-deterring valuation v_{ie} also increases in invention quality

$$\frac{dv_{ie}}{dk} = -\underset{(<0)}{\frac{d\pi_N(e)}{dk}} > 0, \quad \text{for } k \in [0, k^I). \tag{2.17}$$

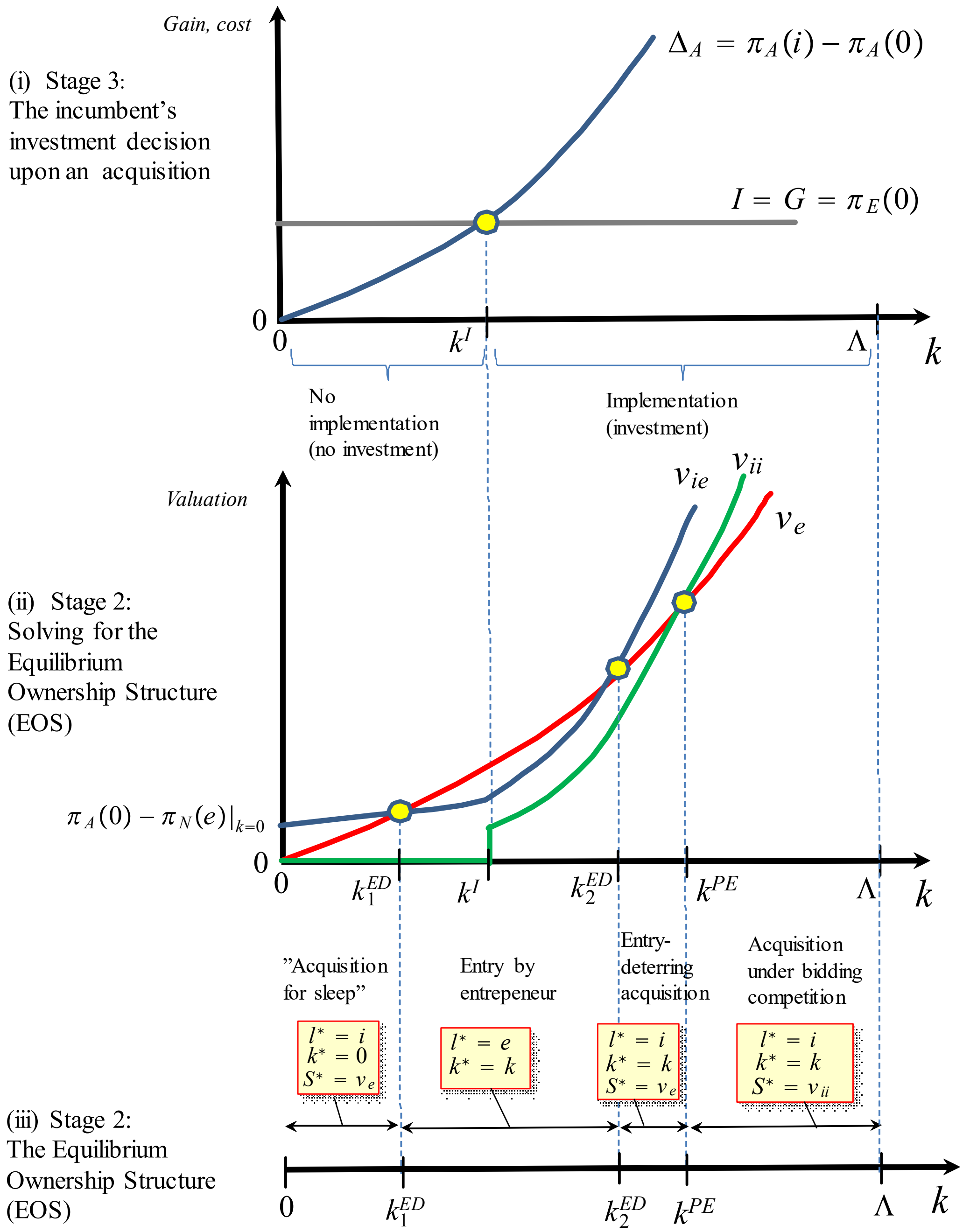

Figure 2.1: Solving the model. Panel (i) solves the implementation decision of an acquiring incumbent, Panel (ii) solves for the Equilibrium Ownership Structure (EOS) of the entrepreneur's invention, while Panel (iii) summarizes the Equilibrium Ownership Structure.

The entry-deterring valuation, v_{ie}, increases in quality—even if the invention is not implemented in the acquirer's technology. The reason is that when not acquiring the invention, the entrepreneur enters the market, worsening the incumbent's competitive position ($\frac{d\pi_N(e)}{dk} < 0$), which gives rise to the increase in the valuation.

However, Lemma 1 (iv) tells us that the reservation price will increase faster than the entry-deterring valuation in invention quality when incumbents do not find implementation worthwhile

$$\frac{d\left(v_e - v_{ie}\right)}{dk} = \underset{(>0)}{\frac{d\pi_E(e)}{dk}} + \underset{(<0)}{\frac{d\pi_N(e)}{dk}} > 0 \text{ for } k \in [0, k^I). \tag{2.18}$$

The intuition in (2.18) stems from the fact that the entrepreneur—as possessor of the invention—perceives an increased value at higher quality from a strategic effect and a direct cost-saving effect (as summarized by the term $\frac{d\pi_E(e)}{dk} > 0$). An incumbent, again, does not implement the invention: she only perceives a higher willingness to pay for the invention through the strategic effect when not in possession (as summarized by the term $\frac{d\pi_N(e)}{dk} < 0$). As shown in panel (ii) of Figure 2.1, since the reservation price increases swifter than the entry-deterring value, there exists a cut-off $k_1^{ED} > 0$ at which $v_e = v_{ie} > v_{ii} = 0$. Hence, if the invention quality is in the region $k \in [k_1^{ED}, k^I)$, $v_e > v_{ie}$ holds, and the entrepreneur will enter the market and use the invention, $k^* = k$. However, if invention quality is in the region $k \in (0, k_1^{ED})$, $v_{ie} \geq v_e$ holds, and one of the incumbents will buy the invention at the reservation price $S^* = v_e$. Following the acquisition, the invention is never implemented — it is "put to sleep", $k^* = 0$. These events are summarized in panel (iii) of Figure 2.1.

High invention quality and bidding competition As shown in panel (i), when the invention quality reaches the cut-off k^I, implementation becomes profitable for an acquiring incumbent. The entry-deterring valuation v_{ie} is increasing in invention quality with a kink at the threshold k^I, as shown in panel (ii).[5] From (2.13) and Lemma 1, we then have

$$\frac{dv_{ie}}{dk} = \underset{(>0)}{\frac{d\pi_A(e)}{dk}} - \underset{(<0)}{\frac{d\pi_N(e)}{dk}} > 0, \; k \in [k^I, \Lambda). \tag{2.19}$$

When the invention quality exceeds the threshold k^I, the willingness to pay to deter entry increases both from the combined effect of a higher profit as acquirer ($\frac{d\pi_A(e)}{dk} > 0$) and from avoiding a lower profits as non-acquirer ($\frac{d\pi_N(e)}{dk} < 0$).

