DISCUSSION PAPER SERIES

No. 8281

CREATIVE DESTRUCTION AND PRODUCTIVE PREEMPTION

Pehr-Johan Norbäck, Lars Persson and Roger Svensson

INDUSTRIAL ORGANIZATION

Centre for Economic Policy Research

www.cepr.org

Available online at: www.cepr.org/pubs/dps/DP8281.asp

ISSN 0265-8003

CREATIVE DESTRUCTION AND PRODUCTIVE PREEMPTION

Pehr-Johan Norbäck, Research Institute of Industrial Economics (IFN)
Lars Persson, Research Institute of Industrial Economics (IFN) and CEPR
Roger Svensson, Research Institute for Industrial Economics (IFN)

Discussion Paper No. 8281
March 2011

Centre for Economic Policy Research
77 Bastwick Street, London EC1V 3PZ, UK
Tel: (44 20) 7183 8801, Fax: (44 20) 7183 8820
Email: cepr@cepr.org, Website: www.cepr.org

CEPR Discussion Paper No. 8281

March 2011

ABSTRACT

Creative Destruction and Productive Preemption*

We develop a theory of innovation for entry and sale 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. 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 data on patents granted to small firms and individuals, we find evidence that high-quality inventions are sold under bidding competition. Asymmetric information problems are shown to be solved by verification through entry for sale.

JEL Classification: G24, L1, L2, M13 and O3
Keywords: acquisitions, entrepreneurship, innovation, ownership, patent and start-ups

Pehr-Johan Norbäck
The Research Institute of Industrial Economics (IUI)
Box 5501
S-11485 Stockholm
SWEDEN

Email: PJN@iui.se

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=153438

Lars Persson
Research Institute of Industrial Economics (IFN)
Box 55665
S-102 15 Stockholm
SWEDEN

Email: lars.persson@ifn.se

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=134788

Roger Svensson
Research Inst for Indust Economics
Box 55665
S-102 15 Stockholm
SWEDEN

Email: roger.svensson@ifn.se

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=173297

* We have greatly benefitted from comments from Marcus Asplund, Magnus Henrekson, Jim Levinsohn, Hodaka Morita, Sören-Bo Nielsen and Marie Thursby, and participants in seminars at IIOC Conference 2009, IFN Stockholm Conference 2007, Copenhagen Bussines School, Tilburg University and Royal Institute of Technology (Stockholm). Financial support from Jan Wallander's and Tom Hedelius' Research Foundation is gratefully acknowledged. This paper was written within the Gustaf Douglas Research Program on Entrepreneurship.

Submitted 21 February 2011

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 extensively studied in the case where an entrepreneur commercializes the invention by entering the product market.[1] However, if incumbent profits are diminished by entrepreneurial entry, incumbents have an incentive to acquire these entrepreneurial firms (or their inventions) to block entry (entry-deterring acquisitions), or preempt rivals from obtaining superior assets (preemptive acquisitions).[2],[3]

This raises the question: Do the increasingly more active Merger and Acquisition (M&A) markets across the world harm the innovation process by allowing incumbents to undertake acquisitions of small innovative firms? The purpose of this paper is to answer this question with a theoretical study of how the innovation process is affected by the hitherto ignored fact that entrepreneurial entry might be blocked by incumbents - either by entry-deterring or by preemptive acquisitions. We empirically test if there is evidence of preemptive acquisitions of entrepreneurial inventions.

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. 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. All players in the base model are completely informed about their own and other players' characteristics. This allows us to clearly attribute product market force effects, as opposed to, say, problems of incomplete information, which have been extensively studied in the literature.[4]

What type of inventions will be sold? We 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 not only increases entrants' and acquirers' profits in a similar fashion, but also reduces the profit of the non-acquirers. This implies that the

[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] Indeed, according to the Economist (Feb 18th, 1999), innovators know that incumbent firms that risk tough competition from not buying are willing to pay a lot for inventions, as indicated by the following quote: *"Companies like Cisco, Intel and Microsoft recognize the threat posed by nimble young firms getting technologies to market at unimaginable speeds," says Red Herring's Brian Taptich. "And they're willing to pay extremely high premiums to protect their franchises."*

An example is Cerent, which was acquired by Cisco at $6.9 billion.

[3] Granstrand and Sjölander (1990) and Hall (1990) present evidence of firms acquiring innovative targets to gain access to their technologies. Bloningen and Taylor (2000) find evidence from the US high-tech sector 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.

[4] Anton and Yao (1994), and Gans and Stern (2000).

incumbents' 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 commercialization mode affects the incentive to develop high-quality inventions. When the entrepreneur commercializes by entry, the marginal revenue of providing a higher quality invention is the marginal change in product market profit as an entrant. When commercializing by sale the marginal revenue will be higher. Increased quality of the invention not only increase the profit of an acquirer of the invention, but will also decrease the profit of a 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 mode of commercialization (sale or entry). To identify bidding competition, we note that the rent accruing to the entrepreneur from entry-deterring acquisitions will be differently affected by changes in the quality of the invention, and fixed costs and entry costs, than will be the rent from preemptive acquisitions. Hence, a structural model can be used to identify preemptive acquisitions in the data. We then estimate the entrepreneur's decision of mode of commercialization on a detailed data 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.[5] 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 are shown to identify preemptive bidding competition between incumbent firms. To our knowledge, we are the first to provide evidence of preemptive bidding competition in a structural model approach.

