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Creative Destruction and Productive Preemption

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Abstract

We develop a theory of commercialization mode (entry or sale) of entrepreneurial inventions into oligopoly, and show that an invention of higher quality is more likely to be sold (or licensed) to an incumbent due to strategic product market effects on the sales price. Moreover, preemptive acquisitions by incumbents are shown to stimulate the process of creative destruction by increasing the entrepreneurial effort allocated to high-quality invention projects. Using detailed data on patents granted to small firms and individuals, we find evidence that high-quality inventions are often sold, and that they are sold under bidding competition.

Keywords: Acquisitions, Entrepreneurship, Innovation, Start-ups, Patent, Ownership, Quality
JEL classification: G24, L1, L2, M13, O3

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1. Introduction

Schumpeter (1942) argued that the ongoing process where new inventions create "monopoly rents" for entrepreneurs while reducing rents for incumbent firms is central for sustained growth in a market economy. This process of "creative destruction" and its welfare implications has been studied in formal theory in the case where an entrepreneur commercializes the invention by entering the product market.[1] However, if incumbent profits are hurt by entrepreneurial entry, incumbents should have an incentive to block entry by acquiring these entrepreneurial firms (or their inventions). Indeed, entrepreneurial inventions are often sold or licensed to incumbent firms.[2] Figure 1.1 shows the importance of commercialization by sale in the last decade by depicting the exit value through M&As (proxying for commercialization by sale to incumbents) and IPOs (proxying for commercialization by entry), respectively, in the US venture capital market.

The purpose of this paper is to study how the innovation process is affected by the fact that entrepreneurial entry might be blocked by preemptive acquisitions by incumbents. To this end, we construct a theoretical model with the following ingredients: Initially, an entrepreneur decides how much to invest in research to discover an invention. Then, if successful, the entrepreneur could either enter the product market with the invention or sell it to one of many incumbent firms competing to acquire the invention. Finally, firms compete in oligopoly fashion, thereby generating profits.

We first show that the incentive for commercialization by sale relative to commercialization by entry increases with a higher quality of the invention. This occurs because higher invention quality increases entrants' and acquirers' profits in a similar fashion, but also reduces the profit when not acquiring the invention. This implies that the incumbent's willingness to pay for the invention increases more than the entrant's profit in quality and thereby the entrepreneur benefits from selling the invention instead of entering the market.

We then turn to how the quality of an invention affects the research incentives. When the entrepreneur commercializes by entry, she will set the effort level such that the marginal cost of research equals the marginal change in product market profit as an entrant. When commercializing by sale, the marginal cost will be the same but the marginal revenue will be higher at a high level of quality. Once again, increased quality of the invention does not only increase the profit of an acquirer of the invention but will also decrease the profit of a

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[1] In the endogenous growth literature see, for instance, Aghion and Howitt (1992), Grossman and Helpman (1991), Segerstrom, Anant, and Dinopoulos (1990), and Howitt (2008) for an overview, and in the Industrial Organization literature see, for instance, Arrow (1962), Gilbert and Newberry (1982) and Gilbert (2006) for an overview.

[2] Granstrand and Sjölander (1990) present evidence from Sweden, and Hall (1990) presents evidence from the US that firms acquire innovative targets to gain access to their technologies. Bloningen and Taylor (2000) find evidence from US high-tech industries of firms making a strategic choice between the acquisition of outside innovators and in-house R&D. In the biotech industry, Lerner and Merges (1998) note that acquisitions are important for know-how transfers. Baumol (2004) stresses the importance of the different roles played by small entrepreneurial firms and large established firms in the innovation process in the USA, where small entrepreneurial firms create a large share of breakthrough innovations and large established firms provide more routinized R&D.

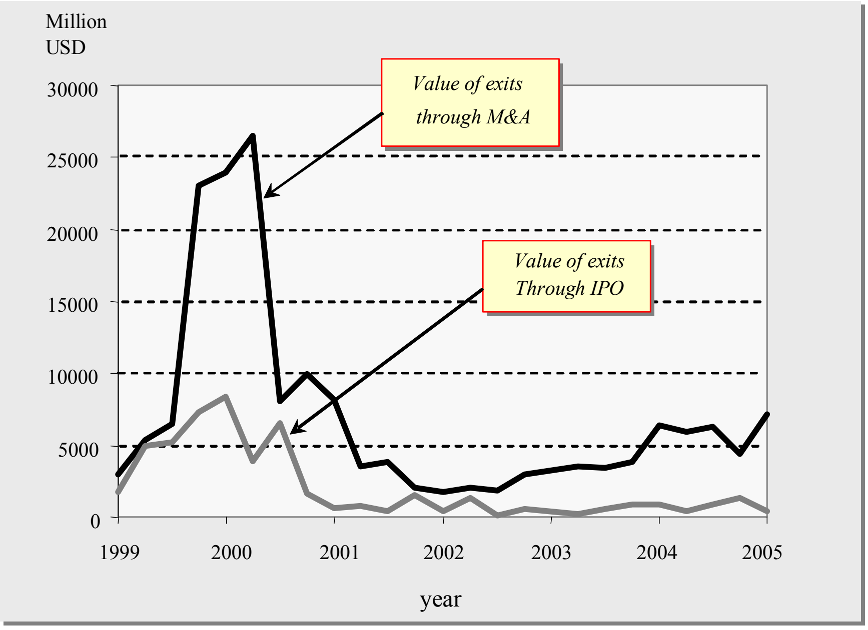

Figure 1.1: The value of exits through M&A and IPO in the US. Source: Thomson Venture Economics/National Venture Capital Association.

non-acquirer. Both these effects will increase incumbents' willingness to pay, thus driving the sales price above the entrepreneur's profit as an entrant. Entrepreneurs who commercialize by sale therefore have a stronger incentive to develop high-quality inventions than entrepreneurs who commercialize by entry. Since preemptive incumbent acquisitions give entrepreneurs the incentive to increase their efforts in high-quality research projects, expected consumer welfare can be higher under commercialization by sale despite the risk of increased market power.

Next, we derive an estimation equation from the entrepreneur's decision of commercialization (sale or entry), and test it on a detailed dataset on patents granted to Swedish small firms and individual inventors. We use forward patent citations as a proxy for the quality of the invention. Consistent with theory, we find that higher patent quality is conducive to commercialization by sale. The estimates show that if a patent receives one more forward citation in a five-year period, the probability of sale increases by about five percentage points. Additional predictions of the model such as higher entry costs being conducive to sale are also supported by data. Importantly, our estimates identify preemptive bidding competition between incumbent firms.

We undertake a number of extensions of the empirical analyses. These include estimating a multinomial logit model, a probit model with selection and a duration model to control for the fact the data include patents that are not commercialized. These extensions yield no qualitative changes in results and, in particular, forward citations remain conducive to commercialization by sale.

This paper relates to the literature studying which type of products will be sold on the market. In his seminal paper, Akerlof (1970) showed that informational asymmetries can give rise to adverse selection on markets, resulting in that only low-quality products will be sold.[3] In

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[3] The existing empirical literature on the "lemons" effect gives mixed evidence. For instance, Bond (1982) found no evidence, Genesove (1993) weak evidence, and Gilligan (2004) strong evidence of adverse

contrast, we show theoretically that when inventions are sold into oligopolistic markets, absent the information problem, product market externalities imply that only high-quality products will be sold on the market. We also find empirical evidence that only high-quality inventions are sold on the market, using patent data. However, these data also show that commercialization by sale takes longer than commercialization by entry; thus, the asymmetric information problem could materialize in the cost of sale preparation.

This paper also contributes to the literature on commercialization mode, which has shown how different types of transaction costs and entry costs affect the commercialization mode (see, for instance, Anton and Yao (1994), Gans and Stern (2000) and Gans et al. (2002)). We add to this literature by theoretically and empirically showing that when the invention will be commercialized under bidding competition in an oligopolistic market, the invention is more likely to be commercialized through a sale to an incumbent, the higher is its quality.

This paper also relates to the literature on auctions with externalities (see, for instance, Jehiel, Moldovanu and Stacchetti (1996, 1999)). We add to this literature by endogenizing the choice of whether to sell the asset or use it to compete with the potential bidders. Moreover, to our knowledge, we are the first to provide evidence of preemptive bidding competition.

Finally, this paper contributes to the literature on entrepreneurship (for overviews, see Audreatch and Achs (2005) and Bianchi and Henrekson (2005)), by constructing an oligopoly model where the equilibrium commercialization mode pattern, the acquisition price and the entrepreneur's investments are endogenously determined.[4]

2. The theoretical model.

The interaction is illustrated in Figure 2.1. Consider a market served by n symmetric incumbent firms. There is also an entrepreneur, denoted e. In stage 1, the entrepreneur decides how much to invest in research, thereby affecting the probability of discovering an invention with a fixed quality k.[5] In stage 2, if successful, the entrepreneur commercializes the invention into an innovation. She either sells the invention at a first-price perfect information auction, where the n incumbent firms are the potential buyers, or enters the product market. There may then be exits of incumbent firms. Finally, in stage 3, the active firms in the product market compete in oligopoly interaction, setting an action x_i. Following the literature, we will try use the term "invention" as long as k has not reached the market, while using the term "innovation" when k is used in the product market.

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selection.

[4] This paper is also related to the literature on patent licensing (for an overview, see Kamien (1992), and to the literature on the persistence of monopoly (see, for instance, Chen (2000) and Gilbert and Newbery (1982). However, to our knowledge, these literatures do not study how the trade-off between entry and sales (licence) for the potential entrant depends on the quality of the invention, which is the focus of our analysis.

[5] The quality of an invention k is for many types of inventions fixed, such as for vaccines, or solutions to specific technical problems. However, for other inventions the quality of an invention can be affected, such as the capacity of a micro processor. We discuss the case where the entrepreneur chooses the quality in Section 5.1.

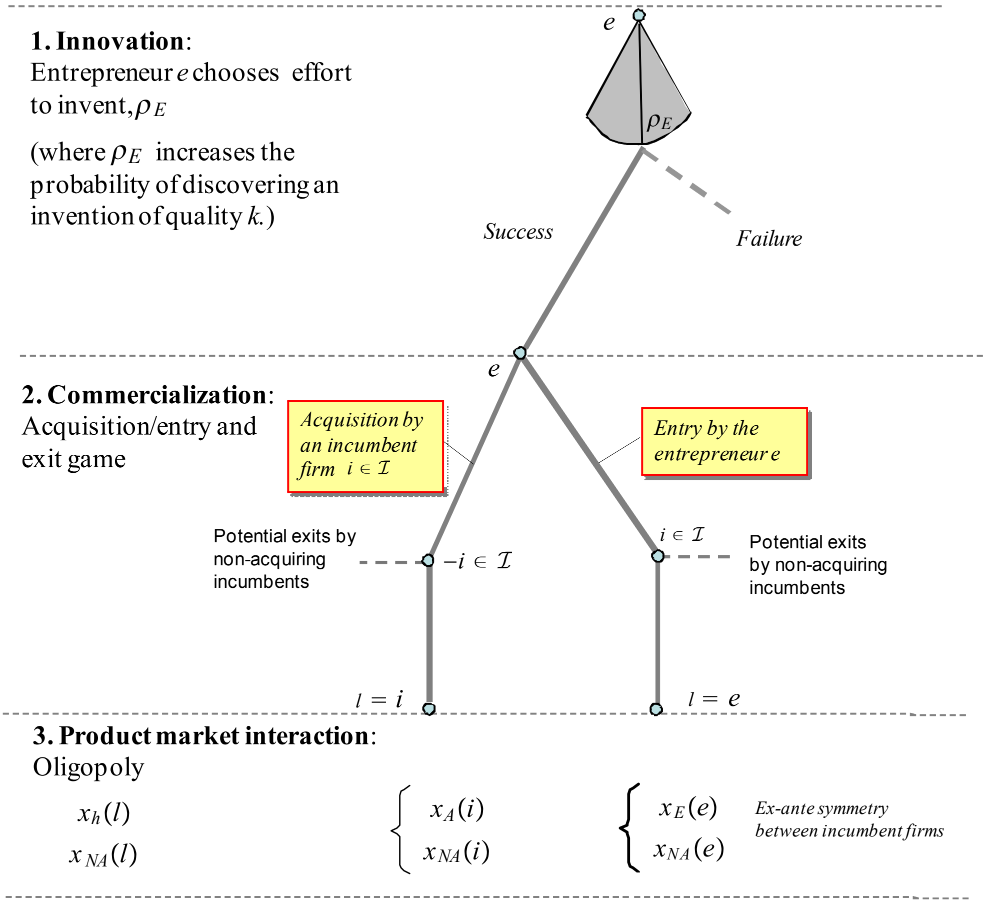

Figure 2.1: The structure of the game.

2.1. Stage 3: Product-market equilibrium

Let the set of firms in the industry be $\mathcal{J} = e \cup \mathcal{I}$, where $\mathcal{I} = \{i_1, i_2 ... i_n\}$ is the set of incumbent firms. Denote the owner of the entrepreneur's invention, k, by $l \in \mathcal{J}$. Using backward induction, we start with product market interaction where firm j chooses an action $x_j \in R^+$ to maximize its *direct* product market profit, $\pi_j(x_j, \mathbf{x}_{-j}, l) - \tau$, which depends on its own and its rivals' market actions, x_j and $\mathbf{x}_{-j}$, the identity of the owner of the invention, l, and a fixed cost τ to serve the market. We may consider the action x_j as setting a quantity or a price, as will be shown in later sections. We assume there to exist a unique Nash-Equilibrium, $\mathbf{x}^*(l)$, defined as:

$$\pi_j(x_j^*, x_{-j}^* : l, k) \geq \pi_j(x_j, x_{-j}^* : l, k), \quad \forall x_j \in R^+, \tag{2.1}$$

where we assume the product market profits to be positive.

From (2.1), we can define a reduced-form product market profit for a firm j, taking as given ownership l:

$$\pi_j(l) \equiv \pi_j(x_j^*(l), x_{-j}^*(l), l). \tag{2.2}$$

The assumption that incumbents $i_1, i_2, ..., i_n$ are symmetric before the acquisition takes place implies that we need only distinguish between two types of ownership; *entrepreneurial* ownership ($l = e$) and *incumbent* ownership ($l = i$). Note that there are then three types of firms of which to keep track, $h = \{e, A, NA\}$, i.e. the entrepreneurial firm (e), an acquiring incumbent (A) and the non-acquiring incumbents (NA).