Indeed, the fact that the acquiring incumbent will implement the technology also changes the preemptive valuation, v_{ii}. From (2.14), the preemptive valuation jumps from $v_{ii} = 0$ to $v_{ii} > 0$

[5] v_{ie} is continuous at $k = k^I$. This follows since by definition $\Delta_A - I = 0$, at $k = k^I$. Hence, the upper line and the lower line in (2.13) are equal at $k = k^I$.

at $k = k^I$. From Lemma 1, the preemptive valuation is now also strictly increasing

$$\frac{dv_{ii}}{dk} = \underset{(>0)}{\frac{d\pi_A(e)}{dk}} - \underset{(<0)}{\frac{d\pi_N(i)}{dk}} > 0, \ k \in [k^I, \Lambda). \tag{2.20}$$

Which type of valuation then—the entrepreneurs' reservation price, v_e, or the incumbents' valuations, v_{il}—increases the most when incumbents implement the invention?

Using (2.16) and (2.19), we first have

$$\frac{d(v_{ie} - v_e)}{dk} = \begin{cases} \underset{(>0)}{\frac{d\pi_A(e)}{dk}} - \underset{(<0)}{\frac{d\pi_N(e)}{dk}} - \underset{(>0)}{\frac{d\pi_E(e)}{dk}} > 0, \ \text{for } k \in [k^I, \tilde{k}), \\ \underset{(>0)}{\frac{d\pi_A(e)}{dk}} - \underset{(<0)}{\frac{d\pi_N(e)}{dk}} - \underset{(>0)}{\frac{d\pi_E(e)}{dk}} < 0, \ \text{for } k \in [\tilde{k}, \Lambda). \end{cases} \tag{2.21}$$

An incumbent's entry-deterring value v_{ie} is again driven by the increase in profit as possessor (a "carrot", $\frac{d\pi_A(e)}{dk} > 0$) — as well as by the reduction in profit as non-possessor (a "whip", $\frac{d\pi_N(e)}{dk} < 0$). In contrast, the entry value is only driven up by the increase in profit as possessor (a "carrot", $\frac{d\pi_E(l)}{dk} < 0$). When the invention is of medium, or high quality, $k \in [k^I, \tilde{k})$, this will make v_{ie} more responsive to increasing invention quality than the reservation price, v_e. As shown in panel (ii) in Figure 2.1, the entry-deterring valuation reaches the reservation price, $v_{ie} = v_e$, at the invention quality $k = k_2^{ED}$. A further increase in quality then implies the inequality $v_{ie} > v_e > v_{ii}$. As shown in panel (iii), an entry-deterring acquisition yet again arises where one incumbent pays the reservation price $S^* = v_e$ without being challenged by its rivals. However, the invention is not "put to sleep" this time—it is implemented in the acquirer's technology and used in the product market, $k^* = k$.

What if invention quality is driven up even further? Using (2.16) and (2.20), we also have

$$\frac{d(v_{ii} - v_e)}{dk} = \begin{cases} \underset{(>0)}{\frac{d\pi_A(e)}{dk}} - \underset{(<0)}{\frac{d\pi_N(i)}{dk}} - \underset{(>0)}{\frac{d\pi_E(e)}{dk}} > 0, \ \text{for } k \in [k^{PE}, \hat{k}) \text{ and } \hat{k} > \tilde{k}, \\ \underset{(>0)}{\frac{d\pi_A(e)}{dk}} - \underset{(<0)}{\frac{d\pi_N(i)}{dk}} - \underset{(>0)}{\frac{d\pi_E(e)}{dk}} < 0, \ \text{for } \ k \in [\hat{k}, \Lambda). \end{cases} \tag{2.22}$$

The preemptive valuation is also driven by the combination of two forces: the increase in profit as possessor (the "carrot", $\frac{d\pi_A(i)}{dk} > 0$) and the reduction in profit when a rival incumbent stands as acquirer (the "whip", $\frac{d\pi_N(i)}{dk} < 0$). Since the entry value is only driven up by the increase in profit as possessor ($\frac{d\pi_E(i)}{dk} < 0$), the preemptive valuation at first becomes more responsive in quality. As shown in panel (ii) of Figure 2.1, the preemptive valuation v_{ii} reaches the entry deterring valuation v_e at $k = k^{PE} > k^{ED}$. A further increase in invention quality then implies that the inequality $v_{ie} > v_{ii} > v_e$ holds. Since the preemptive valuation exceeds the reservation price, a bidding war among incumbents is initiated and the acquisition price is driven up to $S^* = v_{ii} > v_e$.

Preemptive acquisitions at $S^* = v_{ii}$ with implementation $k^* = k$ thus prevail in the region where invention quality is high, $k \in [k^{PE}, \Lambda)$. This is despite the fact that for very high invention quality, the reservation price v_e is the most responsive valuation to increasing invention quality, k, to very high levels, as evident from the lower lines in (2.21) and (2.22). The stronger response of the reservation price occurs since at very high invention quality, the negative impact on a non-acquiring incumbent ($\frac{d\pi_N(l)}{dk} < 0$) declines as the possessor of the invention—the entrant or an incumbent—approach monopoly. However, there is no reversal of ownership. To see this, let $\pi^m(i) = \pi^m(e)$ be the monopoly profit at $k^{\max} = \Lambda$, where $\pi_N(l) = 0$. From Assumption 2 and (2.12), (2.13) and (2.14), we have $v_{ie} = v_{ii} = \pi^m(i) - I = v_e = \pi^m(e) - G$.

2.3.2. Acquisition for sleep: Arrow, Gilbert and Newbery meets Salant

Let us set the outcome of a acquisition for sleep in a more general context. For acquisition for sleep to occur in equilibrium, two conditions must be fulfilled.

First, the acquiring incumbent should not have an incentive to implement the invention

$$\underbrace{\pi_A(i) - \pi_A(0)}_{\Delta_A(k)} < I. \tag{2.23}$$

From Lemma 2, we know that for (2.23) to be fulfilled, the quality of the invention k needs to be low. In the region $k \in (0, k^I)$, the so-called "Arrow replacement effect" (Arrow (1962) is sufficiently strong to kill the acquisition in equilibrium: at low quality, the profit from implementing the invention $\pi_A(i)$ gives limited additional profits compared to the "old" profit $\pi_A(0)$, which makes implementation unprofitable.

Second, it must be profitable for the acquiring incumbent to buy the invention—without implementing it, i.e.,

$$\underbrace{\pi_A(0) - \pi_N(e)}_{v_{ie}} > \underbrace{[\pi_E(e) - G]}_{v_e}. \tag{2.24}$$

This condition is reminiscent of Gilbert and Newbery (1983), who pointed out that a firm with market power has an incentive to patent new technologies before potential competitors, and how this can lead to patents that are neither used nor licensed (i.e., "sleeping patents"). To see how their mechanism is in play in our setting, first note that the gain for the entrant of entering with the invention is limited at low quality k. When invention quality is close to zero, entry stability (Assumption 1) implies a profit close to zero, $\pi_E(e) - G \approx 0$. The gain for the incumbent, $\pi_A(0) - \pi_N(e) > 0$, is higher since—as noted by Gilbert and Newbery—the incumbent internalizes the business stealing effect if the entrepreneur enters the market.