We also show that the result of high quality inventions being sold under bidding competition remains in many extensions of the base model, allowing for inventions which are not commercialized, asymmetric incumbents, synergies between the invention and incumbents' assets, and multi-firm licensing.

We then examine how asymmetric information problems may affect our findings. We focus on the situation where only the entrepreneur initially knows whether she has succeeded with the invention or not. The entrepreneurs can then mitigate such information problems by first entering the product market and revealing high profits, low costs or high sales. Entry is a credible verification in most countries since mandatory disclosure laws and different type of auditing systems are built up to certify that information about firms' revenues, cost and profits are accurately reported.[6] Indeed, in the data we find that 30 out of the 91 sold patents where

[5] Most reported sales in the data involved large incumbent acquirers.

[6] There is a small literature on costly disclosure and debt financing (see Townsend (1979) and Gale and Hellwig (1985).

first commercialized by entry and then subsequently sold.

The entrepreneur then faces the choice of selling early under asymmetric information, entering to stay, or entering to sell late under perfect information. We show that a higher quality of the invention is conducive to late sale (after an initial commercialization by entry), whereas higher quality is not conducive to a direct sale (without first commercializing by entry). These predictions are also supported by the data. To explore this issue further, we also conduct a duration analysis where we measure the time to commercialization. The data confirms the presence of information costs, in that commercialization by sale take longer time than commercialization by entry. However, we also find higher quality of invention significantly reduces the time to commercialization, and that this effect is stronger on commercialization by sale than under commercialization by entry.

This paper contributes to the literature studying when assets will be sold on the market. To date it has been found that commercialization by sale is more likely when entry costs are high, when the entrepreneurial firm lacks complementary assets, when brokers facilitating trade are available, and when the expropriation problem associated with asset transfers are low (see, for instance, Anton and Yao (1994), Gans and Stern (2000) and Gans et al. (2002)). Moreover, in his seminal paper, Akerlof (1970) showed that informational asymmetries can give rise to adverse selection on markets, resulting in only low-quality assets being sold.[7] In contrast, we show theoretically that when inventions are sold into oligopolistic markets, absent the information problem, product market externalities imply that only high-quality assets will be sold on the market. In the presence of information problems, we show that the entrepreneur has an incentive to verify high quality inventions by entering the product market and then selling the invention. Using patent data we also find empirical evidence that high-quality inventions are sold on the market. However, these data also show that the strongest effect is found for the case where the entrepreneur first enters the product market and then sells the invention; thus, the asymmetric information problem could materialize in the cost of entry for verification of quality of the invention.

This paper is also closely related to the literature on auctions with externalities (see, for instance, Jehiel, Moldovanu and Stacchetti (1996, 1999). To date it has been shown that the externalities associated with the use of an object for sale will affect the equilibrium identity of the buyer, the sales price, and that traditional auction formats need then not be efficient. We add to this literature by endogenizing the effort to provide assets with externalities for sale in an environment where the potential seller can choose to sell the asset or use it to compete with the potential buyers.[8] Moreover, to our knowledge, we provide the first structural model empirical support of an auction of externality model.[9] We also expect similar mechanisms of how quality

[7] The 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 selection.

[8] Most papers in this literature treat the size of the asset for sale as exogenous. To our knowledge, the only exceptions are Katz and Shapiro (1986), who determine the optimal licensing fee of a research lab which can affect the size of the innovation and Norbäck and Persson (2009), who determine the optimal development investment for a venture-backed firm that will exit by a trade sale to an incumbent.

[9] For an overview see Jehiel and Moldovanu (2006).

affects the entry sale pattern to be in play in multi-firm bargaining oligopoly models, as long as the threat points of the firms vary with the quality of the invention.[10] However, it seems less straightforward determining how to identify bargaining (bidding) competition in such a model.

Finally, this paper contributes to the literature on entrepreneurship and innovation (for overviews, see Achs and Audreatch (2005) and Bianchi and Henrekson (2005)). 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 be even more important than the role of de-novo entrant. Indeed, we show that the possibility of preemptive incumbent acquisition gives entrepreneurs an incentive to increase their efforts in high-quality research projects so that expected welfare can increase despite the risk of increased market power.[11]

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.[12] 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 use the term "invention" as long as k has not reached the market, and the term "innovation" when k is used in the product market.

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

[10] Extending the models provided by Gans et al. (2002) and Jehiel and Moldovanu (1995) by allowing for quality differences seems a fruitful way to proceed in this respect.

[11] 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, this corpus of research never examines 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.

[12] The quality of an invention k for many types of inventions is 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 6.