We will now define the quality of an invention in this setting:

Definition 1. *(i)* $\dfrac{d\pi_A(i)}{dk} > 0$, *(ii)* $\dfrac{d\pi_E(e)}{dk} > 0$, *and (iii)* $\dfrac{d\pi_{NA}(l)}{dk} < 0$, $l = e, i$.

Definitions 1 (i) and (ii) state that the reduced-form product market profit for the possessor is strictly increasing in the quality of the invention, whereas Definition 1 (iii) states that increased quality strictly decreases the rivals' profits. This will, for instance, hold for a process innovation where a more drastic innovation leads to a larger reduction in the marginal cost of selling and producing for the product market.

Example 1 (The LC-model). *As an example, we use a Linear-Cournot model (LC-model). This model is also used to derive more specific results. The oligopoly interaction in period 3 is Cournot competition in homogenous goods. The product market profit is* $\pi_j = (P - c_j)q_j$ *where firms face inverse demand* $P = a - \frac{1}{s}\sum_{i=1}^{N} q_i$, *where* $a > 0$ *is a demand parameter,* s *may be interpreted as the size of the market, and* N *is the total number of firms in the market. In the LC-model, ownership of the invention reduces the marginal cost. Making a distinction between firm types, we have:*

$$c_{NA} = c, \qquad c_A = c - k, \qquad c_E = c - k. \tag{2.3}$$

In the LC model, (2.1) takes the form $\frac{\partial \pi_j}{\partial q_j} = P - c_j - \frac{q_j}{s} = 0 \ \forall j$, *which can be solved for optimal quantities* $\mathbf{q}^*(l)$. *Noting that* $\frac{\partial \pi_j}{\partial q_j} = 0$ *implies* $P - c_j = -\frac{q_j}{s}$, *reduced-form profits are* $\pi_j(l) = \frac{1}{s}\left[q_j^*(l)\right]^2$, *where* $q_A^*(l) = s\frac{a-c+N(i)k}{N(i)+1}$, $q_E^*(e) = s\frac{a-c+N(e)k}{N(e)+1}$ *and* $q_{NA}^*(l) = s\frac{a-c-k}{N(l)+1}$ *for* $l = e, i$. *Note that* $max : N(i) = n(i)$ *and* $max : N(e) = n(e) + 1$ *where* $n(l) \leq n$ *is the number* *of active incumbent firms. Holding the total number of firms $N(l)$ fixed, it thus follows that reduced-form profits $\pi_j(l)$ fulfill Definition 1.*

2.2. Stage 2: Commercialization

In stage 2, there is first an entry-acquisition game where the entrepreneur can decide whether to sell the invention to one of the incumbents or enter the market at a fixed cost, G. Given the mode of commercialization of the invention, there may then be exits of non-acquiring incumbents.

The firm in possession of the invention is assumed to always make positive profits, i.e. we assume the quality of the invention k to be sufficiently large so that $\pi_A(l) > \tau$ and $\pi_E(e) > \tau + G$ holds. Non-acquiring incumbents will exit until the total number of firms on the market $N(l)$ fulfils the *exit condition*:

$$\pi_{NA}(l : N(l)) > \tau, \qquad \pi_{NA}(l : N(l) + 1) < \tau, \tag{2.4}$$

where $max : N(i) = n(i)$ and $max : N(e) = n(e) + 1$, where $n(l) \leq n$.

The commercialization process is depicted as an auction where n incumbents simultaneously post bids and the entrepreneur then either accepts or rejects these bids. If the entrepreneur rejects these bids, she will enter the market. Each incumbent announces a bid, b_i, for the invention. $\mathbf{b} = (b_1, ..b_i.., b_m) \in R^m$ is the vector of these bids. Following the announcement of $\mathbf{b}$, the invention may be sold to one of the incumbents at the bid price, or remain in the ownership of entrepreneur e. If more than one bid is accepted, the bidder with the highest bid obtains the invention. If there is more than one incumbent with such a bid, each such incumbent obtains the invention with equal probability. The acquisition is solved for Nash equilibria in undominated pure strategies. There is a smallest amount, ε, chosen such that all inequalities are preserved if ε is added or subtracted.

There are three different valuations:

- v_{ii} in (2.5) is the value for an incumbent of obtaining k, when a rival incumbent would otherwise obtain k. The first term shows the profit when possessing the invention k. The second term shows the expected profit if a rival incumbent obtains k, where Γ is the transaction cost associated with acquiring the invention k, and $\lambda(\mathrm{i})$ is the probability of staying in the market as a non-acquirer

$$v_{ii} = \pi_A(i) - \tau - \Gamma - \lambda(\mathrm{i}) \left[\pi_{NA}(i) - \tau\right]. \tag{2.5}$$

- v_{ie} in (2.6) is the value for an incumbent of obtaining k, when the entrepreneur would otherwise keep it. The profit for an incumbent of not obtaining invention k is different in this case, due to the change of identity of the firm that would otherwise possess the assets

$$v_{ie} = \pi_A(i) - \tau - \Gamma - \lambda(\mathrm{e}) \left[\pi_{NA}(e) - \tau\right]. \tag{2.6}$$

- v_e in (2.7) is the value for the entrepreneur of keeping an invention with quality k and entering the market

$$v_e = \pi_E(e) - \tau - G. \tag{2.7}$$

Note that we assume that $\pi_E(i) = 0$, so that the entrepreneur cannot enter the market without ownership of the invention. Note also that one possibility is that entry takes place through a sale to a large firm outside this industry.

We can now proceed to solve for the Equilibrium Ownership Structure (EOS). Since incumbents are symmetric, valuations v_{ii}, v_{ie} and v_e can be ordered in six 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 1. *Equilibrium ownership l^*, acquisition price S^* and entrepreneurial reward R_E are described in table 2.1:*

Proof. See the Appendix. ■

Table 2.1: The equilibrium ownership structure and the acquisition price.

Inequality:	Definition:	Ownership l^*:	Acquisition price, S^*:	Entrepreneurial reward, R_E :
$I1$:	$v_{ii} > v_{ie} > v_e$	i	v_{ii}	v_{ii}
$I2$:	$v_{ii} > v_e > v_{ie}$	i *or* e	v_{ii}	v_{ii} or v_e
$I3$:	$v_{ie} > v_{ii} > v_e$	i	v_{ii}	v_{ii}
$I4$:	$v_{ie} > v_e > v_{ii}$	i	v_e	v_e
$I5$:	$v_e > v_{ii} > v_{ie}$	e	.	v_e
$I6$:	$v_e > v_{ie} > v_{ii}$	e	.	v_e

Lemma 1 shows that when one of the inequalities $I1$, $I3$, or $I4$ holds, k is obtained by one of the incumbents. Under $I1$ and $I3$, the acquiring incumbent pays the acquisition price $S = v_{ii}$, and $S = v_e$ under $I4$. When I_5 or I_6 holds, the entrepreneur keeps its assets. When $I2$ holds, there exist multiple equilibria. The last column summarizes the reward R_E accruing to the entrepreneur.

2.3. Stage 1: Effort by the entrepreneur

In stage 1, entrepreneur e invests in research ρ_E to succeed with the invention k. For simplicity, assume that the probability of succeeding with an invention is simply the effort, i.e. $\rho_E \in [0,1]$, and that effort is associated with an increasing and convex cost $y(\rho)$, i.e. $y'(\rho) > 0$, and $y''(\rho) > 0$. With $R_E(l)$ given from Lemma 1, $\Pi_E = \rho_E R_E(l) - y(\rho_E)$ is the expected net profit of undertaking a research effort for the entrepreneur. The optimal effort ρ_E^* is given from:

$$\frac{d\Pi_E}{d\rho_E} = R_E(l) - y'(\rho_E^*(l)) = 0, \tag{2.8}$$

with the associated second-order condition (omitting the ownership variable l), $\frac{d^2\Pi_E}{d\rho_E^2} = -y''(\rho) < 0$.

Applying the implicit function theorem in (2.8), we can state the following Lemma:

Lemma 2. *The equilibrium effort by the entrepreneur in stage 1,* $\rho_E^*(l)$ *and hence, the probability of a successful invention, increases in the expected reward for an invention, i.e.* $\frac{d\rho_E^*(l)^*}{dR_E} > 0$.

3. Why entrepreneurs sell their best inventions

In this section, we examine how the mode of commercialization – by entry or by sale – is related to the quality of the invention, k. It is then useful to define the *net value of an incumbent acquisition*, i.e. the difference between incumbents' valuations and the entry value for the entrepreneur, $v_{il} - v_e$. In particular, note that from Lemma 1, commercialization by sale occurs as a unique equilibrium if and only if $v_{il} - v_e > 0$.

Using (2.5)-(2.7), we have:

$$v_{il} - v_e = [\pi_A(i) - \pi_E(e) + G - \Gamma] - \lambda(1)\left[\pi_{NA}(l) - \tau\right], \quad l = \{e, i\}. \tag{3.1}$$

Examining the net value of an acquisition (3.1), the first term is an *invention-transfer effect* and shows the change in profits from an ownership change of the invention from the entrepreneur to an incumbent firm. The second term can be viewed as the *opportunity cost* of an ownership change, since this terms captures the profit for an incumbent when not acquiring the invention.

3.1. Market-structure neutral entry

To isolate how the quality of the invention k affects the entrepreneur's choice between entering and selling the invention, we will assume that the entrant and the acquirer make a symmetric use of assets, and will obtain a symmetric market position when exposed to the same market conditions, i.e. $\pi_A(i) = \pi_E(e)$ when the total number of firms on the market is $N = n(i) = n(e)$. We refer to such entry as "large scale entry". Once more, note that one possibility is that large scale entry takes place through a sale to a large firm outside this industry which uses the invention to enter the market.[6]

To proceed, we then use the following definition:

Definition 2. $\pi_{NA}(l, \bar{k}(l)) = \tau$ *for* $l = e, i$.

$\bar{k}(l)$ is thus the maximum quality of the invention such that *all* non-acquirers can cover their fixed cost τ associated with serving the market. It follows that $\bar{k}(i) > \bar{k}(e)$, since non-acquirers' profits will be lower with one more firm in the market.

We then make the following assumption:

Assumption A1 *Entry is Market–structure-neutral-entry:* $k \in (\bar{k}(e), \bar{k}(i))$.

Thus, when $k \in (\bar{k}(e), \bar{k}(i))$, entry by the entrepreneur leads to the exit of one incumbent firm, i.e. $N(l) = n$. Assumption A1 thus implies that the entrant obtains exactly the same market position as would the acquiring incumbent in the case of a sale of the invention, i.e.

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[6] The LC-model in Example 1 fulfills the large scale entry assumption.

$\pi_A(i) = \pi_E(e)$. Moreover, since one of the incumbents is forced out of the market under entry, we have that the probability of remaining in the market for a non-acquiring incumbent is $\lambda(\mathrm{i}) = 1 > \lambda(\mathrm{e}) = \frac{n-1}{n} > 0$.

Assumption A1 greatly simplifies the exposition while, as will be seen in Section 3.2, not qualitatively affecting the results. Under Assumption A1, the net value for an incumbent in (3.1) can be written as:

$$v_{il} - v_e = \begin{cases} v_{ie} - v_e = G - \Gamma - \left(\frac{n-1}{n}\right)[\pi_{NA}(e) - \tau], & l = e \\ v_{ii} - v_e = G + \tau - \Gamma - \pi_{NA}(i), & l = i \end{cases}, \tag{3.2}$$

where the invention-transfer effect is now given from the net fixed cost savings, $G - T$. In (3.2), $v_{ie} - v_e$ thus represents the *net value for an incumbent of deterring entry*, whereas $v_{ii} - v_e$ represents the *net value for an incumbent of preempting rivals* from obtaining the entrepreneur's invention.

To characterize the entrepreneur's choice of mode of commercialization, we make use of the following definition:

Definition 3. *Let* k^{ED} *be defined from* $v_{ie}(k^{ED}, \cdot) = v_e(k^{ED}, \cdot)$ *and* k^{PE}*be defined from* $v_{ii}(k^{PE}, \cdot) = v_e(k^{PE}, \cdot)$.

k^{ED} is thus the quality level where the entry-deterring motive for an incumbent acquisition just matches the entrepreneur's entry value, whereas k^{PE} is the quality level where the preemptive motive for an incumbent acquisition is equal to the entrepreneur's entry value. Note that from (3.2), the existence of the cut-off qualities k^{ED} and k^{PE} requires that entry costs G are larger than the transaction cost Γ.

We then have the following Lemma:

Lemma 3. *Suppose that Assumption A1 holds and* k^{ED} *and* k^{PE} *exist. Then, (i) commercialization by entry takes place if the quality of the invention is sufficiently low,* $k \in (\bar{k}(e), k^{ED})$*, (ii) commercialization by sale occurs at sales price* $S^* = v_e$ *if the quality of the invention is of intermediate size,* $k \in [k^{ED}, k^{PE})$*, and (iii) commercialization by sale occurs at sales price* $S^* = v_{ii}$ *if the quality of the invention is sufficiently high,* $k \in [k^{PE}, \bar{k}(i))$.

Lemma 3 is proved below and illustrated in Figure 3.1. Figure 3.1(i) solves the acquisition entry game as a function of the quality of the invention, k. When the quality of the invention is low $k \in (\bar{k}(e), k^{ED})$, the net value for entry deterrence is negative, i.e. an incumbent's entry deterring valuation is lower than the entrant's entry value, $v_{ie} - v_e < 0$. In this region, the entrepreneur will thus choose commercialization by entry ($l^* = e$).