Condition (2.24) can also be rewritten into a condition known as the Salant et al. (1983) merger condition

$$\pi_A(0) > \pi_N(e) + [\pi_E(e) - G]. \tag{2.25}$$

Rewritten in this way, (2.25) states that an acquisition will only take place if the combined entity makes a higher profit than the two firms standing alone. Salant et al. (1983) showed that this condition is only fulfilled for a merger to monopoly in a symmetric Cournot model with homogeneous goods and with no cost savings. In our setting, although we have the same oligopoly model, acquisitions arise without the post-acquisition market structure being a monopoly. Why? As noted above, the entry cost G significantly reduces the entrant's standalone profit, $\pi_E(e) - G$. At low invention quality, the entry-deterring incentive of an incumbent, $\pi_A(0) - \pi_N(e) > 0$, then dominates.

Thus, a acquisition for sleep can occur in equilibrium if and only if the Arrow condition (2.23) and the Salant condition (2.25) are both fulfilled. Additionally, these conditions are only fulfilled when the quality of the invention k is low. However, what happens if the quality of the invention increases? First, from Lemma 1, we know that the reservation price will increase faster in invention quality than the entry-deterring valuation when incumbents do not find implementation worthwhile. This implies that the Salant condition (2.25) is no longer fulfilled. Thus, for higher but still low levels of quality of the invention, we will have entry. Nevertheless, from (2.11), we know that when the quality of the invention becomes sufficiently high, $k > k^I$, the Arrow condition in (2.23) is reversed

$$\underbrace{\pi_A(i) - \pi_A(0)}_{\Delta_A(k)} > I. \tag{2.26}$$

Thus, for a sufficiently high level of quality of the invention, the incumbent will no longer put the patent to sleep. The Salant condition (2.25) then becomes

$$\pi_A(i) - I > \pi_N(e) + \pi_E(e) - G \tag{2.27}$$

As noted by Tirole (1992), the "efficiency" effect implies that the acquiring incumbent will make a higher profit with the invention than the entrant, $\pi_A(i) > \pi_E(e)$. In addition, with increasing quality of the invention, the entry-deterring motive (identified by Gilbert and Newbery) becomes stronger, as the profit under entry, $\pi_N(e)$, falls. In summary, acquisition for sleep occurs when invention quality is low. Acquisitions may also occur when invention quality is high—but not as acquisitions for sleep.

Let us end this section by discussing the generality of these results. It is outside the scope of this paper to address this issue fully and a more elaborated analysis is left to future research. However, note that to have acquisition for sleep in equilibrium, (i) implementation should not be profitable for the acquirer incumbent, while (ii) this firm should nevertheless find it profitable to pay the entrepreneur's reservation price. These prerequisites are the—by now— familiar Arrow condition (2.23) and Salant condition (2.27). These conditions should be fulfilled in many oligopoly models with cost-reducing inventions, when the invention quality k is low, and when the implementation cost I and the entry cost G are not too small.[6] Moreover, under the mild

[6] For instance, it can be shown that acquisition for sleep occurs for low invention quality also if we change

assumption that the profit for the acquirer is increasing in invention quality, we should expect a reversal of the Arrow condition (2.23) at higher invention quality, removing acquisition for sleep as an equilibrium outcome at higher invention quality.

2.3.3. A note on welfare

We have shown that acquisition for sleep occurs when invention quality is low. This suggests that blocking acquisition for sleep may not be worthwhile from a welfare point of view. Indeed, Mankiw and Whinston (1986) show that if an entrant enters a market with the same technology as incumbents in a free entry setting (conforming to Assumption 1), the business-stealing effect implies that entry is more desirable to the entrant than it is for society. Thus, if acquisition for sleeps are associated with low-quality inventions, this seems to be less of a problem from a welfare perspective. There are, however, several caveats to such a proposition.

First, if one adopts a strict consumer-welfare perspective (and ignores the business-stealing effect on incumbents from entry), acquisition for sleeps will make consumers worse off due to higher concentration and less efficient production.

Second, the Mankiw and Whinston (1986) result on excessive entry holds for homogeneous product Cournot competition (which is our setting). However, they also show that if products are (sufficiently) differentiated, entry will be welfare enhancing. Hence, acquisition for sleep can reduce welfare compared to entry if goods are sufficiently differentiated. Cunningham et al. (2019) use a model with differentiated products with product innovations (but absent process innovations) and show that so-called "killer acquisitions", i.e., acquisition for sleep, indeed reduce welfare.

Third, we have assumed that the entrepreneur faces no implementation cost, I. It is tedious but straightforward to show that if the entrepreneur—in addition to the entry cost G—also incurs the implementation cost I, entry becomes less frequent. In such a setting, the entrepreneur also faces the Arrow condition of profitable implementation. It can then be shown that—while it is still true that acquisition for sleeps occur for a lower invention quality than do acquisitions for implementation—introducing the implementation cost for the entrepreneur can also lead to acquisition for sleep for patents at significant invention quality. An acquisition for sleep may then reduce welfare since entry by a more efficient entrant is blocked.

the present setting of homogenous Cournot competition in quantities to Bertrand competition in prices with differentiated goods. In the latter setting, the acquiring incumbent holds two varieties and can now choose to implement the cost-reducing technology in both varieties at the fixed implementation cost.

3. Intellectual Property Protection

Let us now turn to how the pattern of acquisition without implementation depends on the strength of intellectual property (IP) protection. To this end, we can think of the government choosing a patent protection policy in a stage 0. The existing literature mostly takes its starting point in that increased IP protection reduces the expropriation problems associated with assets sales. We instead focus on the post-transfer effect of strengthened IP protection.

To this end, we define increased patent protection as follows:

Definition 2. *Increased patent protection λ, where $\lambda \in [0,1]$, implies that the spillover to non-possessors decreases and, thus, that there is an increase in non-possessors' variable costs,* $c_N = c - (1-\lambda)k$.

Similar to Lemma 1 on how changes in variable cost affect profits, we then derive the following lemma:

Lemma 4. *Under Assumptions 1, when patent protection λ increases, the product market profit of the rival firms decreases, i.e.,* $\frac{d\pi_N(l)}{d\lambda} < 0$, $l = \{i,e\}$ *, and the possessor's profit increases, i.e.,* $\frac{d\pi_A(i)}{d\lambda} > 0$ *and* $\frac{d\pi_E(e)}{d\lambda} > 0$. *In case of entry, stronger patent protection has a larger impact on the entrant's profit than on the profit of rival firms such that* $\frac{d\pi_E(e)}{d\lambda} > \left|\frac{d\pi_N(e)}{d\lambda}\right|$.

Proof. See appendix ■

We then show in the online Appendix that increased patent protection makes acquisition for sleep less likely in equilibrium:

Proposition 2. *Under Assumptions 1* $\frac{dk_1^{ED}}{d\lambda} < 0$, *acquisitions for sleep thus become less likely.*

This intuition follows from the point that stricter patent protection increases the entry value, v_e, more than the entry-deterring value, v_{ie}. To see why, first note that $\frac{dv_e}{d\lambda} = \frac{d\pi_E(e)}{d\lambda}$ and $\frac{dv_{ie}|_{k<kI}}{d\lambda} = \frac{d\pi_A(0)}{d\lambda} - \frac{d\pi_N(e)}{d\lambda}$. Then, note that the stricter patent law will not directly benefit the acquirer because the acquirer will not use the invention, i.e., $\frac{d\pi_A(0)}{d\lambda} = 0$. Moreover, the reduction in profits for non-acquiring firms$\frac{d\pi_N(e)}{d\lambda} < 0$ is limited since all non-acquiring firms will face a higher variable cost when patent protection becomes stricter. This implies that the reservation price becomes more responsive in patent protection, i.e., $\frac{dv_e}{d\lambda} > \frac{dv_{ie}|_{k<kI}}{d\lambda}$. An interesting implication from Proposition 2 is that acquisition for sleeps will be more likely to occur in countries with weak patent laws.