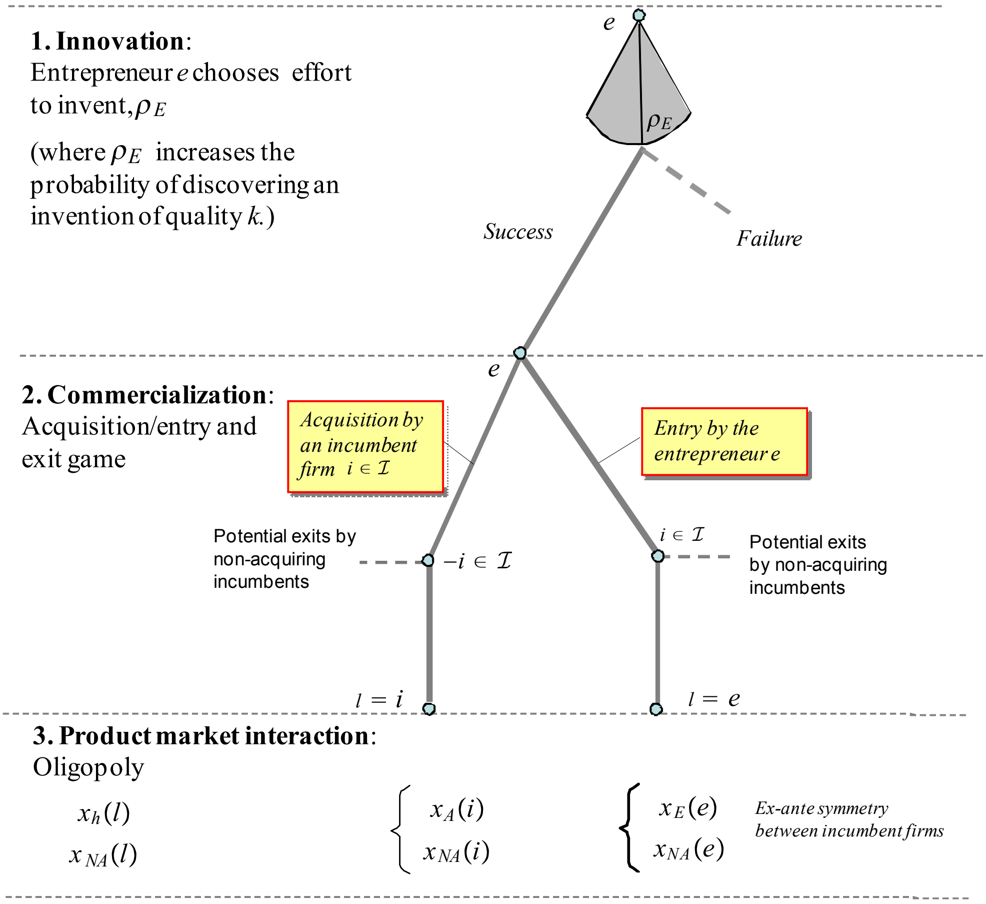

Figure 2.1: The structure of the game.

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).

Let us 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* $q_A^*(l) = s\frac{\Lambda + N(i)k}{N(i)+1}$, $q_E^*(e) = s\frac{\Lambda + N(e)k}{N(e)+1}$ *and* $q_{NA}^*(l) = s\frac{\Lambda - k}{N(l)+1}$ *for* $l = e, i$ *and* $\Lambda = a - c$. *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 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 either to sell the invention to one of the incumbents or enter the market at a fixed cost, G. Given the mode of commercialization, non-acquiring incumbents may then exit the market.

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 $\pi_E(e) > \tau + G$ hold. 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. $\mathbf{b} = (b_1, ..b_i.., b_n) \in R^n$ 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 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 of obtaining k for an incumbent, when otherwise a rival incumbent would 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 of obtaining k for an incumbent, when otherwise the entrepreneur would 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 otherwise would 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 we assume that $\pi_E(i) = 0$, so the entrepreneur cannot enter the market without ownership of the invention. Note also 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 retains 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 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 for the entrepreneur of undertaking a research effort. 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 with 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 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:

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

Examining the net value of an acquisition (3.1), the first term is an *invention-transfer effect,* showing the change in profits from a change of ownership 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.

We will in this and the next section show that higher quality k will induce an entrepreneur to commercialize an invention by sale rather than by entry, and that higher quality will lead to bidding competition among incumbents. This competition will increase the entrepreneur's reward from sale above the reward from entry. For expositional reasons, we will assume that entry is "large-scale" and "market-neutral". While these assumptions improve the exposition, they do not qualitatively change the results (as discussed in detail in Section 6).

Large-scale entry We assume the entrant and the acquirer make a symmetric use of assets, and will attain 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 thus refer to such entry as "large scale entry".[13]

Market-neutral entry We also assume that entry does not change the number of firms in the market. 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 reduced 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 the entrant attains exactly the same market position as would the acquiring incumbent in the case of a sale of the invention, i.e. $\pi_A(i) = \pi_E(e)$. In addition, non-acquiring incumbents obtain the same profit regardless ownership of

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

the invention, $\pi_N(e) = \pi_N(i)$. However, since one of the incumbents is forced out of the market under entry, the probability of remaining in the market for a non-acquiring incumbent is lower under entry, $\lambda(i) = 1 > \lambda(e) = \frac{n-1}{n} > 0$.

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. Due to the risk of exit when not acquiring, net value of entry-deterrence is larger than the net value of preemption.