What happens if the quality of the invention increases? Differentiate the net value of entry deterrence $v_{ie} - v_e$ in k to obtain

$$v'_{ie,k} - v'_{e,k} = -\left(\frac{n-1}{n}\right)\frac{d\pi_{NA}(e)}{dk} > 0, \tag{3.3}$$

where we use v'_k as the notation for the derivative, $\frac{dv}{dk}$. Thus, the entry-deterring valuation of an incumbent v_{ie} increases more than the entrepreneur's value of entry v_e when the quality

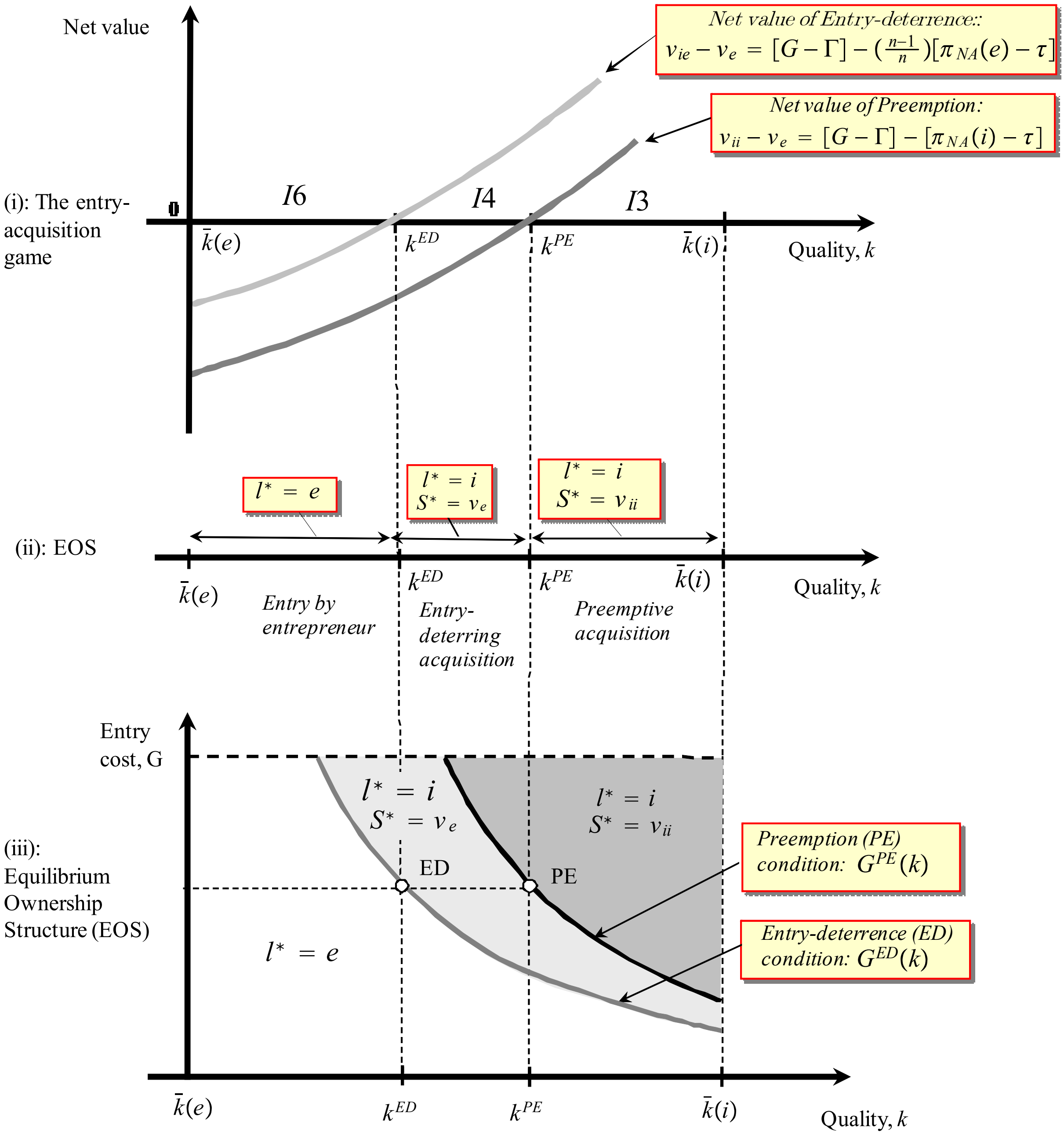

Figure 3.1: Solving for the equilibrium mode of commercialization.

of the invention increases. To see why, note that the first term in $v_{ie} = \pi_A(i) - \tau - \Gamma - \lambda(\mathrm{e})\left[\pi_{NA}(e) - \tau\right]$ increases by the same amount as the first term in $v_e = \pi_E(e) - \tau - G$, since the acquiring incumbent and the entrepreneur have the same increase in profit from Assumption A1, $\pi_A(i) = \pi_E(e)$. However, since the profit of a non-acquirer $\pi_N(e)$ decreases in k, there is an additional increase in the incumbent's valuation, thereby implying that $v'_{ie,k} > v'_{e,k}$. Thus, since an incumbent's net value of entry deterrence $v_{ie} - v_e$ is increasing in the quality of the invention k, an *entry deterring acquisition* at the acquisition price $S^* = v_e$ occurs at $k = k^{ED}$, as shown in Figure 3.1(ii). Other incumbents will not preempt a rival acquisition in the region $k \in [k^{ED}, k^{PE})$, since the net value of preemption is negative, $v_{ii} - v_e < 0$. Thus, the entrepreneur will commercialize by sale ($l^* = i$) at price $S^* = \pi_E(e) - \tau - G$ in this region.

What if the quality increases even further? Since a higher quality decreases the profit of a non-acquiring incumbent also when there is an incumbent acquisition, the net value of preempting rivals is also increasing in quality. Differentiating $v_{ii} - v_e$ in k we obtain

$$v'_{ii,k} - v'_{e,k} = -\tfrac{d\pi_{NA}(i)}{dk} > 0. \tag{3.4}$$

As shown in Figure 3.1(i), increasing the quality of the invention into the region $k \geq k^{PE}$ will then imply that the net value of preemption is strictly positive, $v_{ii} - v_e > 0$. This induces a bidding war between incumbents driving the equilibrium sales price above the entry value for the entrepreneur, $S^* = v_{ii} = \pi_A(i) - \Gamma - \pi_{NA}(i) > v_e$. The entrepreneur will thus commercialize by sale ($l^* = i$), receiving the sales price $S^* = v_{ii}$ in this region.

Let us now derive additional predictions. Figure 3.1(iii) shows how the equilibrium ownership is jointly determined by the quality of the invention k and the entry cost G. Let $G^{ED}(k^{ED})$ be the *entry-deterrence condition* (ED-condition) defined from $v_{ie}(k^{ED}, G) = v_e(k^{ED}, G)$, and let $G^{PE}(k^{PE})$ be the *preemption condition* (PE-condition) defined from $v_{ii}(k^{PE}, G) = v_e(k^{PE}, G)$. Solving for G in each equation, we have:

$$G^{ED}(k) = \Gamma - \left(\tfrac{n-1}{n}\right)\tau + \left(\tfrac{n-1}{n}\right)\pi_{NA}(e), \quad G^{PE}(k) = \Gamma - \tau + \pi_{NA}(i). \tag{3.5}$$

The loci associated with the takeover condition $G^{ED}(k^{ED})$ and the preemption condition $G^{PE}(k^{PE})$ are downward-sloping in the $k - G$ space. This follows from the profit of a non-acquirer $\pi_{NA}(l)$ decreasing in the quality of the invention k, and a lower fixed entry cost G being needed to balance the incumbent's higher value of obtaining the invention. The equilibrium ownership structure involves commercialization by entry below the entry deterrence locus $G^{ED}(k)$, indicated as $l^* = e$. Entry deterring acquisitions occur for combinations of k and G between the takeover locus $G^{ED}(k)$ and the preemption locus $G^{PE}(k)$, indicated as $l^* = i$ and $S^* = v_e$. Preemptive acquisitions occur above the preemption locus $G^{PE}(k)$, as indicated by $l^* = i$ and $S^* = v_{ii}$. From (3.5), we also note that increases in transaction costs Γ shift the entry deterrence locus $G^{ED}(k)$ and the preemption locus upwards in Figure 3.1(iii), thus reducing the region where commercialization by sale occurs, whereas increasing the fixed operating cost τ has the opposing effect.

Thus, we can state the following result:

Proposition 1. *Assume that Assumption A1 holds. In the choice between commercializing by* *sale to incumbents and entering the market, an entrepreneur will then prefer sale when (i) the quality of the invention k is high, (ii) when entry costs G are high, (iii) when operating fixed costs τ are high, and (iv) when the transaction costs associated with a sale Γ are low.*

3.2. Non-market-structure neutral entry

We will now relax Assumption A1. Let us first examine the case when the quality of the invention is so low that no incumbent is forced out of the market post-entry, i.e. $N(i) = n < N(e) = n+1$, i.e. we assume

Assumption A2 *Non-neutral-entry without exit:* $k \in (0, \bar{k}(i))$.

From (2.5), (2.6), and 2.7), (3.1) now becomes:

$$v_{il} - v_e = [\pi_A(i) - \Gamma - \pi_E(e) + G] - [\pi_{NA}(l) - \tau], \quad l = \{e, i\}. \tag{3.6}$$

Differentiating (3.6) in k, we obtain:

$$v'_{ie,k} - v'_{e,k} = \left[\frac{d\pi_A(i)}{dk} - \frac{d\pi_E(e)}{dk}\right] - \frac{d\pi_{NA}(l)}{dk} \quad l = \{e, i\}. \tag{3.7}$$

The main difference from the above analysis is that the effects on the entrant and the acquirer of an increase in quality now differ, i.e. $\frac{d\pi_A(i)}{dk} \neq \frac{d\pi_E(e)}{dk}$, so we cannot in general sign the invention transfer effect. However, in many oligopoly models, including the Linear Cournot model, $\frac{d\pi_A(i)}{dk} > \frac{d\pi_E(e)}{dk}$ holds, i.e. a larger acquirer (as compared to the entrant) would have more to gain from increased quality due to larger sales, and $v'_{ie,k} - v'_{e,k} > 0$. As can be shown, we can state the following result[7]:

Lemma 4. *Proposition 3 is fulfilled in the LC-model for* $k \in (0, \bar{k}(i))$.

What would then happen if we allowed for such drastic inventions that more than one incumbent firm would exit the market? Let π^m denote the monopoly profit. Then, make the following assumption

Assumption A3 $k \in (\bar{k}(i), k^{\max}]$, *where* $\pi_A(i) = \pi_E(e) = \pi^m$ for $k = k^{\max}$.

Under Assumption A3, (3.6) becomes

$$v_{il} - v_e = [\pi_A(i) - \Gamma - \pi_E(e) + G] - \lambda(l)[\pi_{NA}(l) - \tau], \ l = \{e, i\}'. \tag{3.8}$$

To see that a higher quality of the invention is conducive to innovation also in this setting, suppose that $v_{il} - v_e > 0$ holds for some $k > \bar{k}(i)$. Note that the first term in (3.8) would remain positive, while the second term would decrease in the quality of the invention. The second term could increase discretely when the exit of an incumbent takes place (since π_{NA} increases). Such discrete changes would nevertheless decrease in size as non-acquirers become smaller. While there would be situations where small changes in quality imply that we move from an equilibrium

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[7] Proofs are available from the authors upon request.

of commercialization by sale to one with commercialization by entry, commercialization by sale will prevail when the quality of the invention becomes sufficiently high.[8]

4. Why preemptive acquisitions may promote the process of creative destruction

In this section, we will show that preemptive acquisition will accelerate the process of creative destruction. To illustrate this, first assume that Assumption A1 holds. The following proposition concerning research incentives for the entrepreneur is then immediate:

Proposition 2. *Assume that Assumption A1 holds, then $\rho^*(i) > \rho^*(e)$ for $k \in [k^{PE}, \bar{k}(i))$. That is, entrepreneurs with high-quality projects will be substantially more likely to succeed with an invention under commercialization by sale as compared to commercialization by entry.*

The proposition is proved in Figure 4.1 where, for convenience, Figure 4.1(i) derives the equilibrium commercialization strategy for the entrepreneur and Figure 4.1(ii) depicts the reward of the entrepreneur $R_E(l)$ as a function of the quality of the invention k. When quality is low $k \in (\bar{k}(e)), k^{ED})$, commercialization by entry occurs and the reward is $R_E(e) = v_e = \pi_E(e) - \tau - G$ for the entrepreneur. From Definition 1, $R_E(e)$ is increasing in quality and from Lemma 2, the research incentives are increased. The same holds if an entry deterring acquisition occurs in region $k \in [k^{ED}, k^{PE})$ since $R_E(i) = S^* = v_e$.

However, at an even higher quality $k \geq k^{PE}$, preemptive acquisitions occur, and the bidding competition between incumbents over the benefits as an acquirer – as well as over avoiding a weak position as a non-acquirer – drives the reward for commercialization by sale to be strictly higher than the reward for commercialization by entry, $R_E(i) = v_{ii} > v_e = R_E(e)$. But then, since the research effort and hence, the likelihood of a successful innovation $\rho^*(l)$, is increasing in the reward $R_E(l)$ from Lemma 2, it directly follows that the probability of a successful invention will be higher under commercialization by sale. This is illustrated in Figure 4.1(iii) which shows that preemptive incumbent acquisitions of entrepreneurial inventions can be productive by substantially increasing the research incentives for entrepreneurs.

More generally, we may also note that Lemma 1 and Lemma 2 imply that preemptive incumbent acquisitions will always increase the reward to research for entrepreneurs substantially, since $S^* = v_{ii} > v_e$ and hence $\rho^*(i) > \rho^*(e)$ will hold for any of the inequalities I1, I2 or I3 in table 2.1.

4.1. Preemptive acquisitions and welfare

Let us first examine how incumbent acquisitions of entrepreneurial inventions affect consumer welfare. To this end, we compare a Non-discriminatory (ND) policy (where incumbent acquisitions of entrepreneurial firms are allowed) to a Discriminatory (D) policy (which prohibits the acquisitions of small innovative firms). Consider a stage 0 where a government chooses between the two polices. Formally, let $\bar{\Gamma}$ be defined from $v_{ie}(\cdot, \bar{\Gamma}) = 0$. In the ND-policy, $\Gamma < \bar{\Gamma}$, whereas in the D-policy, $\Gamma > \bar{\Gamma}$. This is a highly stylized comparison, but it can be seen as a simple way of

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[8] This can be shown using a numerical example in the LC-model.