In the above analysis, we have assumed that there is no direct spillover of knowledge when the patent is granted or applied for; instead, spillovers require the patent owner to spend implementation costs and start to use the patented technology. An alternative assumption is that the act of patenting per se discloses information that makes imitation easier. At first sight, one might then believe that a acquisition for sleep will not be present in such a setting. However, it can be shown that a acquisition for sleep is still an equilibrium under such early disclosure effects—and that a acquisition for sleep becomes less likely to emerge when patent protection increases.[7] Under early disclosure, all incumbents' variable costs decrease when the patent is granted. This will depreciate the "commercial quality of the implemented invention"—i.e., reduce the advantage of being in possession of the invention. Early disclosure of the technology in the patent will also reduce the incentive for an incumbent acquirer to make the costly implementation. Thus, acquisition for sleeps can occur also under early disclosure effects. A stricter patent protection will make a acquisition for sleep harder as long as early disclosure effects are not too strong. Again, this occurs as the reservation price increases more in patent protection than the value for an incumbent to deter entry without implementing the invention. A more detailed study of this is left for future research.

4. Concluding remarks

Will incumbents acquire small entrepreneurial firms to block the commercialization of new process inventions in the market? Yes, but this will occur only if the quality of the invention is low. Otherwise, the incumbent will commercialize the invention herself because it is too costly *not* to do so. We also show that the incentive for acquisition for sleeps decreases when IP law becomes stricter because the profit for the entrant increases more than the entry-deterring value from a stricter IP law.

The paper also has important implications for entrepreneurs as well as incumbents. First, with strong patent protection, entrepreneurs have an incentive to develop high-quality inventions rather than inventions that will be put to sleep by the acquirer. The reason is that high-quality inventions create a bidding competition over the invention and the entrepreneur then captures most of the surplus associated with the selling of the patent. Incumbents, in contrast, have an incentive to avoid such bidding competitions. Thus, incumbents have an incentive to find strategies to preempt the entrepreneur from innovating.

From a policy perspective, our results suggest that a combination of a strict patent law and

[7] Without disclosure effects, the marginal cost for a non-acquiring incumbent is $c_N = c-(1-\lambda)k$ (see, Definition 2). To introduce disclosure effects, let the marginal cost for a non-acquiring incumbent instead be $c_N(l) = c-\theta k-(1-\lambda)(1-\theta)k$. The share $\theta \in [0,1]$ then represents the early disclosure effect, i.e., the spillover that occurs immediately when the patent of quality k is granted or applied, while $\lambda \in [0,1]$ is the level of patent protection. Moreover, let $c_0(0) = c-\theta k$ be the marginal cost for the acquiring incumbent when the patent is not implemented. If the patent is implemented, $c_A(i) = c_E = c-k$. It is tedious to show that acquisition for sleep can occur in this framework, given that the early disclosure effect is not too strong. It can also be shown that stronger patent protection leads to fewer acquisitions for sleep.

a strict competition law may be associated with the highest welfare levels. A strict patent law allows the buyer of the patent to exploit the market value of the patent. At the same time, a strict competition law guarantees bidding competition over the patent, implying that the entrepreneur gains a sufficient share of the surplus created. The strict competition law will also make sure that the product market does not become too concentrated, guaranteeing a sufficiently high consumer surplus.

In the analysis, we have assumed that the seller of the innovation uses a first-price sealed bid auction. We believe that this auction set-up captures essential features of the bidding competition over a scarce asset in situations where acquisitions are used to gain access to innovations. Sealed bid first-price auctions are indeed also frequently used in practice. Nevertheless, this implies that some possibilities for creating additional rents are potentially neglected. More generally, Jehiel, Moldovanu and Stacchettis (1999) show that sophisticated mechanisms are needed to maximize revenues in auctions with externalities. For instance, it might be the case that all firms in the market need to provide transfers to the seller. However, as pointed out by Jehiel and Moldovanu (2000), a problem with these mechanisms is that the seller needs unrealistically strong commitment power and thus, these mechanisms are often not feasible. Nevertheless, if more sophisticated selling mechanisms were available, they would allocate a larger share of the surplus to the entrepreneur.

What would happen if we allowed for sequential investment, i.e., new innovations emerging that build on existing innovations? We could then extend our game with several repeated sequences of our three-period game, to study the long-run development of the industry. We would expect that our identified mechanism would still be in play. However, this analysis is a very complicated exercise and left for future research.

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Part I

Web Appendix for "Acquisition for sleep"

A. Proof of Lemma 1

A.1. Part (i): $\frac{d\pi_A(i)}{dk} > 0$, $\frac{d\pi_E(e)}{dk} > 0$

The profit function for the possessor of the invention is $\pi_A(i) = \left(\frac{\Lambda+nk}{n+1}\right)^2$ in case of acquisition by an incumbent, and $\pi_E(e) = \left(\frac{\Lambda+(n+1)k}{n+2}\right)^2$ in case of entry. Taking the derivatives with respect to invention quality k generates the following expressions:

$$\frac{d\pi_A(i)}{dk} = \frac{d\left(\left(\frac{\Lambda+nk}{n+1}\right)^2\right)}{dk} = 2n\frac{\Lambda+kn}{(n+1)^2} > 0$$

$$\frac{d\pi_E(e)}{dk} = \frac{d\left(\left(\frac{\Lambda+(n+1)k}{n+2}\right)^2\right)}{dk} = 2\frac{n+1}{(n+2)^2}(k+\Lambda+kn) > 0$$

A.2. Part (ii): $\frac{d\pi_N(i)}{dk} < 0$, $\frac{d\pi_N(e)}{dk} < 0$

The profit function for the incumbent rivals is $\pi_N(i) = \left(\frac{\Lambda-k}{n+1}\right)^2$ in case of acquisition and implementation by an incumbent, and $\pi_N(e) = \left(\frac{\Lambda-k}{n+2}\right)^2$ in case of entry. Taking the derivatives with respect to invention quality generates the following expressions:

$$\frac{d\pi_N(i)}{dk} = \frac{d\left(\left(\frac{\Lambda-k}{n+1}\right)^2\right)}{dk} = -\frac{2\Lambda-2k}{(n+1)^2} < 0$$

$$\frac{d\pi_N(e)}{dk} = \frac{d\left(\left(\frac{\Lambda-k}{n+2}\right)^2\right)}{dk} = -\frac{2\Lambda-2k}{(n+2)^2} < 0$$

A.3. Part (iii): $\frac{d\pi_h(0)}{dk} = 0$, where $h = A, N$.