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 of the invention increases. To see why, note that the first term in $v_{ie} = \pi_A(i) - \tau - \Gamma - \lambda(\mathrm{e})\,[\pi_{NA}(e) - \tau]$

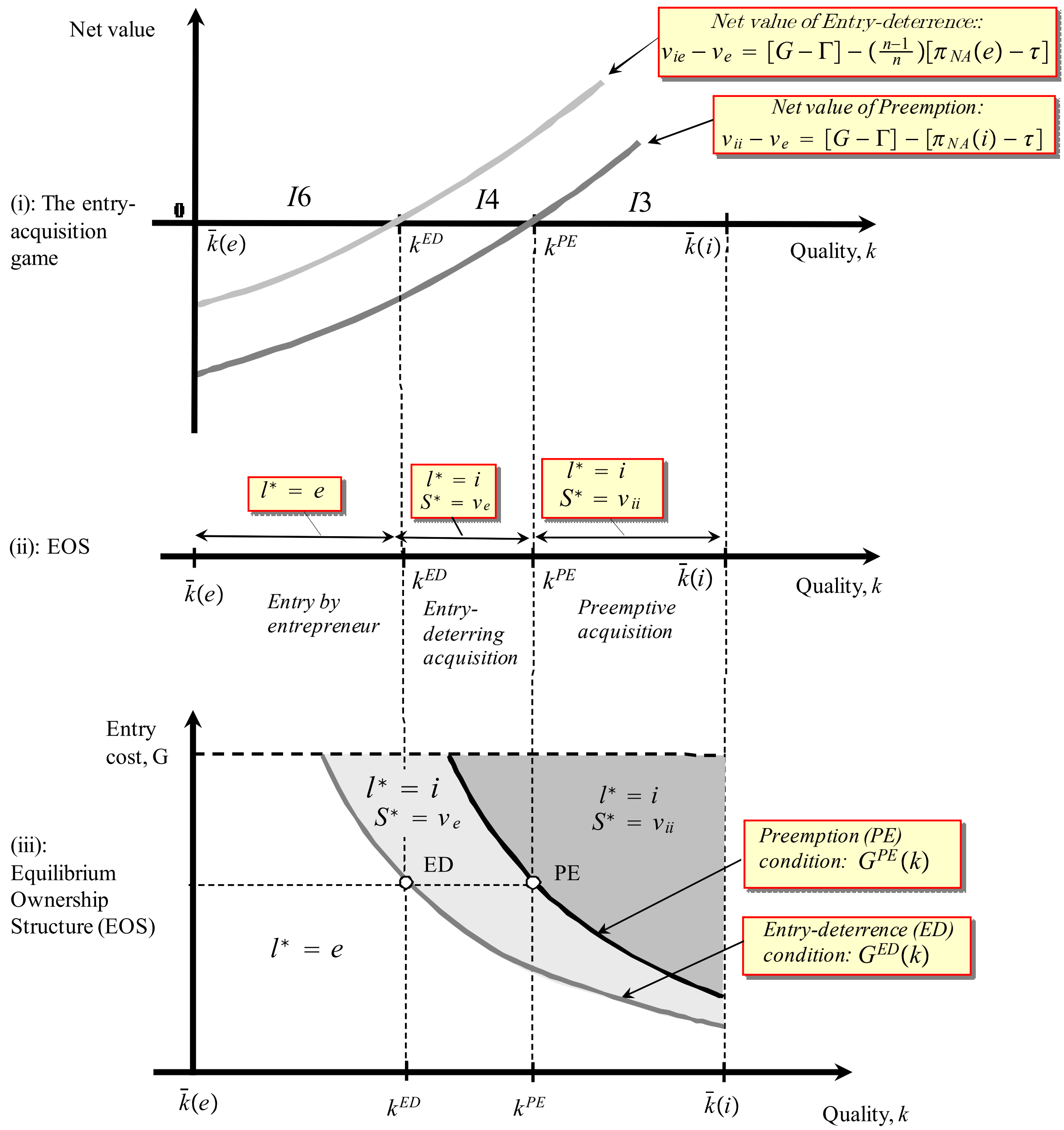

Figure 3.1: Solving for the equilibrium mode of commercialization.

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, implying $v'_{ie,k} > v'_{e,k}$. 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

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

As shown in Figure 3.1(i), increasing the quality of the invention into the region $k \geq k^{PE}$ will then imply 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 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 both 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 increases in transaction costs Γ shift both the entry deterrence locus $G^{ED}(k)$ and the preemption locus upwards in Figure 3.1(iii), 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 or entering the market, an entrepreneur will then prefer sale when (i) the* *quality of the invention k is high, (ii) entry costs G are high, (iii) operating fixed costs τ are high, and (iv) the transaction costs associated with a sale Γ are low.*

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

In this section, we will show that preemptive acquisitions will accelerate the process of creative destruction. To this end we state the following proposition concerning research incentives for the entrepreneur:

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. 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 among incumbents for the benefits as an acquirer – as well as to avoid 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, $R_E(i) = v_{ii} > v_e = R_E(e)$. Since the research effort, and hence the likelihood of a successful innovation $\rho^*(l)$ is increasing in the reward $R_E(l)$, it directly follows from Lemma 2 that there will be a higher probability of a successful invention 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 substantially increase the reward to research for entrepreneurs, 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 in its simplicity can be seen as a valuable way of capturing the effects of substantial changes of transaction costs for acquisitions