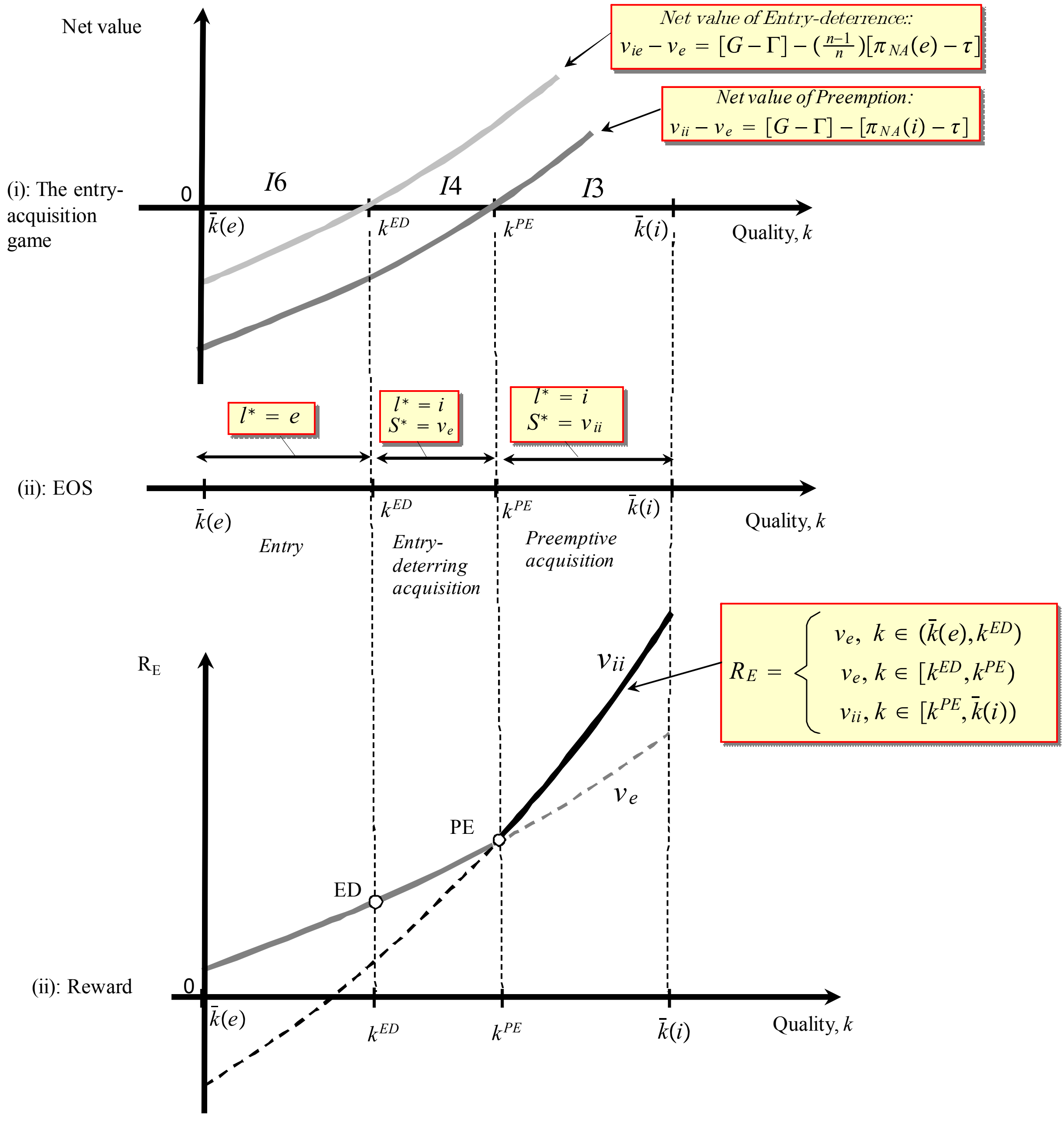

Figure 4.1: The equilibrium reward to innovation and the equilibrium probabality of success.

capturing the effects of substantial changes of transaction costs for acquisitions due to changes in policies that might block or increase the cost of acquisitions of small innovative firms.[9] [10] The change in transaction costs could also stem from technological and institutional changes.

Assume that, all else equal, consumers benefit from a higher quality of the innovation and from more firms being present in the market. Let the consumer surplus under ownership l be denoted $CS(l)$, and let $CS(0)$ denote the consumer surplus when the entrepreneur fails. From Lemma 1, we have:

$$CS^{ND-D} = \begin{cases} 0, \text{ for I5,I6} \\ \quad \rho(e)\left[CS(i)) - CS(e)\right] \leq 0, \text{ for I4} \\ \rho(i)\left[CS(i) - CS(0)\right] - \rho(e)\left[CS(e) - CS(0)\right] \text{ for I1-I3,} \end{cases} \tag{4.1}$$

noting that $\rho(e) = \rho(i)$ under I4 in Table 2.1.

If incumbent acquisitions are driven by entry deterrence motives, consumers will be better off from the Discriminatory policy, as shown by $CS^{ND-D} \leq 0$ under I4. However, the differential CS^{ND-D} in (4.1) also reveals that consumers may prefer the ND-policy when inventions are sold under bidding competition, since a successful invention is more likely, i.e. since $\rho_E^*(i) > \rho_E^*(e)$ under inequalities I1-I3 in Table 2.1. Since a higher quality of the invention will induce bidding competition among incumbents, this suggests that consumers may prefer the ND-policy when potential innovations are of high quality. This is shown by the following proposition:

Proposition 3. *If inventions have a sufficiently high quality $k > \bar{k}(e)$, consumers will prefer the ND-policy over the D-policy, $CS^{ND-D} > 0$.*

Proof. First, note that $k > \bar{k}(e)$ implies that $n(i) = n(e)$ from Definitions 2 and 3 and, hence, $CS(i) = CS(e)$, since no market power effect then arises from the acquisition. The higher entrepreneurial research effort under the ND policy $\rho_E^*(i) > \rho_E^*(e)$ then implies $CS^{ND-D} > 0$ for $k > \bar{k}(e)$. ■

Thus, preemptive incumbents' acquisitions may benefit consumers by giving entrepreneurs stronger incentives to succeed with high-quality inventions. For inventions of lower quality $k < \bar{k}(e)$, the market power effect may dominate the higher probability of a successful invention.

Let us end with a brief remark on how the total surplus is affected by policy. It directly follows that the entrepreneur gains from the ND-policy, since the bidding competition may give premium reward to successful invention.[11] What about incumbents? Let $\pi_N(0)$ denote the profit for incumbents absent the invention. From Lemma 1, we can then derive the difference in expected incumbents' profits from the two polices:

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[9] Examples are a restrictive merger policy in R&D industries, or tax policies concerning the sale of innovative firms.

[10] An alternative policy with qualitatively the same effect would be a reduction in the cost of entry.

[11] To see this, define the reduced-form entrepreneurial profit as $\Pi_E(l) = \rho^*(l)R_E(l) - y(\rho^*(l))$. Since $R_E^{ND}(l) = R_E^D = v_e$ under I4, I5 or I6 in Table 2.1, whereas $R_E^{ND}(l) = S^* = v_{ii} > R_E^D = v_e$, $\Pi_E^{ND}(l) \geq \Pi_E^D(l)$.

$$PS^{ND-D}=\begin{cases} 0, \quad \text{for I5,I6} \\ \rho^*(e)\left\{ n\{\underbrace{\lambda(i)\left[\pi_N(i)-\tau\right]-\lambda(e)\left[\pi_N(e)-\tau\right]}_{>0}\}+\underbrace{v_{ii}-v_e}_{<0}\right\}, \text{ for I4} \\ \left\{\underbrace{\rho^*(e)-\rho^*(i)}_{<0}\right\}\pi_N(0)+n\left\{\underbrace{\rho^*(i)\lambda(i)\left[\pi_N(i)-\tau\right]-\rho^*(e)\lambda(e)\left[\pi_N(e)-\tau\right]}_{>0}\right\}, \text{ I1-I3.} \end{cases} \tag{4.2}$$

Expression (4.2) reveals that which policy incumbents prefer is ambiguous. For instance, under preemptive acquisitions, when one of the inequalities I1-I3 in Table 2.1 is fulfilled, there is a larger expected loss of ex ante rents due to higher research efforts under the ND policy (as shown by the first term in the third line). But, given that the entrepreneur succeeds, which occurs with probability $\rho^*(l)$, the expected profit is higher under the ND-policy since incumbents either gain from a higher concentration by avoiding entry or by avoiding a less uncertain position as a non-acquirer (as shown by the second term in the third line).

5. Empirical analysis

We now turn to the empirical analysis. We first derive a probit model from the entrepreneur's decision on the mode of commercialization in stage 2, which is then estimated on a unique dataset on patents granted to Swedish small firms and individual inventors.

5.1. Deriving an estimation equation for the mode of commercialization

To identify if the model is consistent with the data and, in particular, with preemptive acquisitions, we will estimate the entrepreneur's choice of commercialization in Stage 2. Then, let $R_{e,m}$ be the reward for an entrepreneur e choosing commercialization mode $m = (Sale, Entry)$, consisting of the reward $R_{E,m}(k_e, \tau_e, \Gamma_e, G_e)$ given from Lemma 1 and a stochastic term $\varepsilon_{e,m}$, i.e.

$$R_{e,m} = R_{E,m}(k_e, \tau_e, \Gamma_e, G_e) + \varepsilon_{e,m}, \quad m = (Sale, Entry), \tag{5.1}$$

where $\varepsilon_{e,m}$ captures idiosyncractic factors affecting entrepreneur e's choice of commercialization not captured in the theory. In what follows, we assume that the entrepreneur knows $R_{e,m}$ and its components, while the error term is unknown to the econometrician.

To proceed, we linearize $R_{E,m}(k_e, \tau_e, \Gamma_e, G_e)$ in its components assuming that Assumption A1 is fulfilled. Noting that $R_{E,Entry}(k_e, \tau_e, \Gamma_e, G_e) = v_e$ under entry, whereas $R_{E,Sale}(k_e, \tau_e, \Gamma_e, G_e) = S^*$ under sale, we have:

$$R_{E,Entry}(k_e, \tau_e, \Gamma_e, G_e) \approx \alpha_0 + \underset{(+)}{\alpha_k} k_e + \underset{(-)}{\alpha_G} G_e + \underset{(0)}{\alpha_T} \Gamma_e + \underset{(-)}{\alpha_\tau} \tau_e = \mathbf{x}_e' \boldsymbol{\alpha} \tag{5.2}$$

$$R_{E,Sale}(k_e, \tau_e, \Gamma_e, G_e) \approx \beta_0 + \underset{(+)}{\beta_k} k_e + \underset{(?)}{\beta_G} G_e + \underset{(?)}{\beta_T} \Gamma_e + \underset{(?)}{\beta_\tau} \tau_e = \mathbf{x}_e' \boldsymbol{\beta}. \tag{5.3}$$

To identify preemptive acquisitions in the data, we proceed as follows. First, note that the signs in (5.2) directly follow from (2.7) and Definition 1. In (5.3), we note that when an entry-deterring acquisition takes place, $S^* = v_e$, and $\boldsymbol{\beta} = \boldsymbol{\alpha}$. In contrast, when an acquisition is preemptive, the bidding competition between incumbents drives up the the acquisition price to $S^* = v_{ii} > v_e$, which implies $\boldsymbol{\beta} \neq \boldsymbol{\alpha}$. To see this, first note that (3.4) implies $\beta_k - \alpha_k > 0$, which is illustrated in Figure 4.1(ii) where the reward-locus under sale and bidding competition, $R_E = v_{ii}$, being steeper in quality k than the corresponding reward under innovation for entry, $R_E = v_e$. Then, note that (2.5) and (2.7) directly imply $\beta_G - \alpha_G > 0$, $\beta_\Gamma - \alpha_\Gamma < 0$ and $\beta_\tau - \alpha_\tau > 0$.

Using (5.1)-(5.3), we can now write down the probability that the entrepreneur will choose commercialization by sale as:

$$\begin{aligned} \text{Prob}[Sale_e] &= \text{Prob}[R_{e,Sale} > R_{e,Entry}] = \text{Prob}[\varepsilon_{e,Entry} - \varepsilon_{e,Sale} < \mathbf{x}_e'(\boldsymbol{\beta} - \boldsymbol{\alpha})] \\ &= \text{Prob}[\varepsilon_e < \mathbf{x}_e'\boldsymbol{\gamma}] = \int_{-\infty}^{\mathbf{x}_e'\boldsymbol{\gamma}} f(\varepsilon_e) d\varepsilon_e = F(\mathbf{X}_e'\boldsymbol{\gamma}), \end{aligned} \tag{5.4}$$

where $\boldsymbol{\gamma} = \boldsymbol{\beta} - \boldsymbol{\alpha}$ and $f(\varepsilon_e)$ is the density of the error term, $\varepsilon_e = \varepsilon_{e,Entry} - \varepsilon_{e,Sale}$. If $\varepsilon_{e,m}$ is distributed according to the Gumbel distribution, then ε_e will be distributed according to the logistic distribution and $F(\mathbf{x}_e'\boldsymbol{\gamma}) = \Lambda(\mathbf{x}_e'\boldsymbol{\gamma})$, where $\Lambda(\cdot)$ is the cumulative density function of the logistic distribution. When $\varepsilon_{e,m}$ are mean-zero normally distributed, ε_e will also be normally distributed and $F(\mathbf{x}_e'\boldsymbol{\gamma}) = \Phi(\mathbf{x}_e'\boldsymbol{\gamma})$, where $\Phi(\cdot)$ is the cumulative density function of the normal distribution. In either case, parameters $\boldsymbol{\gamma}$ can be estimated by maximizing the likelihood function:

$$\mathcal{L} = \underset{e}{\Pi} F(\mathbf{x}_e'\boldsymbol{\gamma})^{m_e} F(1 - \mathbf{x}_e'\boldsymbol{\gamma})^{1-m_e}, \tag{5.5}$$

where $m_e = 1$ when commercialization by sale is chosen and $m_e = 0$ when commercialization by entry is chosen.

Thus, using the fact that $\boldsymbol{\gamma} = \boldsymbol{\beta} - \boldsymbol{\alpha}$ in (5.4), we can derive a testable hypothesis on the nature of incumbent acquisitions from our proposed model. We have the following proposition:

Proposition 4. *Suppose that Assumption A1 holds. Then:*

(i) If commercialization by sale takes place by entry-deterring acquisitions at $S^* = v_e$, *then* $\boldsymbol{\gamma} = \mathbf{0}$, *or equivalently,* $\boldsymbol{\beta} = \boldsymbol{\alpha}$.