The profit function for both the possessor and its rivals is $\pi_A(0) = \pi_N(0) = \left(\frac{\Lambda}{n+1}\right)^2$ in case the invention is not implemented. The profits are thus not affected by invention quality since

$$\frac{d\pi_A(0)}{dk} = \frac{d\pi_N(0)}{dk} = \frac{d\left(\left(\frac{\Lambda}{n+1}\right)^2\right)}{dk} = 0$$

A.4. Part (iv): $\frac{d\pi_A(i)}{dk} > \left|\frac{d\pi_N(l)}{dk}\right|$ and $\frac{d\pi_E(e)}{dk} > \left|\frac{d\pi_N(l)}{dk}\right|$, where $l = i, e$.

Invention quality has a larger impact on the acquiring incumbent's profits than on the non-acquiring incumbents'profits, i.e.

$$\frac{d\pi_A(i)}{dk} > \left|\frac{d\pi_N(i)}{dk}\right| \Leftrightarrow 2n\frac{\Lambda+kn}{(n+1)^2} > \left|-\frac{2\Lambda-2k}{(n+1)^2}\right|,$$

$$\frac{d\pi_A(i)}{dk} > \left|\frac{d\pi_N(e)}{dk}\right| \Leftrightarrow 2n\frac{\Lambda + kn}{(n+1)^2} > \left|-\frac{2\Lambda - 2k}{(n+2)^2}\right|.$$

Invention quality also has a larger impact on the entrant's profits than on the incumbents' profits, i.e.

$$\frac{d\pi_E(e)}{dk} > \left|\frac{d\pi_N(i)}{dk}\right| \Leftrightarrow 2\frac{n+1}{(n+2)^2}(k + \Lambda + kn) > \left|-\frac{2\Lambda - 2k}{(n+1)^2}\right|,$$

$$\frac{d\pi_E(e)}{dk} > \left|\frac{d\pi_N(e)}{dk}\right| \Leftrightarrow 2\frac{n+1}{(n+2)^2}(k + \Lambda + kn) > \left|-\frac{2\Lambda - 2k}{(n+2)^2}\right|,$$

which, in turn, can be rewritten such that both expressions hold if:

$$\underbrace{\frac{(n+1)^3}{(n+2)^2}}_{>1 \text{ when } n>1}(\Lambda + k + kn) > \Lambda - k.$$

B. Proof of Lemma 2

An acquiring incumbent will only implement the innovation if the gain is larger than the cost:

$$\Delta_A(k) = \pi_A(i) - \pi_A(0) = \left(\frac{\Lambda + nk}{n+1}\right)^2 - \left(\frac{\Lambda}{n+1}\right)^2 > I$$

If the implementation cost is limited in size, $I \in (0, \Delta_A^{\max})$, where $\Delta_A^{\max} = \pi_A(i)|_{k=\Lambda} - \pi_A(0)$, then the unique invention quality at which the acquiring firm is indifferent between implementing or letting the invention sleep, k^I, defined from $\Delta_A(k^I) = I$, is:

$$k^I = \frac{\sqrt{I + 2nI + \Lambda^2 + n^2 I} - \Lambda}{n}.$$

For $k \in [0, k^I)$, the acquiring incumbent will not implement the invention, while for $k \in [k^I, \Lambda)$, the acquiring incumbent implements the invention. Also note that this threshold shifts upwards when the implementation cost increases:

$$\frac{dk^I}{dI} = \frac{(n+1)^2}{2n\sqrt{In^2 + 2In + \Lambda^2 + I}} > 0.$$

C. Proof of Proposition 1

We start by evaluating values for k where incumbents will not implement, that is for $k \in \left(0, k^I\right)$. The valuations are as follows:

$$v_e = \pi_E(e) - G > 0 \tag{C.1}$$

$$v_{ie}|_{k<k^I} = \pi_A(0) - \pi_N(e) > 0 \tag{C.2}$$

$$v_{ii}|_{k<k^I} = \pi_A(0) - \pi_N(0) = 0 \tag{C.3}$$

Acquisition for sleep will occur where $v_{ie}|_{k<k^I} > v_e$ and entry will occur when $v_e > v_{ie}|_{k<k^I}$, such that the shift in ownership occurs at $v_{ie}|_{k<k^I} - v_e = 0$. Using (C.1) and (C.2):

$$\begin{aligned} v_{ie}|_{k<k^I} - v_e &= \pi_A(0) - \pi_N(e) - (\pi_E(e) - G), \\ &= \left(\frac{\Lambda}{n+1}\right)^2 - \left(\frac{\Lambda - k}{n+2}\right)^2 - \left(\frac{\Lambda + (n+1)k}{n+2}\right)^2 + \underbrace{\left(\frac{\Lambda}{n+2}\right)^2}_{G}. \end{aligned}$$

If $k = 0$, then $v_{ie}|_{k<k^I} - v_e > 0$ since:

$$v_{ie}|_{k=0} - v_e|_{k=0} = \left(\frac{\Lambda}{n+1}\right)^2 - \left(\frac{\Lambda}{n+2}\right)^2 > 0. \tag{C.4}$$

Further, note that the slope is negative:

$$\begin{aligned} \frac{d\left(v_{ie}|_{k<k^I} - v_e\right)}{dk} &= \frac{d}{dk}\left(\left(\frac{\Lambda}{n+1}\right)^2 - \left(\frac{\Lambda - k}{n+2}\right)^2 - \left(\frac{\Lambda + (n+1)k}{n+2}\right)^2 + \left(\frac{\Lambda}{n+2}\right)^2\right), \\ &= -2\frac{2k + n\Lambda + kn^2 + 2kn}{(n+2)^2} < 0. \end{aligned} \tag{C.5}$$

Now find k_1^{ED} by setting $v_{ie}|_{k<k^I} - v_e = 0$ and solve for k:

$$\begin{aligned} v_{ie}|_{k<k^I} - v_e &= 0, \\ \left(\frac{\Lambda}{n+1}\right)^2 - \left(\frac{\Lambda - k}{n+2}\right)^2 - \left(\frac{\Lambda + (n+1)k}{n+2}\right)^2 + \left(\frac{\Lambda}{n+2}\right)^2 &= 0. \end{aligned} \tag{C.6}$$

Equation (C.6) can be rewritten as:

$$k^2 + \frac{2n}{n^2 + 2n + 2}\Lambda k - \frac{2n+3}{(n+1)^2(n^2 + 2n + 2)}\Lambda^2 = 0. \tag{C.7}$$

Further rewrite (C.7) to get:

$$k^2 + \alpha k - \beta = 0, \tag{C.8}$$

where

$$\alpha = \frac{2n}{n^2 + 2n + 2}\Lambda > 0, \tag{C.9}$$

and

$$\beta = \frac{2n+3}{(n+1)^2(n^2 + 2n + 2)}\Lambda^2 > 0. \tag{C.10}$$

Solving (C.8) for k results in:

$$k_1 = \frac{1}{2}\sqrt{\alpha^2 + 4\beta} - \frac{1}{2}\alpha > 0, \tag{C.11}$$

and

$$k_2 = -\frac{1}{2}\alpha - \frac{1}{2}\sqrt{\alpha^2 + 4\beta} < 0. \tag{C.12}$$