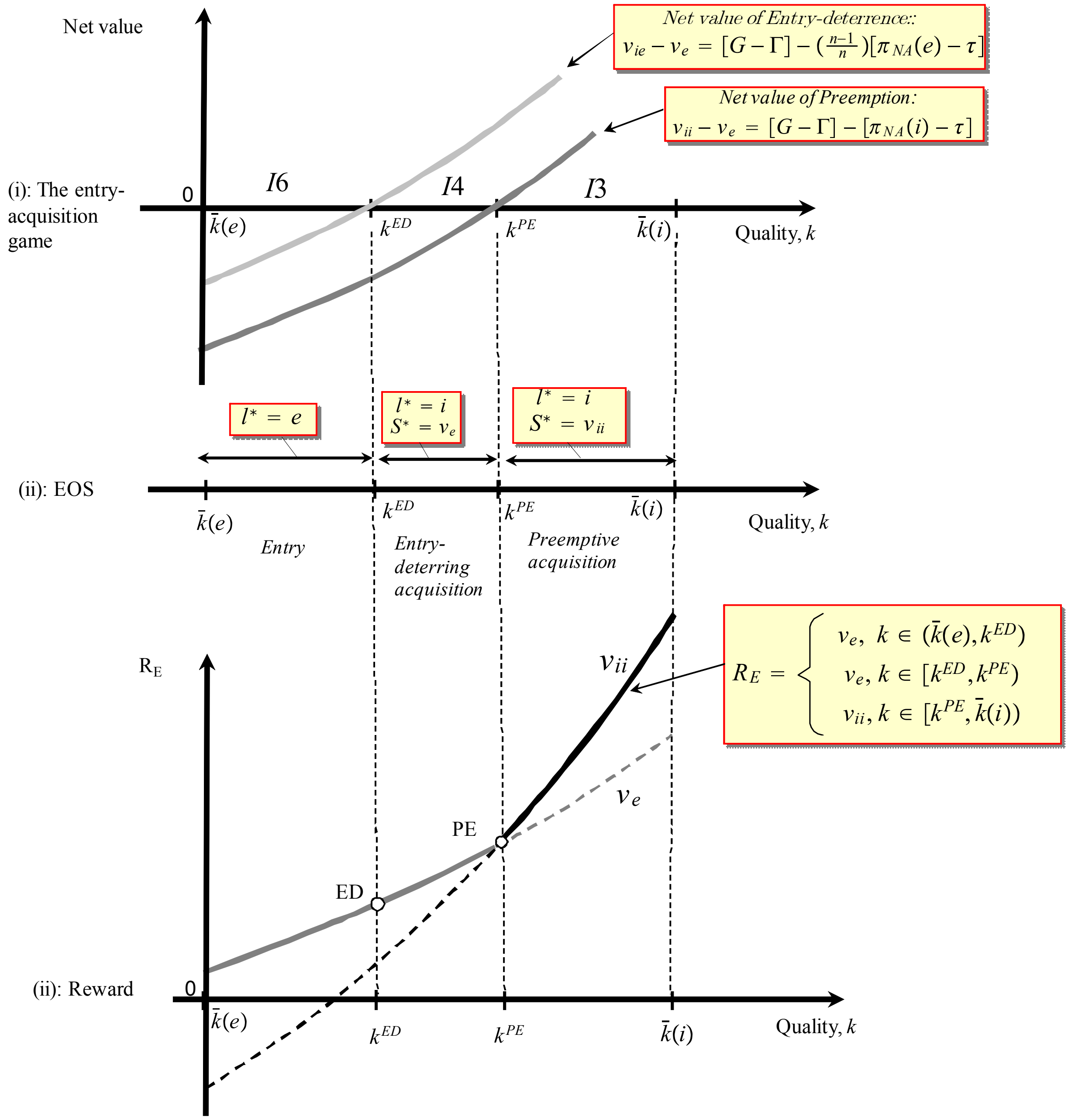

Figure 4.1: The equilibrium reward to innovation and the equilibrium probabality of success.

due to changes in policies that might block or increase the cost of acquiring small innovative firms.[14] The change in transaction costs could also stem from technological and institutional changes.

Assume, everything else being equal, that consumers benefit both from the higher quality of an innovation and 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:

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

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. $\rho_E^*(i) > \rho_E^*(e)$ under inequalities I1-I3 in Table 2.1. Inasmuch as the higher quality of an invention will induce bidding competition among incumbents, its reasonable to infer 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 conclude this argument 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.[15] 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:

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

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

[15] 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 $R_E^{ND}(l) = S^* = v_{ii} > R_E^D = v_e$, $\Pi_E^{ND}(l) \geq \Pi_E^D(l)$.

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

Expression (4.2) reveals incumbents' preference for a particular policy 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 the circumstance the entrepreneur succeeds, which occurs with probability $\rho^*(l)$, the expected profit is higher under the ND-policy. This is because incumbents gain either 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 reporting patents granted to Swedish small firms and individual inventors.

5.1. Deriving an estimation equation for the mode of commercialization

To determine if the model is consistent with the data, and with preemptive acquisitions in particular, 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. 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:

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

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

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, $R_E = v_{ii}$, is 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:

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

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 $\gamma_\tau = \beta_\tau - \alpha_\tau > 0$.

In terms of Figure 4.1(ii), Proposition 4(ii) implies that incumbent acquisitions take place in the dark-shaded area where acquisitions are preemptive at $S^* = v_{ii}$, whereas 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 requires $\boldsymbol{\gamma} \neq \mathbf{0}$, as well as a reversal of all signs in Proposition 4(ii).

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.[16] In that year, 1082 patents were granted to Swedish small firms and individuals.[17] 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.[18] They were asked where the invention was created, if and when the invention had been commercialized, which mode of commercialization 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. The falling off was not systematic.[19] The survey data set was complemented with data on forward citations from www.espacenet.com.