(ii) If commercialization by sale takes place by preemptive acquisitions at $S^* = v_{ii} > v_e$, $\boldsymbol{\gamma} \neq \mathbf{0}$, *or equivalently,* $\boldsymbol{\beta} \neq \boldsymbol{\alpha}$. *More specifically,* $\gamma_k = \beta_k - \alpha_k > 0$, $\gamma_G = \beta_G - \alpha_G > 0$, $\gamma_\Gamma = \beta_\Gamma - \alpha_\Gamma < 0$ *and* $\gamma_\tau = \beta_\tau - \alpha_\tau > 0$.

Before proceeding, we make a number of remarks on the generality of Proposition 4.

Assumption A1: Proposition 4 does not require that entrepreneurial entry is "market neutral". This follows directly from table 2.1 (which applies also in situations where Assumptions A2 and A3 are fulfilled) where we again note that preemptive bidding competition implies $S^* = v_{ii} > v_e$.

Linearization of $R_{E,m}(\cdot)$: Proposition 4 is based on a linearization of $R_{E,m}(\cdot)$ in (5.1). Ambiguities may then arise in Proposition 4(ii), since theory gives no guidance to whether

$R_{E,m}(\cdot)$ is concave or convex in k. Note however that (2.5) and (2.7) implies that $R_{E,m}$ is linear in G and T. Then, simultaneously finding that $\gamma_k > 0$, $\gamma_G > 0$, $\gamma_\Gamma < 0$ and $\gamma_\tau > 0$ can only be only consistent with preemptive bidding competition between incumbents generating the sales price $S^* = v_{ii} > v_e$.

Proposition 1: Propositions 4(i) and (ii) are, respectively, sufficient conditions for the theory in Proposition 1. That is, in terms of Figure 4.1(ii), evidence for Proposition 4(ii) must imply that incumbent acquisitions take place in the dark-shaded area where acquisitions are preemptive at $S^* = v_{ii}$, whereas evidence for Proposition 4(i) would correspond to acquisitions taking place in the light-shaded area where acquisitions are entry-deterring at $S^* = v_e$. Rejecting our proposed theory on the mode of commercialization of entrepreneurial inventions thus requires $\boldsymbol{\gamma} \neq \mathbf{0}$ as well as a reversal of all signs in Proposition 4(ii).

Endogenous quality: Proposition 4 also holds in a setting where the entrepreneur chooses the level of quality k in stage 1 (rather than affecting the probability of discovering an invention of a given quality). To see this, let $C(k)$ be a strictly convex development cost. Assuming that Assumption A1 is fulfilled, (2.5) and (2.7) then imply $k^{Sale} = \arg\max_k [v_{ii} - C(k)] > k^{Entry} = \arg\max_k [v_e - C(k)]$. Thus, our theory would also predict that entrepreneurs choosing commercialization by sale will have a stronger incentive to develop inventions to higher quality. This suggests a potential endogeniety problem in (5.4). However, note that the entrepreneur will choose the mode of commercialization to maximize $R_{E,m}(\cdot)$ in (5.1) in stage 2, where the quality of the innovation k is *given* from stage 1. It then follows that we can use Proposition 4 to identify preemptive acquisitions, irrespective of whether the quality of an innovation is exogenously given for the entrepreneur, or if the the entrepreneur could affect the quality prior to commercialization.

Asymmetric incumbents: We should finally note that identifying preemptive acquisitions through Proposition 4(ii) does not require symmetric incumbents. This follows from the fact that with a market with asymmetric incumbents, the sales price would either be the reservation price v_e or the valuation for the incumbent with the second highest valuation, v_{ii}^2. If the invention generates negative externalities through the product market for the firm with the second highest valuation, and if these externalities are sufficiently strong, the acquisition price will once more be bid up above v_e.

5.2. Data

To estimate (5.4), we will use a dataset on patents granted to small firms (less than 200 employees) and individual inventors. The dataset is based on a survey of Swedish patents granted in 1998.[12] In that year, 1082 patents were granted to Swedish small firms and individuals.[13]

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[12] A further description of the data can be found at http://www.ifn.se/web/Databases_9.aspx and in Svensson (2007).

[13] In 1998, 2760 patents were granted in Sweden. 776 of these were granted to foreign firms, 902 to large Swedish firms with more than 1000 employees, and 1082 to Swedish individuals and firms with less than 1000 employees. In a pilot survey carried out in 2002, it turned out that large Swedish firms refused

Information about inventors, applying firms, their addresses and the application date for each patent was obtained from the Swedish Patent and Registration Office (PRV). Thereafter, a questionnaire was sent out to the inventors of the patents in 2004.[14] The inventors were asked where the invention was created, if and when the invention had been commercialized, which kind of commercialization mode was chosen, type of financing, etc. 867 out of 1082 inventors filled out and returned the questionnaire, i.e., the response rate was 80 percent.[15]

From the theory, we are interested in those patents where the inventors can decide themselves whether to commercialize the patent. Therefore, we will only consider 624 patents where the inventors have some ownership. 364 out of these 624 patents were commercialized, that is, the holder received income from the patent.[16] Among the 364 commercialized patents, 91 patents were commercialized by selling or licensing the patent, and 273 patents were commercialized by entry and own commercialization. Since the mode of commercialization is chosen from maximizing the reward or income from an innovation, R_E in (5.1), we will use commercialized patents when estimating (5.4). The potential econometric problems arising from 260 out of 624 patents in the sample not being commercialized will be dealt with in Section 5.4.

5.2.1. Dependent variable: mode of commercialization

As the dependent variable in (5.4), we thus define a binary variable $Sale$ taking the value of one if the patent was sold or licensed to another firm, and zero if the patent was commercialized internally by the inventor. Note that a sale of an invention and an exclusive licence of an invention are equivalent in our theory. Since the licensing contracts are almost only exclusive in the data, we treat licence contracts and sales as symmetric in the empirical analysis.[17]

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to provide information on individual patents. Furthermore, it is impossible to persuade foreign firms to fill out questionnaires about patents. These firms are almost always large multinationals firms

[14] Each patent always has at least one inventor and often an applying firm. The inventors or the applying firm can be the owner of the patent, but the inventors can also indirectly be owners of the patent, via the applying firm. Sometimes, the inventors are only employed in the applying firm which owns the patent. If the patent had several inventors, the questionnaire was sent to one inventor only.

[15] The falling off was not systematic. The falling off was due to 10% of the inventors having old addresses, 5% having correct addresses but we did not get any contact with the inventors and 5% refusing to reply. The only information we have about the non-respondents is the IPC-class of the patent and the region of the inventors. For these variables, there was no systematic difference between respondents and non-respondents.

[16] The commercialization rate for our sample is 58 percent. This rate should be compared to the few available studies which have measured the commercialization of patents: 47 percent for American patents found by Morgan et al. (2001) and 55 percent in the studies surveyed by Griliches (1990). The higher commercialization rate in the present study is explained by the fact that only patents directly or indirectly owned by the inventors are included – large (multinational) firms have a much larger number of defensive patents. Griliches (1990) confirms this view and reports that the commercialization rate is 71 percent for small firms and inventors.

[17] In many cases, when the invention to a large extent consists of indivisible assets in terms of capital or human capital, exclusive licences are self evident. However, in some situations, several buyers might hold a licence to utilize the innovations. Kamien and Tauman (1986) and Katz and Shapiro (1986) show that there exists an equilibrium where some potential buyers are left without a licence also when multi-firm licensing is an option. Thus, exclusivity is also a possible outcome in situations where entrepreneurs can

5.2.2. Explanatory variables

The explanatory variables used in estimating (5.4) and their expected signs are given in Table 5.1.

The quality of an invention, k To measure the quality of an invention k, we use the number of forward citations (excluding self-citations) that a patent received from the application date until November 2007. With patents having different application years, the length of the time periods they can be cited differs. Therefore, in the estimations, we adjust our citation variables so that they measure the number of forward citations in a five-year period.[18]

Forward citations are seen as the most important quality indicator of patents in the literature (Harhoff *et al.*, 1999; Lanjouw and Schankerman, 1999; Hall *et al.*, 2005). We divide the forward citation variable into two groups: (i) forward citations where the cited and citing patents have at least one common technology class at the four-digit ISIC-level, denoted as W_CIT; and (ii) forward citations where they have no common technology class at the four-digit ISIC-level, denoted as B_CIT. Proposition 4(ii) implies that if incumbent acquisitions are driven by preemptive motives, we would expect $\gamma_k = \beta_k - \alpha_k > 0$. The quality of the invention k driving incumbents' preemptive motives should then be reflected in obtaining a positive estimate on W_CIT rather than for B_CIT, since the former should indicate how frequently competitors cite the patent; competitors should apply for similar patents, and frequent citations from competitors should therefore indicate high quality within the industry.[19]

The 624 patents in the sample together have 636 forward citations within technologies and 79 between technologies. In table 5.2, the relationship between commercialization mode and forward citations within technologies (W_CIT) is shown. Most patents (64 percent) have no forward citations at all, and cited patents seldom have more than three citations. Among non-commercialized patents, only 28 percent are cited, whereas 40 and 46 percent of the entry and sale patents are cited. In line with the theory, we note that patents which are commercialized through sale have a higher average number of forward citations than patents which are commercialized through entry. Patents which are not commercialized have the lowest average.

A potential concern with our quality measure is endogeneity, since forward citations in general occur after the patents have been commercialized. Forward citations are registered by administrators at the national patent offices, who can be seen as independent actors; they are hardly affected by any commercialization decision. However, the fact that commercialization by sale or entry has occurred may make competitors apply for related patents which, in turn,

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sell several licences and our set-up is also valid in situations where firms have the option to sell a licence to more than one firm.

[18] Here, we follow the approach of Trajtenberg (1990) and weight the number of received patent citations by linear time trend.

[19] It is also competitors that should be interested in acquiring or licensing the patent. For example, a high-quality drug patent, which largely affects competitors' profit flows, should have more citations from future patents of drugs than from patents of semi-conductors, say. The cost for competitors should then come from limits in their own patents or through increased costs of generating competitive new patentable innovations.

cite the original patent. If this is true, forward citations would increase for around 2-5 years (the time it should take to develop a new invention and file a patent) after sale or entry has occurred. Table 5.3 shows the number of forward citations that patents have received during the years before and after application, entry and sale occurred. If it is assumed that a competitor cannot apply for a new patent within two years after entry or sale occurs, it seems as if neither entry nor sale affects forward citations.[20] To deal with this potential endogeneity problem, we transform the citation variables W_CIT and B_CIT into binary variables, D_W_CIT and D_B_CIT indicating whether a patent received a citation**.** Such citation dummy variables should be less sensible to the endogeneity problem than the original ones.

Entry costs, G To measure the costs of commercialization under entry G, we use additive dummies for different firm sizes. Firms which already have marketing, manufacturing and financial resources in-house should have lower costs of entering the market for a new product, G. We define the variable $SMALL$ taking on the value of 1 for firms with 11-200 employees, and 0 otherwise, whereas $MICRO$ equals 1 for micro companies with 2-10 employees, and 0 otherwise. Entrepreneurial firms with either of these characteristics should face lower entry costs than the reference group of inventors without any employees. Since larger firms should face *lower* entry costs G, the bidding competition among incumbents for entrepreneurial inventions implies that $\gamma_G = \beta_G - \alpha_G > 0$ and Proposition 4(ii) thus implies $\gamma_{G_{\text{Micro}}} < 0$ and $\gamma_{G_{Small}} < 0$. In Table 5.4, the commercialization mode rates are shown for different firm sizes. Commercialization by sale is more frequent the smaller is firm size, whereas entry is more frequent the larger is the firm, which is consistent with Proposition 4(ii).

Transaction costs, Γ We use the variable PVC measuring the percentage of the R&D-stage that was financed by private venture capitalists or business angles as a measure of transaction costs Γ. Gans et al. (2002) find evidence that the involvement of private venture capitalists increased the probability of commercialization by sale, arguing that such agents have networks with firms, thereby decreasing the search and transaction costs associated with finding an external buyer. Thus, if a stronger participation of venture capitalists in the commercialization process reduces the transaction costs Γ, it follows from Proposition 4 that preemptive acquisitions by incumbents of entrepreneurial innovations implies $\gamma_{\Gamma_{PVC}} > 0$.

Operational fixed costs, τ We do not have any measure of fixed operation costs, τ. Instead we use additive dummies (fixed effects) for technologies and regions as well as a trend variable for the application year, broadly controlling for unobservable technology-, region- and time-specific factors. Patents are divided into technology groups based on the patents' main IPC-Class according to Breschi *et al.* (2004). The data is also divided into six different regions. Five additive dummies are included for these six groups in the estimations. A trend variable $APPLY$ is also included, measuring the application year.

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[20] Note also that most entries occur about 1-3 years after the patent application (see Table 5.3), which explains the low value of 23 citations in the first year after entry.

5.3. Results

The results of estimating the probit model (5.4) are shown in table 5.5. Let us first examine if these results are consistent with preemptive acquisitions by incumbents. We start with Model A containing the core variables from the theory, W_CIT, PVC, $SMALL$ and $MICRO$, as well as fixed effects for technologies and regions. The Wald test on the core variables shows that $\boldsymbol{\gamma} = \mathbf{0}$ in (5.4) or, equivalently, $\boldsymbol{\beta} = \boldsymbol{\alpha}$ is rejected. This is also the case in the Wald test on the full specification of Model A.

Next, we turn to individual estimates. A higher quality of the invention as measured by more forward citations (W_CIT) increases the probability of an invention being commercialized by a sale to incumbents. On the other hand, presence in the market as measured by either being a small or a micro firm ($SMALL$ and $MICRO$) decreases the probability of a sale. All these variables are statistically significant. The estimated coefficient of PVC has the correct sign, but is not significant. Since we can reject $\boldsymbol{\gamma} = \mathbf{0}$ and since the coefficients of the core variables are consistent with $\gamma_k = \beta_k - \alpha_k > 0$, $\gamma_\Gamma = \beta_\Gamma - \alpha_\Gamma < 0$ and $\gamma_G = \beta_G - \alpha_G > 0$, Proposition 4(ii) implies that the estimates identify incumbent acquisition as being preemptive in nature.[21]

In Models B and C we add between citations B_CIT and the application year $APPLY$, without qualitative changes in results. The Wald tests and individual estimates are again consistent with the Proposition 4(ii). Calculating marginal effects shows that if a patent receives one more forward citation during a five-year period, the probability of sale increases by about five percentage points in Models A-C. If the inventor has a small firm as compared to the case where she has no firm, the probability of sale decreases by around 20 percentage points.