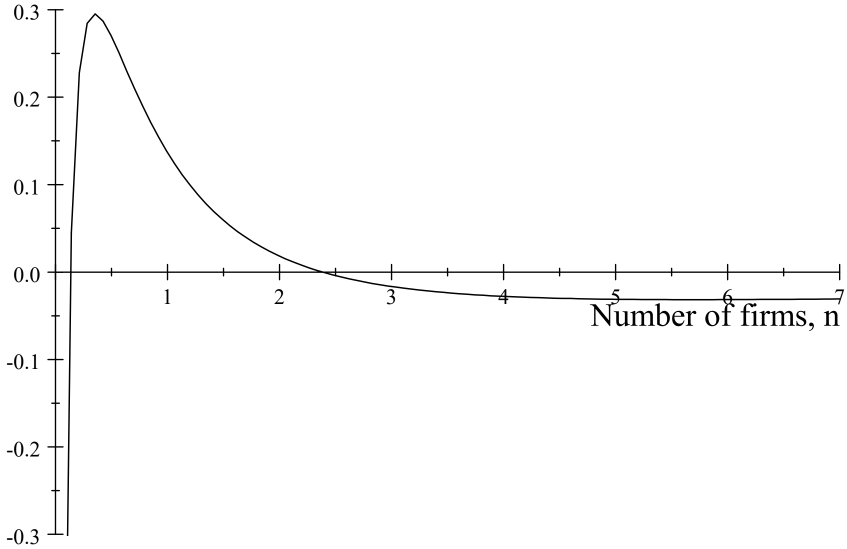

Figure C.1: Plotting $\frac{k_1^{ED}-k^I}{\Lambda}$ (vertical axis) against the number of incumbents n.

Substitute (C.9) and (C.10) into (C.11) to get unique solution:

$$\begin{aligned} k_1^{ED} &= \frac{1}{2}\sqrt{\alpha^2+4\beta}-\frac{1}{2}\alpha, \\ &= \frac{1}{2}\sqrt{\left(\frac{2n}{n^2+2n+2}\Lambda\right)^2+4\left(\frac{2n+3}{(n+1)^2(n^2+2n+2)}\Lambda^2\right)}-\frac{1}{2}\left(\frac{2n}{n^2+2n+2}\Lambda\right), \\ &= \Lambda\left(\sqrt{\left(\frac{n}{n^2+2n+2}\right)^2+\frac{2n+3}{(n+1)^2(n^2+2n+2)}}-\frac{n}{n^2+2n+2}\right) > 0. \end{aligned} \tag{C.13}$$

Is k_1^{ED} smaller than k^I?

$$\begin{aligned} \frac{k_1^{ED}-k^I}{\Lambda} &= \left(\sqrt{\left(\frac{n}{n^2+2n+2}\right)^2+\frac{2n+3}{(n+1)^2(n^2+2n+2)}}-\frac{n}{n^2+2n+2}\right) \\ &\quad -\frac{\left(\sqrt{\left(\frac{1}{n+2}\right)^2+2n\left(\frac{1}{n+2}\right)^2+1+n^2\left(\frac{1}{n+2}\right)^2}-1\right)}{n}. \end{aligned}$$

The graph in Figure C.1 plots $\frac{k_1^{ED}-k^I}{\Lambda}$, showing that k_1^{ED} is smaller than k^I as long as $n > 2$.

Hence:

$$v_{ie}|_{k<k_I}-v_e \begin{cases} > 0 \text{ if } k \in (0, k_1^{ED}) \\ = 0 \text{ if } k = k_1^{ED} \\ < 0 \text{ if } k \in (k_1^{ED}, k^I) \end{cases} \tag{C.14}$$

so that acquisition for sleep occurs when $k \in (0, k_1^{ED})$, and the entreprenur enters herself when $k \in [k_1^{ED}, k^I)$.

Next, we examine values for k where the acquiring incumbent will implement, that is, $k \in (k^I, \Lambda]$. The valuations are as now follows:

$$v_e = \pi_E(e) - G > 0, \tag{C.15}$$
$$v_{ie}|_{k>k^I} = \pi_A(i) - \pi_N(e) - I > 0, \tag{C.16}$$
$$v_{ii}|_{k>k^I} = \pi_A(i) - \pi_N(i) - I > 0. \tag{C.17}$$

Note first that $v_{ie}|_{k>k^I}$ is always larger than $v_{ii}|_{k>k^I}$ due to increased competition in case the entrepreneur enters, i.e since $\pi_N(e) < \pi_N(i)$. Now use (C.15) and (C.16) and find k_2^{ED} by setting $v_{ie}|_{k>k^I} - v_e = 0$:

$$\begin{aligned} v_{ie}|_{k>k^I} - v_e &= 0, \\ \pi_A(i) - \pi_N(e) - I - (\pi_E(e) - G) &= 0, \\ \left(\frac{\Lambda + nk}{n+1}\right)^2 - \left(\frac{\Lambda - k}{n+2}\right)^2 - \left(\frac{\Lambda + (n+1)k}{n+2}\right)^2 + G - I &= 0. \end{aligned} \tag{C.18}$$

Equation (C.18) can be rewritten as:

$$k^2 - 2n\Lambda\frac{2n+3}{3n^2+6n+2}k + \Lambda^2\frac{n^2-2}{3n^2+6n+2} - \frac{\left(n^2+3n+2\right)^2}{3n^2+6n+2}(G-I) = 0. \tag{C.19}$$

Further rewrite (C.19) to get:

$$k^2 - \gamma k + \mu = 0, \tag{C.20}$$

where

$$\gamma = 2n\Lambda\frac{2n+3}{3n^2+6n+2} > 0, \tag{C.21}$$

and

$$\mu = \Lambda^2\frac{n^2-2}{3n^2+6n+2} - \frac{\left(n^2+3n+2\right)^2}{3n^2+6n+2}(G-I). \tag{C.22}$$

Solving (C.20) for k results in:

$$k_1|_{entryd} = \frac{1}{2}\gamma + \frac{1}{2}\sqrt{\gamma^2 - 4\mu}, \tag{C.23}$$

and

$$k_2|_{entryd.} = \frac{1}{2}\gamma - \frac{1}{2}\sqrt{\gamma^2 - 4\mu}. \tag{C.24}$$

First, check $k_1|_{entryd.}$ by substituting (C.21) and (C.22) into (C.23):

$$\begin{aligned} k_1|_{entryd.} &= \frac{1}{2}\gamma + \frac{1}{2}\sqrt{\gamma^2 - 4\mu}, \\ &= \Lambda\left(\frac{2n^2+3n}{3n^2+6n+2} + \sqrt{\left(\frac{n^2+3n+2}{3n^2+6n+2}\right)^2 + \frac{(n^2+3n+2)^2}{\Lambda^2(3n^2+6n+2)}(G-I)}\right) \end{aligned} \tag{C.25}$$

Equation (C.25) shows that $k_1|_{entryd.}$ will be as follows:

$$k_1|_{entryd.} \begin{cases} > \Lambda \text{ if } G > I \\ = \Lambda \text{ if } G = I \\ < \Lambda \text{ if } G < I \end{cases}. \tag{C.26}$$

Now, check $k_2|_{entryd.}$ by substituting (C.21) and (C.22) into (C.24):

$$\begin{aligned} k_2|_{entryd.} &= \frac{1}{2}\gamma - \frac{1}{2}\sqrt{\gamma^2 - 4\mu}, \\ &= \Lambda\left(\frac{2n^2+3n}{3n^2+6n+2} - \sqrt{\left(\frac{n^2+3n+2}{3n^2+6n+2}\right)^2 + \frac{\left(n^2+3n+2\right)^2}{\Lambda^2\left(3n^2+6n+2\right)}\left(G-I\right)}\right) \end{aligned} \tag{C.27}$$