From the theory, we are interested in those patents where the inventors can decide themselves whether to commercialize the patent.[20] Therefore, we begin the analysis by considering the 624 patents where the inventors have some ownership. 364 of these 624 patents were commercialized, that is, the holder received income from the patent.[21] Among the 364 commercialized patents, 91 patents were commercialized by selling or licensing the patent, while 273 were commercialized through entry. 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 problems arising from 260 out of 624 patents in the sample not being commercialized will be dealt with in Section 6.2, where we extend the theory and empirical analysis to also include the decision not to commercialize.

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

[17] 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 to provide information on individual patents. Furthermore, it is impossible to persuade foreign firms to fill out questionnaires about patents. The majority of these foreign firms are large multinationals.

[18] 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.

[19] 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.

[20] We also undertake estimations where the entrepreneurial firm has less than 100 employees, irrespective of inventor ownership. This give us a sample 454 commercialized patents. The results remain unchanged for this different sample. See the Appendix.

[21] 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 the commercialization rate is 71 percent for small firms and inventors.

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**.** Note that 30 of the 91 patents which are sold are first commercialized by entry and thereafter sold. These patents are treated as commercialisation by sale. In section 7.1, we also extend the theory and empirical analysis to explain these late sales. In general, the buyers/licensees of the patents are considerably larger firms than the seller/licensor in the data set.

5.2.2. Measuring the quality of an invention, k

The explanatory variables used in estimating (5.4) and their expected signs are given in Table 5.1. The main variable of interest is the quality of an invention. To measure the quality of an invention k, we use the number of forward citations (excluding self-citations) that a patent had 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.[22]

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.[23]

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

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

[23] Competitors are the ones 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 say patents of semi-conductors. The cost for competitors should then come from limits in their own patents, or through increased costs of generating competitive new patentable innovations.

the entry and sale patents, respectively, are cited. In line with the theory, we note that patents commercialized through sale have a higher average number of forward citations than patents which are commercialized through entry, although the difference is not statistically significant using a simple t-test. Patents which are not commercialized have the lowest average number of citations.

Endogeniety of forward citations A potential concern about our quality measure is endogeneity, since forward citations in general occur after the patents have been commercialized. Forward citations are registered by patent examiners 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, cite the original patent. If this is true, forward citations would increase for 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.[24] To deal with this potential endogeniety problem, we transform the citation variables W_CIT and B_CIT into binary variables, D_W_CIT and D_B_CIT, thereby indicating whether a patent received a citation. Such citation dummy variables should be less sensitive to the endogeneity problem than the original ones.

5.2.3. Other Explanatory variables

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 with a new product, G. We define the variable $SMALL$ taking on the value of 1 for firms with 11-200 employees, and 0 otherwise, and $MICRO$ 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. Proposition 4(ii) implies that if incumbent acquisitions are driven by preemptive motives, we would expect $\gamma_G = \beta_G - \alpha_G > 0$. Since larger firms should face *lower* entry costs G, we predict that $\gamma_{G_{\text{Micro}}} < 0$ and $\gamma_{G_{Small}} < 0$, lower entry cost leads to lower probability of entry. In Table 5.4, the commercialization mode rates are shown for different firm sizes. Commercialization by sale is more frequent the smaller the firm size, whereas entry is more frequent the larger the firm, which is consistent with Proposition 4(ii).

Transaction costs, Γ As a measure of transaction costs we use the variable PVC, the percentage of the R&D-stage that was financed by private venture capitalists or business angels. Gans et al. (2002) find evidence that the involvement of private venture capitalists increased

[24] 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.

the probability of commercialization by sale. They argue that such agents participate in 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 imply $\gamma_{\Gamma_{PVC}} > 0$.

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.

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 specification 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. The individual parameters (γ_k, γ_Γ and γ_G) also have the correct signs. This is also the case in the Wald test on the full specification of specification A. Thus, the reward functions for sale and entry are significantly different from each other and there is evidence of preemptive acquisitions of entrepreneurial inventions.

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 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 sale. All of 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.[25]

In specifications 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 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 specifications 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 with our citation variable and the distribution

[25] 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.

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 any citations or not. 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) that there are preemptive acquisitions, albeit some estimates are less significant.

Additional specifications We also re-estimate Table 5.5 with logit and OLS specifications without finding any qualitative changes in the results (see Appendix Tables A1 and A2). The results are 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 whether the patent was applied in research at a university (Appendix Table A3).

Broadening the sample We then re-estimate Table 5.5 with an extended sample. An objection against the sample could be that the potential buyer/licensee does not care whether the inventor is the owner of the patent or not. Instead of using the sample of patents owned by inventors, there is an alternative sample to use when estimating the models – all patents owned by individuals or firms with less than 100 employees. This implies that the entrepreneur will be small compared to the incumbent firms, as assumed in the theoretical model. Such a sample has 751 patents, of which 449 are commercialized. Among these, 91 patents are commercialized by sale and 364 by entry.

In Appendix Table A4, the Probit model is estimated for the new sample. This gives approximately the same result as in Table 5.5. The Wald tests show that there is evidence of preemptive acquisitions in the market for entrepreneurial inventions, and the quality of the invention (k) and the entry costs (G) have significant impacts on the commercialization mode.

6. Robustness

Our theory predicts that high quality inventions are sold to incumbents under bidding competition. From the theory we have derived an estimation equation which can be used to identify bidding competition among incumbents. Using a unique data set of commercialization of entrepreneurial inventions, we have also shown that commercialization by sale occurs under bidding competition. In this section, we examine the robustness of these results.