Due to the potential endogeneity problem our citation variable and the distribution of forward citations being skewed to the right, we reestimate (5.4) with the citation dummies D_W_CIT and D_B_CIT, indicating whether a patent received a citation. These results are shown in table 5.6. The Wald tests again reject $\boldsymbol{\gamma} = \mathbf{0}$, whereas the results for individual estimates are consistent with $\gamma_k = \beta_k - \alpha_k > 0$, $\gamma_\Gamma = \beta_\Gamma - \alpha_\Gamma < 0$ and $\gamma_G = \beta_G - \alpha_G > 0$. Once more, the results are thus consistent with Proposition 4(ii), albeit some estimates are less precise.

As a second check, we also re-estimated table 5.5 with OLS and logit specifications without finding any qualitative changes in the results. The results were also unaffected by adding a number of control variables such as the share of ownership in the entrepreneurial firms held by the inventor, notwithstanding if the inventor had complementary patents or more patents, individual characteristic of the inventor such a sex or ethnicity, or whether the patent was applied in research at a university.

5.4. Extension: the decision to commercialize

The theory presented makes the implicit assumption that all patents are commercialized. In contrast, about 40 % of the patents in the sample were not commercialized. Among the non-commercialized patents, 163 expired before the end of the data collection in 2005, while 97

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[21] The exception is $\gamma_\tau = \beta_\tau - \alpha_\tau = 0$ since we have no direct measure of operating fixed costs, τ. The impact of τ is indirectly estimated through the Wald test on $\gamma = \beta - \alpha = 0$, where the impact of τ is (imprecisely) accounted for in the technology and region-fixed effects.

patents remained active in 2005 and may, in principle, have been commercialized after the observation period.[22]

We investigate this data problem in three ways. First, we re-estimate the probit model in (5.4) with a sample selection correction, pooling both types of non-commercialized patents. Second, we estimate a multinomial logit model which is based on an extension of the theory to include the decision to not commercialize an invention. The latter model uses the information from non-commercialized patents where the inventors actively dropped their patent. Finally, we employ a duration analysis. This method takes account of the timing decision and controls for the fact that some patents may have been commercialized after the sample period.

5.4.1. Selection bias

Since the group of commercialized patents may not be a random sample of patents, but may have rather specific characteristics which led to them to be commercialized, there is a potential sample selection problem in 5.4.

To control for this, we also model the probability of commercialization

$$c_e = I[\theta_0 + \theta_z z_e + \boldsymbol{\theta}'\mathbf{X}_e + u_e > 0], \tag{5.6}$$

where $c_e = 1$ if commercialization is chosen and $c_e = 0$ otherwise. z_e is a variable which only affects the choice to commercialize but not the mode of commercialization. The variable z_e can be considered as a variable identifying draws of low-quality inventions, or inventions associated with high costs for commercialization, which would imply $R_{E,m}(\cdot) + \varepsilon_{e,m} < 0$ in (5.1). The vector $\mathbf{X}_e$ contains the same explanatory variables as those included in the probit model (5.4).

How may selection bias affect the estimates of $\boldsymbol{\gamma}$ in (5.4)? Suppose that u_e and ε_e in (5.4) and (5.6) contain an unobserved quality of the patent. From Definition 1, patents with a high unobserved quality will tend to be commercialized. But then, since u_e and ε_e are positively correlated (due to the unobserved quality), commercialized patents with high unobserved quality will tend to be sold to incumbents by Lemma 3. This selection mechanism may potentially generate an upward bias on the estimate of $\boldsymbol{\gamma} = \boldsymbol{\beta} - \boldsymbol{\alpha}$ in (5.4).

Assuming that the error terms u_e and ε_e are correlated according to a bivariate standard normal distribution with correlation ρ, (5.4) and (5.6) can be jointly estimated with maximum likelihood to obtain an estimate of $\boldsymbol{\gamma} = \boldsymbol{\beta} - \boldsymbol{\alpha}$ to test Proposition 4.[23] Svensson (2007) shows that government-financed inventions are less likely to be commercialized, arguing that inventions of inferior quality seek government support for commercialization and that the government loan terms discourage commercialization.

In table 5.7, we report the selection model using the full sample of 624 observations. Using the percentage of the R&D-stage financed by government (GOV) as the identifying variable z_e, we note that the results in the second-stage sale equation do not change qualitatively in relation to the corresponding probit specifications in table 5.5 and results are again consistent with Proposition 4(ii). Inspecting individual estimates, we note that W_CIT is still significant

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[22] This is less likely, however. In Svensson (2007), it was shown that the probability is very low that the 97 non-commercialized patents, which are still alive, will ever be commercialized.

[23] See, for instance, Van den Ven and Van Pragg (1981).

at the five-percent level. If a patent receives one more forward citation during a five-year period, the probability of sale increases by 4-5 percentage points in Models A-C. While the first stage identifies the commercialization decision through the government financing variable, the correlation between error terms u_e and ε_e is not significant.[24]

5.4.2. Identification with multinomial logit

The probit model with selection suggests that the error terms in the commercialization decision and the choice of type of commercialization are not correlated. Assuming this to be the case, we can formally integrate the commercialization decision into the theory, thus providing additional information for identification.

To see this, let $R_{e,No}(k,\tau,\Gamma,G) = R_{E,No}(k_e,\tau_e,\Gamma_e,G_e) + \varepsilon_{e,No}$ be the reward for "No commercialization". By definition, $R_{E,No}(k_e,\tau_e,\Gamma_e,G_e) = 0$ which can be (trivially) linearized in its arguments:

$$R_{e,No}(k_e,\tau_e,T_e,G_e) = \underset{(0)}{\psi_0} + \underset{(0)}{\psi_k} k_r + \underset{(0)}{\psi_F} F_r + \underset{(0)}{\psi_T} \Gamma_r = \mathbf{x}_e'\boldsymbol{\psi}. \tag{5.7}$$

Then, let $m,l = (Sale, Entry, No)$. The probability that the entrepreneur will choose commercialization mode m instead of commercialization mode l is then Prob$[m_e]$=Prob$[R_{e,m} > R_{e,l}]$ $\forall m \neq l$, or Prob$[m_e]$=Prob$[\varepsilon_{e,l} - \varepsilon_{e,m} < R_{E,m}(k,\tau,\Gamma,G) - R_{E,l}(k,\tau,\Gamma,G)]$ $\forall m \neq l$. Assuming that $\varepsilon_{e,m}$ is distributed according to the Gumbel distribution, $\varepsilon_e = \varepsilon_{e,m} - \varepsilon_{e,l}$ will be distributed according to the logistic distribution. Under the assumption that $\varepsilon_{e,No}$, $\varepsilon_{e,Sale}$ and $\varepsilon_{e,Entry}$ are not correlated, this gives rise to a multinomial logit model, where:

$$\text{Prob}[Sale_e] = \frac{e^{\mathbf{x}_e'\boldsymbol{\beta}}}{e^{\mathbf{x}_e'\boldsymbol{\beta}} + e^{\mathbf{x}_e'\boldsymbol{\alpha}} + e^{\mathbf{x}_e'\boldsymbol{\psi}}}, \quad \text{Prob}[Entry_e] = \frac{e^{\mathbf{x}_e'\boldsymbol{\alpha}}}{e^{\mathbf{x}_e'\boldsymbol{\beta}} + e^{\mathbf{x}_e'\boldsymbol{\alpha}} + e^{\mathbf{x}_e'\boldsymbol{\psi}}}. \tag{5.8}$$

Maximum Likelihood can now be used to estimate $\boldsymbol{\gamma}^{Sale} = \boldsymbol{\beta} - \boldsymbol{\psi}$ and $\boldsymbol{\gamma}^{Entry} = \boldsymbol{\alpha} - \boldsymbol{\psi}$, where $\boldsymbol{\psi} = \mathbf{0}$ from (5.7) identifies vectors $\boldsymbol{\beta}$ and $\boldsymbol{\alpha}$ from (5.2) and (5.3).

In table 5.8, we show the results from estimating (5.8) for the 364 patents which are commercialized (by Sale or Entry) and the 163 patents where we know that the holder actively chose not to commercialize (i.e. the patent expired without any income for the holder).[25] Given the identifying assumption of $\boldsymbol{\psi} = 0$, Wald tests show that $\boldsymbol{\beta} = \mathbf{0}, \boldsymbol{\alpha} = \mathbf{0}$ and $\boldsymbol{\beta} = \boldsymbol{\alpha}$ can all be rejected. Moreover, the parameter estimates and Wald tests on the citation variable W_CIT and, in particular, the citation dummy D_W_CIT indicate evidence of $\alpha_k > 0$ in (5.2), $\beta_k > 0$ in (5.3) and $\beta_k > \alpha_k$. Calculating marginal effects shows that if a patent receives one more forward citation during a five-year period, the probability of sale increases by 3.8 percentage points, entry increases by 2.6 percentage points and no commercialization decreases by 6.4 percentage points. From the estimates of $SMALL$ and $MICRO$, we also note that the

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[24] We also re-estimated table 5.6 with the citation binary variables, D_W_CIT and D_B_CIT without a qualitative change in the results.

[25] We omit the remaining 97 observations since we do not know the commercialization decision for these patents. This right-censoring problem is taken into account in the next section which uses a duration analysis.

Wald tests are largely consistent with $\alpha_G < 0$, $\beta_G = 0$ and that $\beta_G > \alpha_G$. Thus, the results are again consistent with Proposition 4(ii) identifying preemptive acquisitions.

The multinomial logit model gives additional evidence for the theory in terms of the reward function in (5.2) and (5.3), and the fact that incumbents' acquisitions are preemptive in nature. While the multinomial logit model is informative, it has its drawbacks. As mentioned, it assumes that the error terms in different commercialization modes, $\varepsilon_{e,m}$ are not correlated.[26] Another problem is that the temporal information in the data is not used. To address the latter problem, we finally turn to event history methods, i.e. duration analysis.

5.4.3. Duration analysis

The probit model with selection and the mulitnominal logit model take into account that some patents are not commercialized but not *when* a patent is commercialized, i.e. the temporal information in the data is not used.

To illustrate, the hazard function of the events of commercialization by entry and sale is shown in Figure 5.1, where these events are measured in years from the application date.[27] The hazard function, $h_m(t)$, shows the conditional probability of a patent commercialized by entry or sale in a specific time period Δt, given that it has "survived" (neither been commercialized by entry nor sale) until time point t. Note that the hazard function of entry levels away more quickly than that of sale. Thus, the timing of commercialization seems to be of importance. Inventors who already have firms may be able to start the commercialization more quickly through entry than inventors who try to sell or license their patents. In the latter case, inventors may face the problem of asymmetric information when searching for an external firm. These transaction costs may be inadequately captured by the private venture capital dummy used in the previous analysis. Moreover, there is a time lag of 2-3 years between patent application and granting. This means that there is an uncertainty regarding the scope of the patent protection for the acquiring firm. Acquisition and licensing contracts may then be delayed until the grant date.[28]

In the survival model, we estimate how different factors affect the number of years it takes from the time point of the patent application until the two events, T_{Sale} and T_{Entry}, occur for a patent. The survival model is estimated as a competing risk model, since the two events are mutually exclusive. Since we do not know the exact time point within a year when a patent is commercialized, T_{Sale} and T_{Entry} are interval-censored.[29] The accelerated failure time (AFT)

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[26] We tried to estimate a multinomial probit model which allows for estimating the correlation structure between the error terms. However, we then encountered the problem that our data lacks alternative-specific variables (variables which are constant over commercialization mode).

[27] The hazard can also be expressed as a function of the probability density function, $f(t)$, and the survival function: $\lambda(t) = f(t)/S(t)$, where the survival function, $S(t)$, shows how a large share of the patents survives beyond a time point, t.

[28] Gans *et al.* (2007) show empirically that patent allowance substantially increases the probability of a licensing agreement. But as many as 27 percent of all licensing contracts occur before the patents have been granted.

[29] If the patent is sold (commercialized by the inventor) within the first year, T_{Sale} (T_{Entry}) obtains an interval-censored value between 0.1 and 1, while the second year T_{Sale} (T_{Entry}) is between 1.1 and 2, etc.

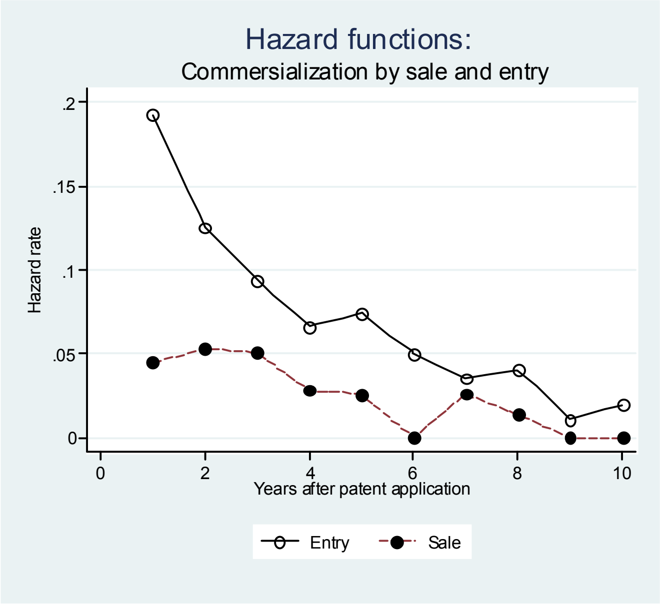

Figure 5.1: Illustrating the hazard rates for commercialization by entry and sale.

model is then the appropriate statistical model (Allison, 1995):

$$\log(T_{Sale,e}) = \mathbf{X}_e' \boldsymbol{\zeta}^{Sale} + \sigma^{Sale} \varepsilon_{e,Sale} \tag{5.9}$$

$$\log(T_{Entry,e}) = \mathbf{X}_e' \boldsymbol{\zeta}^{Entry} + \sigma^{Entry} \varepsilon_{e,Entry}, \tag{5.10}$$

where parameters ζ^m represent the impact of variables X_e on the expected time to commercialization. Note that a positive (negative) sign implies that the time until the event occurs increases (decreases), which is synonymous with a lower (higher) probability that the event occurs. The error term $\varepsilon_{e,m}$ can have various distributions, such as the log-normal, log-logistic, exponential, Weibull and gamma distributions, where estimates of parameter σ^m are used to parameterize the shape of the distribution.