Equation (C.27) shows that $k_2|_{entryd.}$ will be as follows:

$$k_2|_{entryd.} \begin{cases} < \frac{n^2-2}{3n^2+6n+2}\Lambda \text{ if } G > I \\ = \frac{n^2-2}{3n^2+6n+2}\Lambda \text{ if } G = I \\ > \frac{n^2-2}{3n^2+6n+2}\Lambda \text{ if } G < I \end{cases}. \tag{C.28}$$

Since twe focus on the case where $G = I$, the solution is $k = \frac{n^2-2}{3n^2+6n+2}\Lambda < k^{\max}$ and $k = \Lambda = k^{\max}$, sot the unique value of k where a change in ownership will occur is:

$$k_2^{ED} = \frac{n^2-2}{3n^2+6n+2}\Lambda. \tag{C.29}$$

Is k_2^{ED} larger than k^I?

$$\frac{k_2^{ED} - k^I}{\Lambda} = \frac{n^2-2}{3n^2+6n+2} - \frac{\left(\sqrt{\left(\frac{1}{n+2}\right)^2 + 2n\left(\frac{1}{n+2}\right)^2 + 1 + n^2\left(\frac{1}{n+2}\right)^2} - 1\right)}{n}.$$

Figure C.2 plots $\frac{k_2^{ED}-k^I}{\Lambda}$, showing that k_2^{ED} is larger than k^I as long as $n > 2$.

Now, use (C.15) and (C.17) to find k^{PE} by setting $v_{ii}|_{k>k^I} - v_e = 0$:

$$\begin{aligned} v_{ii}|_{k>k^I} - v_e &= 0, \\ \pi_A(i) - \pi_N(i) - I - (\pi_E(e) - G) &= 0, \\ \left(\frac{\Lambda+nk}{n+1}\right)^2 - \left(\frac{\Lambda-k}{n+1}\right)^2 - \left(\frac{\Lambda+(n+1)k}{n+2}\right)^2 + G - I &= 0. \end{aligned} \tag{C.30}$$

Equation C.30 can be rewritten to:

$$k^2 - 2\Lambda\frac{2n+3}{3n+5}k + \frac{\Lambda^2(n+1)}{3n+5} - \frac{(n+1)(n+2)^2}{3n+5}(G-I) = 0. \tag{C.31}$$

Further rewrite (C.31) to get:

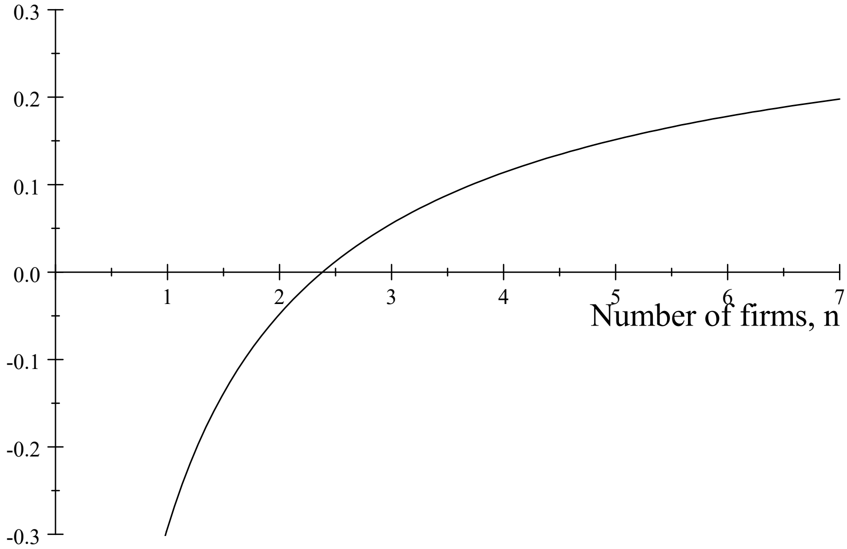

Figure C.2: Plotting $\frac{k_2^{ED}-k^I}{\Lambda}$ against the number of incumbents, n.

$$k^2 - \theta k + \eta = 0, \tag{C.32}$$

where

$$\theta = 2\Lambda \frac{2n+3}{3n+5} > 0, \tag{C.33}$$

and

$$\eta = \frac{\Lambda^2 (n+1)}{3n+5} - \frac{(n+1)(n+2)^2}{3n+5}(G-I). \tag{C.34}$$

Solving (C.32) for k results in:

$$k_1|_{preemp} = \frac{1}{2}\theta + \frac{1}{2}\sqrt{\theta^2 - 4\eta}, \tag{C.35}$$

and

$$k_2|_{preemp} = \frac{1}{2}\theta - \frac{1}{2}\sqrt{\theta^2 - 4\eta}. \tag{C.36}$$

First check $k_1|_{preemp}$ by substituting (C.33) and (C.34) into (C.35):

$$\begin{aligned} k_1|_{preemp} &= \frac{1}{2}\theta + \frac{1}{2}\sqrt{\theta^2 - 4\eta}, \\ &= \Lambda\left(\frac{2n+3}{3n+5} + \sqrt{\left(\frac{2n+3}{3n+5}\right)^2 - \frac{(n+1)}{3n+5} + \frac{(n+1)(n+2)^2}{\Lambda^2(3n+5)}(G-I)}\right). \end{aligned} \tag{C.37}$$

Equation C.37 shows that $k_1|_{preemp}$ will be as follows:

$$k_1|_{preemp}\begin{cases} >\Lambda \text{ if } G>I \\ =\Lambda \text{ if } G=I \\ <\Lambda \text{ if } G<I \end{cases}. \tag{C.38}$$

Now check $k_2|_{preemp}$ by substituting (C.33) and (C.34) into (C.36):

$$\begin{aligned} k_2|_{preemp} &= \frac{1}{2}\theta-\frac{1}{2}\sqrt{\theta^2-4\eta}, \\ &= \Lambda\left(\frac{2n+3}{3n+5}-\sqrt{\left(\frac{2n+3}{3n+5}\right)^2-\frac{(n+1)}{3n+5}+\frac{(n+1)(n+2)^2}{\Lambda^2(3n+5)}(G-I)}\right). \end{aligned} \tag{C.39}$$

Equation C.39 shows that $k_2|_{preemp}$ will be as follows:

$$k_2|_{preemp}\begin{cases} <\frac{n+1}{3n+5}\Lambda \text{ if } G>I \\ =\frac{n+1}{3n+5}\Lambda \text{ if } G=I \\ >\frac{n+1}{3n+5}\Lambda \text{ if } G<I \end{cases}. \tag{C.40}$$

Since we focus on the case where $G=I$, the solution is $k=\frac{n+1}{3n+5}\Lambda<k^{\max}$ and $k=\Lambda=k^{\max}$, so the unique value of k where a change in ownership will occur is:

$$k^{PE}=\frac{n+1}{3n+5}\Lambda>k_2^{ED}. \tag{C.41}$$

We therefore know that:

$$k^I<k_2^{ED}<k^{PE}<\Lambda. \tag{C.42}$$

Now, let us investigate how invention quality impacts the type of equilibrium owner. First check the shape of $v_{ie}|_{k>k^I}-v_e$:

$$\begin{aligned} \frac{d\left(v_{ie}|_{k>k^I}-v_e\right)}{dk} &= 0, \\ &\Rightarrow \widetilde{k}=\frac{3n+2n^2}{6n+3n^2+2}\Lambda, \\ \frac{d^2\left(v_{ie}|_{k>k^I}-v_e\right)}{dk^2} &= -2\frac{3n^2+6n+2}{(n^2+3n+2)^2}<0. \end{aligned}$$

Hence, $v_{ie}|_{k>k^I}-v_e$ is strictly concave in k.