6.1. Entry is not "market-neutral"

Assumption A1 implies that entry by the entrepreneur does not affect the equilibrium number of firms in the product market. Formally, we have assumed that the quality of the invention is sufficiently high, $k \in \bar{k}(i), \bar{k}(e))$. Let us now assume $k \in (0, \bar{k}(i))$. From Definition 2 this implies that entry by the entrepreneur does not lead to exits by incumbents. Assuming that entry is profitable $\pi_E(e) - \tau > G$, entry then reduces market concentration, as the number of firms in the market fulfils $N(e) = n + 1 > N(i) = n$.

To show that entrepreneurs still sell their best inventions (Proposition 1) and that our identification strategy for preemptive acquisitions remains valid (Proposition 4), we need to ensure that the net value of an incumbent acquisition $v_{il} - v_e$ is increasing the quality of the invention, k. Differentiate the ED- and PE-condition $v_{il} = v_{ii}$ in entry costs G and quality of the invention k to obtain:

$$\frac{dG^{ED}}{dk} = \frac{v'_{ie,k} - v'_{e,k}}{v'_{e,G}}, \qquad \frac{dG^{PE}}{dk} = \frac{v'_{ii,k} - v'_{e,k}}{v'_{e,G}} \tag{6.1}$$

Consider the region in Figure 6.1, with combinations of quality k and entry costs G below the Entry-condition traced out by the locus of $G = \pi_E(e) - \tau$ where entry is just profitable, $v_e = 0$. Since $v'_{e,G} < 0$, (6.1) reveals that when $v'_{il,k} - v'_{e,k} > 0$ holds the ED- and PE locuses are downward-sloping as shown in Figure 6.1(i), where the ED-locus is to the left of the PE-locus (since entry lowers incumbent profits, $\pi_{NA}(e) < \pi_{NA}(i)$ and hence $v_{ie} > v_{ii}$). Therefore, when $v'_{il,k} - v'_{e,k} > 0$ holds, higher quality inventions are commercialized by sale: first at the reservation price $S^* = v_e$ and at even higher quality under bidding competition, $S^* = v_{ii}$.

Without exits of incumbents, $\lambda(l) = 1$ in (3.1). Hence, $v'_{ie,k} - v'_{e,k}$ can be written:

$$v'_{ie,k} - v'_{e,k} = \frac{d\pi_A(i)}{dk} - \frac{d\pi_E(e)}{dk} - \frac{d\pi_{NA}(l)}{dk} \tag{6.2}$$

Assumption A1 of "market-neutral entry" implies $\frac{d\pi_A(i)}{dk} = \frac{d\pi_E(e)}{dk}$ and hence always fulfills $v'_{ie,k} - v'_{e,k} > 0$. So, while Assumption A1 is very useful for the exposition, it is not necessary for our results. From (6.2), $v'_{ie,k} - v'_{e,k} > 0$ may hold even if the effect of higher quality on the entry profit of the entrepreneur is stronger than the effect on the acquiring incumbent' profit (i.e. $\frac{d\pi_A(i)}{dk} - \frac{d\pi_E(e)}{dk} < 0$), as long as this difference is not larger than the impact on a non-acquiring incumbent (i.e. $\frac{d\pi_A(i)}{dk} - \frac{d\pi_E(e)}{dk} > \frac{d\pi_{NA}(l)}{dk} < 0$). In many oligopoly models, a larger incumbent acquirer (as compared to the entrant) may also have more to gain from increased quality (i.e.$\frac{d\pi_A(i)}{dk} > \frac{d\pi_E(e)}{dk}$) which directly gives $v'_{ie,k} - v'_{e,k} > 0$. This is the case in the Linear Cournot model in Example 1.

In the remainder of this paper, we will use the following assumption.

Assumption A2 $\frac{d\pi_A(i)}{dk} - \frac{d\pi_E(e)}{dk} > \frac{d\pi_{NA}(l)}{dk} < 0$ for $k \in (0, \bar{k}(i))$

Assumption A2 directly implies that Proposition 1 is fulfilled. Note also that Proposition 4(iii), $\gamma_k = \beta_k - \alpha_k > 0$ that identifies bidding competition, must then be a direct test of Assumption A2, since the latter implies $v'_{ii,k} - v'_{e,k} > 0$ from (6.2). Thus, our empirical results in table 5.5 which identify bidding competition between incumbents under commercialization by sale are also consistent with a setting where entry is not "market neutral".[26]

[26] What would happen if inventions have such high quality that multiple exits of incumbents occur when the invention is commercialized. Formally, let $k > \bar{k}(i)$). It is then not straightforward to differentiate $v_{il} - v_e$ in k because profits $\pi_h(l)$ and the probability $\lambda(l)$ will exhibit discontinuous jumps when the number of incumbents change. Proposition 4(iii), $\gamma_k = \beta_k - \alpha_k > 0$, will still identify bidding competition in commercialization by sale since the latter is yet again a direct test of Assumption A2, which in discrete changes becomes $\Delta v_{il} - \Delta v_e > 0$ when the quality increases. In Norbäck, Persson and Svensson (2009) we also show that in the Linear Cournot model higher quality is conducive to commercialization by sale