The AFT models in (5.9) and (5.10) are estimated by Maximum Likelihood. When estimating the sale event in (5.9), we treat commercialization by entry ($m = Entry$) as right-censored. Likewise, when estimating the entry event in (5.10), we treat the event of commercialization by sale ($m = Sale$) as right-censored. At the end point of observation in 2005, the holder had not yet taken a decision on commercialization for 97 patents and these patents are thus "right-censored" in this year. Furthermore, an expired patent cannot be commercialized. 163 non-commercialized patents that expired before 2005 are thus right-censored in this expiration year.

Estimates of $\boldsymbol{\zeta}^{Sale}$ and $\boldsymbol{\zeta}^{Entry}$ in (5.9) and (5.10) for the full sample of 624 observations are shown for the log normal distribution in Table 5.7.[30] Regardless of specification or measure, as

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[30] The results do not change qualitatively using other distributional assumptions on the error term, $\varepsilon_{e,m}$. The gamma distribution has the advantage that other distributions can be tested against the gamma distribution. However, when applying the assumption of a gamma distribution, we did not achieve convergence. We only report results for the log normal distribution. The results for other distributional

shown by W_CIT in table 5.9 or D_W_CIT in table 5.10, forward citations within the same technology class have a negative and strongly significant impact on the time until commercialization by sale occurs.[31] Quantifying this effect from specification (ii) in table 5.9, if a patent receives one more forward citation within technologies (during a five-year period), the time until sale occurs decreases by around 30 percent. On the other hand, there is no statistically significant impact on the time to commercialization by entry. More importantly, we can reject the null-hypothesis of equal estimates, $\zeta^{Sale}_{W\_CIT} - \zeta^{Entry}_{W\_CIT} = 0$, at the five-percent level.[32] For the variables $SMALL$ and $MICRO$, proxying for the entry costs G, we find strong evidence on the time for commercialization by entry, while these variables have no (or statistically weak) effects on the time to commercialization by sale. Also in these cases, $\zeta^{Sale}_{SMALL} - \zeta^{Entry}_{SMALL} = 0$ and $\zeta^{Sale}_{MICRO} - \zeta^{Entry}_{MICRO} = 0$ are strongly rejected.

These results are consistent with the inventor choosing mode m in t when the reward $R_{E,m}(\cdot) + \varepsilon_{e,m}$ is highest in this alternative in a setting where inventions are sold under preemptive bidding competition between incumbent firms. To see this, note that $\beta_k > \alpha_k > \psi_k = 0$ in (5.2), (5.3) and (5.7). It then follows that increasing the quality of an invention, commercialization by sale will become more profitable – irrespective of if a comparison is made with entry or no commercialization. But this inequality also shows that while higher quality makes commercialization by entry more attractive relative to no commercialization, commercialization by entry becomes less attractive when compared to commercialization by sale. Noting that the impact of entry costs fulfils $\beta_G = \psi_G > \alpha_G < 0$ from (5.2), (5.3) and (5.7), we can also reconcile the results of variables $SMALL$ and $MICRO$, proxying for entry costs G.

Given this interpretation of the parameter signs in the AFT models, we note that the results do not deviate from our findings in the probit and multinomial logit models.

6. Concluding remarks

We propose a theory of the mode of commercialization (sale or entry) of entrepreneurial inventions in oligopoly. We show that when the invention has a higher quality, it is more likely that it is sold (or licensed), due to strategic product market effects on the sales price. Preemptive acquisitions of entrepreneurial firms by incumbents can also stimulate the process of creative destruction by increasing the incentives to develop high-quality inventions. Moreover, we find evidence that high-quality inventions are sold under preemptive bidding competition using unique patent data. Consistent with the model, we find that high entry costs are conducive to selling.

Previous literature has shown that entrepreneurs play an important role in challenging existing oligopolistic markets through de-novo entry into the product market. Yet, we identify another important role of the entrepreneur as challenger of existing oligopolies through the aggressive development of inventions for sale. The role as an aggressive invention supplier may

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assumptions are available upon request.

[31] The results in Model A are not affected when dropping GOV.

[32] Since the events are mutually exclusive, the difference in parameter estimates for a variable x can be tested as $\chi^2_j \sim \frac{(\zeta^{Sale}_x - \zeta^{Entry}_x)^2}{\sigma^2_{\zeta^{Sale}_x} + \sigma^2_{\zeta^{Entry}_x}}$ (Allison, 1995).

be even more important than the role of de-novo entrant. Indeed, we show that the possibility of preemptive incumbent acquisition gives entrepreneurs the incentive to increase their efforts in high-quality research projects so that expected welfare can increase despite the risk of increased market power.

Schumpeter (1942) argued that the ongoing process of "creative destruction" where independent entrepreneurs innovate for entry is crucial for sustained growth. The development of financial markets and the strengthening of property rights over the last decades have, however, implied that incumbent firms face better opportunities to protect their market from such entry by undertaking preemptive acquisitions. However, we have shown that the possibility of such acquisitions creates stronger incentives for entrepreneurs to develop high-quality inventions. Consequently, in the present and in the future, it may be the combination of ”creative destruction and productive preemption” which matters for sustained growth.

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7. Appendix

7.1. Proof of Lemma 1

First, note that $b_i \geq \max v_{il}$, $l = \{\mathrm{e}, \mathrm{i}\}$ is a weakly dominated strategy, since no incumbent will post a bid equal to or above its maximum valuation of obtaining the invention and that firm e will accept a bid iff $b_i > v_e$.

Inequality I1 Consider equilibrium candidate $\mathbf{b}^* = (b_1^*, b_2^*, ..., yes)$. Let us assume that incumbent $w \neq e$ is the incumbent that has posted the highest bid and obtains the assets and firm $s \neq d$ is the incumbent with the second highest bid.

Then, $b_w^* \geq v_{ii}$ is a weakly dominated strategy. $b_w^* < v_{ii} - \varepsilon$ is not an equilibrium, since firm $j \neq w, e$ then benefits from deviating to $b_j = b_w^* + \varepsilon$, since it will then obtain the assets and pay a price lower than its valuation of obtaining them. If $b_w^* = v_{ii} - \varepsilon$, and $b_s^* \in [v_{ii} - \varepsilon, v_{ii} - 2\varepsilon]$, then no incumbent has an incentive to deviate. By deviating to *no*, the entrepreneur's payoff decreases since it foregoes a selling price exceeding its valuation, v_e. Accordingly, the entrepreneur has no incentive to deviate and thus, $\mathbf{b}^*$ is a Nash equilibrium.

Let $\mathbf{b} = (b_1, , , b_n, no)$ be a Nash equilibrium. Let incumbent h be the incumbent with the highest bid. The entrepreneur will then say *no* iff $b_h \leq v_e$. But incumbent $j \neq e$ will have the incentive to deviate to $b' = v_e + \varepsilon$ in period 1, since $v_{ie} > v_e$. This contradicts the assumption that $\mathbf{b}$ is a Nash equilibrium.

Inequality I2 Consider equilibrium candidate $\mathbf{b}^* = (b_1^*, b_2^*, ..., y)$. Then, $b_w^* \geq v_{ij}$ is a weakly dominated strategy. $b_w^* < v_{ij} - \varepsilon$ is not an equilibrium since firm $j \neq w, e$ then benefits from deviating to $b_j = b_w^* + \varepsilon$, since it will then obtain the assets and pay a price lower than its valuation of obtaining them. If $b_w^* = v_{ii} - \varepsilon$, and $b_s^* \in [v_{ii} - \varepsilon, v_{ii} - 2\varepsilon]$, then no incumbent has an incentive to deviate. By deviating to *no*, the entrepreneur's payoff decreases since it foregoes a selling price exceeding its valuation, v_e. Accordingly, the entrepreneur has no incentive to deviate and thus, $\mathbf{b}^*$ is a Nash equilibrium.

Consider the equilibrium candidate $\mathbf{b}^{**} = (b_1^{**}, b_2^{**}, ..., no)$. Then, $b_w^* \geq v_{ie}$ is not an equilibrium since the entrepreneur would then benefit by deviating to *yes*. If $b_w^* \leq v_e$, then no incumbent has an incentive to deviate. By deviating to *yes*, the entrepreneur's payoff decreases since it then sells its assets at a price below its valuation, v_e. The entrepreneur has no incentive to deviate and thus, $\mathbf{b}^{**}$ is a Nash equilibrium.

Inequality I3 Consider equilibrium candidate $\mathbf{b}^* = (b_1^*, b_2^*, ..., yes)$. Then, $b_w^* \geq v_{ii}$ is a weakly dominated strategy. $b_w^* < v_{ii} - \varepsilon$ is not an equilibrium since firm $j \neq w, e$ then benefits from deviating to $b_j = b_w^* + \varepsilon$, since it will then obtain the assets and pay a price lower than its valuation of obtaining them. If $b_w^* = v_{ii} - \varepsilon$, and $b_s^* \in [v_{ii} - \varepsilon, v_{ii} - 2\varepsilon]$, then no incumbent has an incentive to deviate. By deviating to *no*, the entrepreneur's payoff decreases since it foregoes a selling price exceeding its valuation, v_e. Accordingly, the entrepreneur has no incentive to deviate and thus, b^* is a Nash equilibrium.

Let $b = (b_1, ..., b_n, no)$ be a Nash equilibrium. The entrepreneur will then say *no* iff $b_h \leq v_e$. But incumbent $j \neq e$ will then have the incentive to deviate to $b' = v_e + \varepsilon$ in stage 1, since $v_{ie} > v_e$. This contradicts the assumption that $\mathbf{b}$ is a Nash equilibrium.

Inequality I4 Consider equilibrium candidate $b^* = (b_1^*, b_2^*, ..., yes)$. Then, $b_w^* > v_e$ is not an equilibrium since firm w would then benefit from deviating to $b_w = v_e$. $b_w^* < v_e$ is not an equilibrium, since the entrepreneur would then not accept any bid. If $b_w^* = v_e - \varepsilon$, then firm w has no incentive to deviate. By deviating to $b_j' \leq b_w^*$, firm j's, $j \neq w, e$, payoff does not change. By deviating to $b_j' > b_w^*$, firm j's payoff decreases since it must pay a price above its willingness to pay v_{ii}. Accordingly, firm j has no incentive to deviate. By deviating to *no*, the entrepreneur's payoff decreases since it foregoes a selling price above its valuation v_e. Accordingly, the entrepreneur has no incentive to deviate and thus, b^* is a Nash equilibrium.

Let $b = (b_1, , , b_n, yes)$ be a Nash equilibrium. If $b_w \geq v_{ii}$, then firm w will have the incentive to deviate to $b' = b_w - \varepsilon$. If $b_w < v_{ii}$, the entrepreneur will have the incentive to deviate to *no*, which contradicts the assumption that b is a Nash equilibrium.

Let $b = (b_1, ..., b_n, no)$ be a Nash equilibrium. The entrepreneur will then say *no* iff $b_h \leq v_e$. But incumbent $j \neq d$ will have the incentive to deviate to $b' = v_e + \varepsilon$ in stage 1 since $v_{ie} > v_e$, which contradicts the assumption that b is a Nash equilibrium.

Inequalities I5 or I6 Consider equilibrium candidate $b^* = (b_1^*, b_2^*, ..., no)$, where $b_j^* < v_e$ $\forall j \in J$. It then directly follows that no firm has an incentive to deviate and thus, b^* is a Nash equilibrium.

Then, note that the entrepreneur will accept a bid iff $b_j \geq v_e$. But $b_j \geq v_e$ is a weakly dominating bid in these intervals, since $v_e > \max\{v_{ii}, v_{ie}\}$. Thus, the assets will not be sold in these intervals.

Table 5.1. Explanatory variables and basic statistics.

Variable name	Variable description	Measure of:	Expected sign (preemptive acquisition):	All patents (n=624)		Commercialized patents (n=364)	
				Mean	Std.dev.	Mean	Std.dev.
W_CIT	Number of forward citations within technologies per five-year period	k	$\gamma_{W\_CIT} > 0$	0.41	0.93	0.49	1.03
D_W_CIT	Dummy = 1 if the patent has received forward citations within technologies, and 0 otherwise	k	$\gamma_{W\_CIT} > 0$	0.36	0.48	0.41	0.49
SMALL	Dummy which equals 1 for small firms (11-200 employees), and 0 otherwise	G	$\gamma_{SMALL} < 0$	0.16	0.37	0.20	0.40
MICRO	Dummy which equals 1 for micro firms (2-10 employees), and 0 otherwise	G	$\gamma_{MICRO} < 0$	0.20	0.40	0.24	0.43
PVC	Percentage of R&D-phase financed by private venture capitalist	Γ	$\gamma_{PVC} > 0$	3.17	13.9	3.44	14.4
B_CIT	Number of forward citations between technologies per five-year period			0.05	0.21	0.07	0.24
D_B_CIT	Dummy = 1 if the patent has received forward citations between technologies, and 0 otherwise			0.08	0.28	0.10	0.30
APPLY	Application year			1995	1.7	1995	1.7
GOV	Percentage of R&D-phase financed by government			9.26	20.7	6.38	15.7

Table 5.2. Commercialization mode and forward patent citations within technologies, number of patents and citations.

W_CIT	No commercialization	Entry	Sale	All
W_CIT=0	188 (72 %)	164 (60 %)	49 (54 %)	401 (64 %)
W_CIT=1	32	46	16	94
W_CIT=2	15	24	8	47
W_CIT=3	8	11	6	25
W_CIT>3	17	28	12	57
Total No. of patents	260	273	91	624
Total No. of citations	196	294	146	636
Average No. of citations per patent	0.75	1.08	1.60	1.02

Table 5.3. Forward citations (within technologies) in relation to patent application, entry and sale.

	No. of forward citations after		
Year	Patent application (year=0)	Entry (year=0)	Sale (year=0)
-1 - 0	0	13	13
0 - 1	2	23	8
1 - 2	12	34	15
2 - 3	44	**43**	**15**
3 - 4	76	**48**	**16**
4 - 5	95	**33**	**15**
5 - 6	86	39	14
6 - 7	95	33	7
7 - 8	74	25	9
8 - 9	83	15	6
9 - 10	47	10	8
10 - 11	47	2	4
11 – 12	18	2	2

Table 5.4 Commercialization mode across firm sizes, number of patents and percent.