Then, check $v_{ii}|_{k>k^I}-v_e$:

$$\begin{aligned} \frac{d\left(v_{ii}|_{k>k^I}-v_e\right)}{dk} &= 0, \\ &\Rightarrow \widehat{k}=\frac{3+2n}{3n+5}\Lambda, \\ \frac{d^2\left(v_{ii}|_{k>k^I}-v_e\right)}{dk^2} &= -\frac{6n+10}{(n+1)(n+2)^2}<0. \end{aligned}$$

which shows that also $v_{ii}|_{k>k^I} - v_e$ is strictly concave in k.

We therefore have that:

$$v_{ie}|_{k>k^I} - v_e \begin{cases} < 0 \text{ if } k \in (k^I, k_2^{ED}) \\ = 0 \text{ if } k = k_2^{ED} \\ > 0 \text{ if } k \in (k_2^{ED}, \Lambda) \end{cases}, \tag{C.43}$$

and

$$v_{ii}|_{k>k^I} - v_e \begin{cases} < 0 \text{ if } k \in (k^I, k^{PE}) \\ = 0 \text{ if } k = k^{PE} \\ > 0 \text{ if } k \in (k^{PE}, \Lambda) \end{cases}. \tag{C.44}$$

Hence, entry occurs when $k \in (k^I, k_2^{ED})$, entry-deterring acquisiton takes place when $k \in [k_2^{ED}, k^{PE})$, whereas when $k \in [k^{PE}, \Lambda)$, there will be acquisition under bidding competition.

D. Proof of Lemma 4

Assume that Assumption 1 holds.

- Product market profits of the possessor will increase when patent protection is increased:

$$\frac{d\pi_A(i)}{d\lambda} > 0, \frac{d\pi_E(e)}{d\lambda} > 0,$$

since

$$\frac{d\pi_A(i)}{d\lambda} = \frac{d\left(\left(\frac{\Lambda+(n\lambda-\lambda+1)k}{n+1}\right)^2\right)}{d\lambda} = 2k\frac{(n-1)(k+\Lambda-k\lambda+kn\lambda)}{(n+1)^2} > 0,$$

and

$$\frac{d\pi_E(e)}{d\lambda} = \frac{d\left(\left(\frac{\Lambda+(n\lambda+1)k}{n+2}\right)^2\right)}{d\lambda} = 2kn\frac{k+\Lambda+kn\lambda}{(n+2)^2} > 0.$$

- Profits of the rival firms will be reduced when patent protection increases:

$$\frac{d\pi_N(i)}{d\lambda} < 0, \frac{d\pi_N(e)}{d\lambda} < 0,$$

since

$$\frac{d\pi_N(i)}{d\lambda} = \frac{d\left(\left(\frac{\Lambda+(1-2\lambda)k}{n+1}\right)^2\right)}{d\lambda} = -4k\frac{k+\Lambda-2k\lambda}{(n+1)^2} < 0,$$

and

$$\frac{d\pi_N(e)}{d\lambda} = \frac{d\left(\left(\frac{\Lambda+(1-2\lambda)k}{n+2}\right)^2\right)}{d\lambda} = -4k\frac{k+\Lambda-2k\lambda}{(n+2)^2} < 0.$$

- Changes in patent protection has a larger impact on entrant's profits than on non-acquiring incuments profits in case of entry:

$$\frac{d\pi_E(e)}{d\lambda} > \left|\frac{d\pi_N(e)}{d\lambda}\right| \Leftrightarrow 2kn\frac{k+\Lambda+kn\lambda}{(n+2)^2} > \left|-4k\frac{k+\Lambda-2k\lambda}{(n+2)^2}\right|,$$

which can be rewritten such that the expression holds if:

$$\underbrace{\frac{n}{2}}_{\geq 1}\underbrace{\frac{k+\Lambda+kn\lambda}{k+\Lambda-2k\lambda}}_{>1} > 1.$$

E. Proof of Proposition 2

In the acquisition-entry game, and under Assumption 1, $v_{ie}|_{k<k^I} - v_e$ will now be as follows:

$$\begin{aligned} v_{ie}|_{k<k^I} - v_e &= \pi_A(0) - \pi_N(e) - (\pi_E(e) - G), \\ &= \left(\frac{\Lambda}{n+1}\right)^2 - \left(\frac{\Lambda + (1-2\lambda)k}{n+2}\right)^2 - \left(\frac{\Lambda + (n\lambda+1)k}{n+2}\right)^2 + G. \end{aligned}$$

Then, how is the entry condition, k_1^{ED}, affected by changes in patent protection λ? To see this, first differentiate $v_{ie}|_{k=k_1^{ED}} = v_e|_{k=k_1^{ED}}$ in both k_1^{ED} and λ to get:

$$\frac{dk_1^{ED}}{d\lambda} = -\frac{v'_{ie,\lambda} - v'_{e,\lambda}}{v'_{ie,k} - v'_{e,k}}.$$

We then have:

$$\begin{aligned} \frac{d\left(v_{ie}|_{k<k^I} - v_e\right)}{d\lambda} &= \frac{d\left(\left(\frac{\Lambda}{n+1}\right)^2 - \left(\frac{\Lambda+(1-2\lambda)k}{n+2}\right)^2 - \left(\frac{\Lambda+(n\lambda+1)k}{n+2}\right)^2 + \left(\frac{\Lambda}{n+2}\right)^2\right)}{d\lambda}, \\ &= -2\frac{k\left(4k\lambda - 2\Lambda - 2k + n\Lambda + kn + kn^2\lambda\right)}{(n+2)^2} < 0, \end{aligned}$$

and

$$\begin{aligned} \frac{d\left(v_{ie}|_{k<k^I} - v_e\right)}{dk} &= \frac{d\left(\left(\frac{\Lambda}{n+1}\right)^2 - \left(\frac{\Lambda+(1-2\lambda)k}{n+2}\right)^2 - \left(\frac{\Lambda+(n\lambda+1)k}{n+2}\right)^2 + \left(\frac{\Lambda}{n+2}\right)^2\right)}{dk}, \\ &= -\frac{2\left(2k + 2\Lambda - 4k\lambda - 2\Lambda\lambda + 4k\lambda^2 + kn^2\lambda^2 + 2kn\lambda + n\Lambda\lambda\right)}{(n+2)^2} < 0. \end{aligned}$$

Since both $v'_{ie,\lambda} - v'_{e,\lambda}$ and $v'_{ie,k} - v'_{e,k}$ are negative, we can conclude that

$$\frac{dk_1^{ED}}{d\lambda} < 0$$

Thus, acquisition for sleep becomes less likely when patent protection increases.