Kind of firm where invention was created	Total number of patents	Percent latest commercialized in 2003	Percent Entry	Percent Sale
Small firms (11-200 employees)	102	70 %	63 %	7 %
Micro companies (2-10 employees)	122	72 %	57 %	15 %
Individuals (1-4 inventors)	400	51 %	35 %	16 %
Total	624	58 % (n=264)	44 % (n=273)	14 % (n=91)

Table 5.5. Results of the probit model

Explanatory variables	Dependent variable = *SALE*		
	Statistical model: Binomial probit model		
	Model A	Model B	Model C
W_CIT	0.144 **	0.161 **	0.161 **
	(0.069)	(0.073)	(0.075)
SMALL	-0.946 ***	-0.938 ***	-0.954 ***
	(0.247)	(0.247)	(0.246)
MICRO	-0.342*	-0.31)	-0.318 *
	(0.190)	(0.192)	(0.191)
PVC	6.1 E-3	5.8 E-3	6.0 E-3
	(5.2 E-3)	5.1 E-3)	(5.1 E-3)
B_CIT		-0.429	-0.428
		(0.38)	(0.38)
APPLY			-0.031
			(0.05)
Technology FE	Yes	Yes	Yes
Region FE	Yes	Yes	Yes
Log Likelihood	-185.2	-184.7	-184.4
I. Wald, χ^2	42.8 **	43.5 **	44.2 **
II. Wald, χ^2 (Core var.)	20.55***	20.80***	21.79***

Note: The number of observations is 364. *SALE* equals 1 for 91 observations. ***, ** and * indicate significance at the 1, 5 and 10 percent level. Standard errors clustered on inventor are given in parentheses. Parameter estimates for constants, technology and region dummies are not shown, but are available from the authors upon request.

Wald χ^2 I tests the hypothesis $\boldsymbol{\gamma} = \mathbf{0}$ in (5.4). Wald χ^2 test II repeats this for the core variables for *W_CIT, SMALL, MICRO* and *PVC*.

Table 5.6. Results of the probit model with citation dummies

Explanatory Variables	Dependent variable = *SALE*		
	Statistical model: Binomial probit model		
	Model A	Model B	Model C
D_W_CIT	0.280 *	0302 *	0.303 *
	(0.166)	(0.170)	(0.171)
SMALL	-0.967 ***	-0.959 ***	-0.972 ***
	(0.247)	(0.247)	(0.246)
MICRO	-0.365*	-0.351 *	-0.354 *
	(0.192)	(0.194)	(0.193)
PVC	5.6 E-3	5.3 E-3	5.4 E-3
	(5.1 E-3)	5.2 E-3)	(5.2 E-3)
D_B_CIT		-0.193	-0.198
		(0.259)	(0.25)
APPLY			-0.033
			(0.045)
Technology FE	Yes	Yes	Yes
Region FE	Yes	Yes	Yes
Log Likelihood	-185.2	-184.7	-184.4
I. Wald, χ^2	40.9 **	41.9 **	45.1 **
II. Wald, χ^2 (Core var.)	19.40***	19.36***	21.32***

Note: The number of observations is 364. *SALE* equals 1 for 91 observations. ***, ** and * indicate significance at the 1, 5 and 10 percent level. Standard errors clustered on inventor are given in parentheses. Parameter estimates for constants, technology and region dummies are not shown, but are available from the authors upon request.

Wald χ^2 I tests the hypothesis $\gamma = 0$ in (5.4). Wald χ^2 test II repeats this for the core variables for *D_W_CIT, SMALL, MICRO* and *PVC*.

Table 5.7. Results of the probit model with selectivity

Explanatory Variables	Dependent variable = *SALE*					
	Statistical model: Binomial probit model with sample selection					
	Model A		Model B		Model C	
	Sale	Commers. (*selection*)	Sale	Commers. (*selection*)	Sale	Commers. (*selection*)
W_CIT	0.156 **	0.143 **	0.172 **	0.133 *	0.174 **	0.135 **
	(0.074)	(0.069)	(0.077)	(0.068)	(0.077)	(0.067)
SMALL	-0.892 ***	0.302 *	-0.883 ***	0.293 *	-0.895 ***	0.289 *
	(0.297)	(0.173)	(0.298)	(0.16)	(0.295)	(0.16)
MICRO	-0.278	0.516 ***	-0.249	0.509 ***	-0.25	0.506 ***
	(0.263)	(0.155)	(0.263)	(0.14)	(0.257)	(0.144)
PVC	6.4 E-3	1.9 E-3	6.1 E-3	1.9 E-3	6.3 E-3	1.8 E-3
	(5.2 E-3)	(4.5 E-3)	(5.1 E-3)	(3.8 E-3)	(5.1 E-3)	(3.8 E-3)
B_CIT			-0.411	0.142	-0.410	0.140
			(0.382)	(0.31)	(0.378)	(0.31)
APPLY					0.029	0.016
					(0.047)	(0.032)
GOV		-8.9 E-3 ***		-8.9 E-3 ***		-9.1 E-3 ***
		(2.5 E-3)		(2.6 E-3)		(2.6 E.-3)
Technology FE	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
Log Likelihood	-583.2		-582.5		-582.2	
ρ	0.208		0.216		0.226	
	(0.546)		(0.549)		(0.524)	
I. Wald, χ^2	38.8**	49.43***	38.9**	49.3***	39.5**	49.6***
II Wald, χ^2 (Core var.)	15.3***	20.2***	17.8***	17.4***	18.4***	17.3***
III. Wald, χ^2 (ρ=0)	0.14		0.15		0.17	

Note: The number of observations in the selection stage (commercialization decision) is 624. In the sale stage (mode of commercialization decision) there are 364 observations, where *SALE* equals 1 for 91 observations. ***, ** and * indicate significance at the 1, 5 and 10 percent level. Standard errors clustered on inventor are given in parentheses. Parameter estimates for constants, technology and region dummies are not shown, but are available from the authors upon request.

Wald test I tests for $\boldsymbol{\gamma} = \mathbf{0}$ in (5.5), $\boldsymbol{\eta} = (\theta_z\ \boldsymbol{\Theta})' = \mathbf{0}$ in (5.6), respectively. Wald χ^2 test II repeats this for the core variables for *W_CIT, SMALL, MICRO* and *PVC*. Wald tests III tests the null hypothesis of no correlation between the error terms in (5.5) and (5.6).

Table 5.8. Results of the multinomial logit model

Explanatory variables	Multinomial logit model with “No commercialization” as the base alternative					
	Model A (Quality measured with W_CIT)			Model B (Quality measured with D_W_CIT)		
	SALE	*ENTRY*	Wald χ^2 (diff)	*SALE*	*ENTRY*	Wald χ^2 (diff)
W_CIT	0.454*	0.268	3.32*	1.340***	0.859***	2.78*
	(0.241)	(0.216)		(0.323)	(0.256)	
SMALL	-0.458	1.174***	12.84***	-0.595	1.075***	13.08***
	(0.526)	(0.361)		(0.530)	(0.364)	
MICRO	0.856**	1.376***	2.50	0.678	1.274***	3.19*
	(0.397)	(0.337)		(0.400)	(0.335)	
PVC	1.1 E-2	4.1 E-3	1.66	8.9 E-3	-7.5 E-3	1.36
	(8.2 E-3)	(8.6 E-3)		(8.2 E-3)	(8.6 E-3)	
Technology dummies	Yes	Yes		Yes	Yes	
Regional dummies	Yes	Yes		Yes	Yes	
Log likelihood	483.0			-476.9		
I. Wald χ^2	90.2***			99.4***		
II. Wald χ^2	37.2**	49.9***	39.7**	55.0***	55.5***	38.2**
III, Wald χ^2 (core)	13.2**	28.5***	19.0***	23.9***	29.2***	17.8***

Note : The number of observations equals 527, of which *ENTRY*=1 for 273 observations and *SALE*=1 for 91 observations. 163 observations classified as No commercialized, where the patent has expired with the inventor receiving no income. Standard errors clustered on inventor are given in parentheses. ***, ** and * indicate significance at the 1, 5 and 10 percent level. Parameter estimates for technology and region dummies are not shown, but are available from the authors upon request.

Wald test I tests the full specification of (5.8). Wald test II in columns two and three tests $\beta = 0$ and $\alpha = 0$ in (5.8), respectively, under the assumption of $\psi = 0$. Wald test II in column four tests $\beta = \alpha$. Wald test III repeats these tests for the core variables *W_CIT, SMALL, MICRO* and *PVC.*

The Wald tests in column four test if the individual parameter estimates of the core variables differ between equations.

Columns five to seven repeats the procedure using specifications with variables *D_W_CIT, SMALL, MICRO* and *PVC.*

Table 5.9. Results of the survival model with competing risks, part I (cont.)

Explanatory variables	Accelerated failure time model with competing risks – log-normal model					
	Model A			Model B		
	ENTRY	*SALE*	Diff. χ^2	*ENTRY*	*SALE*	Diff. χ^2
W_CIT	-0.0112	-0.30***	3.59*	-5.1 E-3	-0.34***	4.33**
	(0.11)	(0.11)		(0.12)	(0.11)	
SMALL	-1.22***	1.05**	21.9***	-1.21***	1.03**	21.8***
	(0.26)	(0.41)		(0.26)	(0.41)	
MICRO	-0.98***	-0.029	6.41**	-0.98***	-0.064	5.85**
	(0.24)	(0.29)		(0.24)	(0.30)	
PVC	3.9 E-3	-5.3 E-3	0.85	3.9 E-3	-5.1 E-3	0.81
	(7.1 E-3)	(7.0 E-3)		(7.1 E-3)	(7.0 E-3)	
B_CIT				-0.085	0.74	1.02
				(0.42)	(0.70)	
GOV	0.012**	7.3 E-3	0.31	0.017**	7.7 E-3	0.26
	(5.2 E-3)	(5.9 E-3)		(5.2 E-3)	(5.9 E-3)	
σ	1.96	1.73		1.92	1.72	
Technology dummies	Yes	Yes		Yes	Yes	
Regional dummies	Yes	Yes		Yes	Yes	
Log likelihood	-879.8	-403.6		-879.8	-403.0	

Note: The number of observations equals 624, of which *ENTRY*=1 for 273 observations and *SALE*=1 for 91 observations. ***, ** and * indicate significance at the 1, 5 and 10 percent level. Standard errors are in parentheses. Parameter estimates for technology and region dummies are not shown, but are available from the authors upon request.

Note 2. A positive parameter estimate increases the time to commercialization (by entry or sale). A negative estimate decreases the time to commercialization (by entry or sale).

Table 5.9. part II (cont.)

Explanatory variables	Accelerated failure time model with competing risks – log-normal model		
	Model C		
	ENTRY	*SALE*	Diff. χ^2
W_CIT	-0.013	-0.35 ***	4.22**
	(0.12)	(0.11)	
SMALL	-1.20***	1.01 **	21.04***
	(0.26)	(0.41)	
MICRO	-0.97***	-0.06	5.77**
	(0.24)	(0.29)	
PVC	4.6 E-3	-5.0 E-3	0.93
	(7.1 E-3)	(7.0 E-3)	
B_CIT	-0.079	0.75	0.69
	(0.42)	(0.70)	
APPLY	-0.081	-0.042	0.20
	(0.057)	(0.066)	
GOV	0.013**	8.1 E-3	0.31
	(5.2 E-3)	(5.9 E-3)	
σ	1.91	1.71	
Technology dummies	Yes	Yes	
Regional dummies	Yes	Yes	
Log likelihood	-878.8	-402.8	

Table 5.10. Results of the survival model with competing risks, part I (cont.)

Explanatory variables	Accelerated failure time model with competing risks – log-normal model					
	Model A			Model B		
	ENTRY	*SALE*	Diff. χ^2	*ENTRY*	*SALE*	Diff. χ^2
D_W_CIT	-0.0248	-0.66***	4.06**	-0.028 E-3	-0.71***	4.33**
	(0.20)	(0.25)		(0.20)	(0.25)	
SMALL	-1.21***	1.11***	22.5***	-1.22***	1.10***	22.4***
	(0.26)	(0.41)		(0.26)	(0.41)	
MICRO	-0.98***	-0.073	7.58***	-0.98***	-0.062	7.45**
	(0.24)	(0.30)		(0.24)	(0.30)	
PVC	3.9 E-3	-4.4 E-3	0.68	3.9 E-3	-4.2 E-3	0.64
	(7.1 E-3)	(7.1 E-3)		(7.1 E-3)	(7.2 E-3)	
D_B_CIT				-0.024	0.33	0.31
				(0.33)	(0.44)	
GOV	0.012**	7.1 E-3	0.34	0.012**	7.3 E-3	0.31
	(5.2 E-3)	(5.9 E-3)		(5.2 E-3)	(5.9 E-3)	
σ	1.92	1.74		1.92	1.74	
Technology dummies	Yes	Yes		Yes	Yes	
Regional dummies	Yes	Yes		Yes	Yes	
Log likelihood	-879.8	-404.0		-879.8	-403.7	

Note: The number of observations equals 624, of which *ENTRY*=1 for 273 observations and *SALE*=1 for 91 observations. ***, ** and * indicate significance at the 1, 5 and 10 percent level. Standard errors are in parentheses. Parameter estimates for technology and region dummies are not shown, but are available from the authors upon request.

Table 5.10. part II (cont.)

Explanatory variables	Accelerated failure time model with competing risks – log-normal model		
	Model C		
	ENTRY	*SALE*	Diff. χ^2
D_W_CIT	-0.019	-0.70***	4.43**
	(0.20)	(0.25)	
SMALL	-1.20***	1.10***	22.2***
	(0.26)	(0.41)	
MICRO	-0.97***	-0.063	7.34***
	(0.24)	(0.30)	
PVC	4.5 E-3	-4.1 E-3	0.73
	(7.1 E-3)	(7.1 E-3)	
D_B_CIT	-0.043	0.32	0.27
	(0.33)	(0.44)	
APPLY	-0.081	-0.022	0.45
	(0.057)	(0.066)	
GOV	0.013**	7.5 E-3	0.40
	(5.2 E-3)	(5.9 E-3)	
σ	1.91	1.73	
Technology dummies	Yes	Yes	
Regional dummies	Yes	Yes	
Log likelihood	-878.8	-403.7	