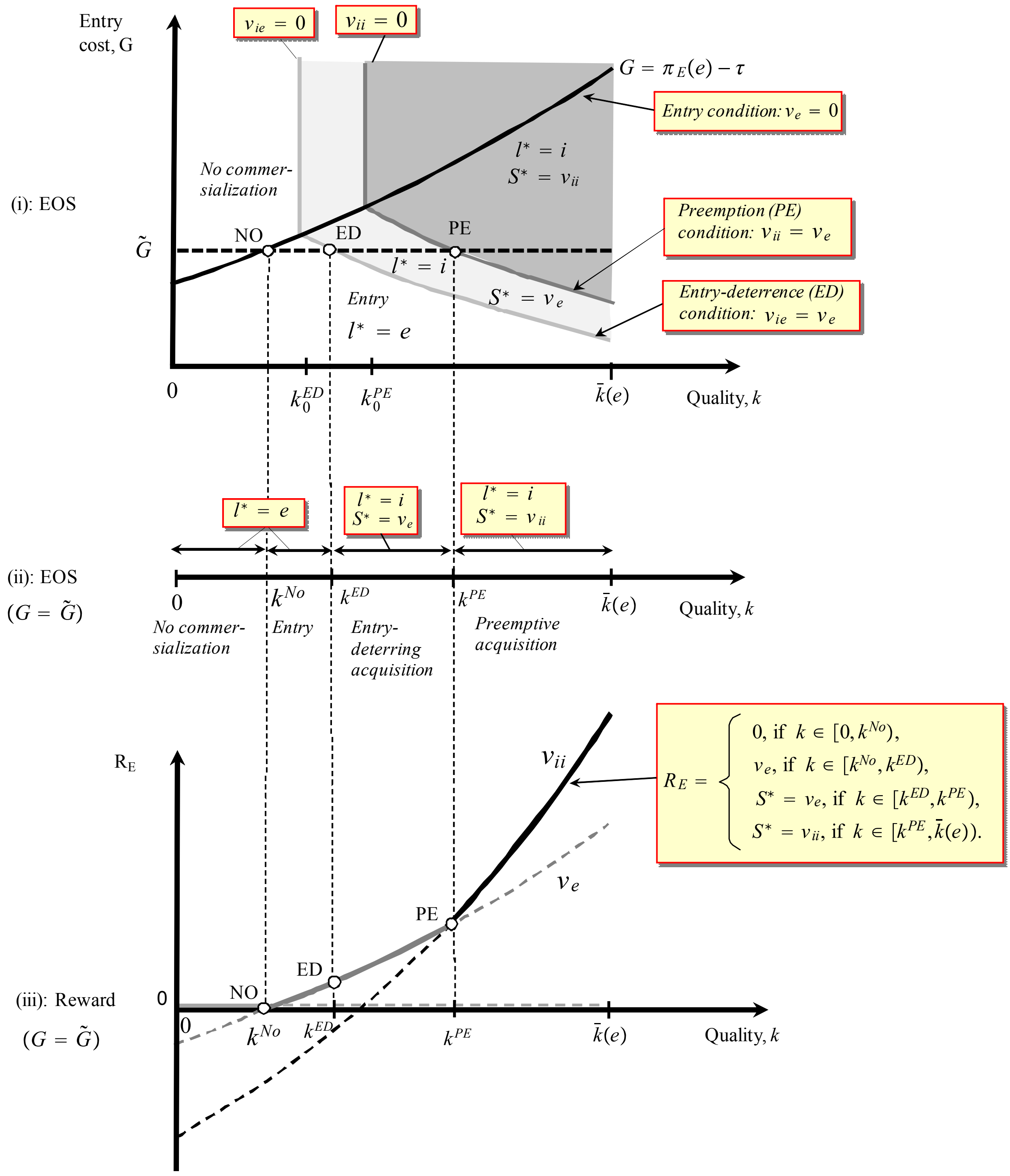

Figure 6.1: The equilibrium mode of commersialization and the reward to innovation when allowing for non-commersialization.

6.2. All patents are not commercialized

We have assumed that the entrepreneur can always commercialize through entry. In contrast, 260 of the 624 patents in our data were not commercialized How would our results change if we were to include non-commerzialized patents in the model?

Consider the region in Figure 6.1(i) above the entry condition where $G > \pi_E(e) - \tau$. In this region, the ED-condition becomes $v_{ie}(k_0^{ED}) = 0$ and $v_{ie}(k_0^{PE}) = 0$ since $v_e = 0$ (the entrepreneur cannot enter). The ED-locus is the vertical line at k_0^{ED}, whereas the PE-locus is the vertical locus at k_0^{PE}, where $k_0^{ED} < k_0^{PE}$. Note that inventions of lower quality than k_0^{ED} (associated with entry costs $G > \pi_E(e) - \tau$) will never be commercialized.

It is now straightforward to extend the empirical analysis and the identification of preemptive acquisitions in Proposition 1 to take into account that some inventions are not commercialized. This is illustrated in Figure 6.1(iii) which shows the reward to commercialization for a given level of entry costs $\tilde{G}$. Note that there is no commercialization for very low qualities $k < k^{No}$, where $\tilde{G} = \pi_E(e : k^{No})$. The reward to commercialisation is then zero, $R_E = 0$. 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". $R_{E,No}(k_e, \tau_e, \Gamma_e, G_e) = 0$ can be (trivially) linearized in its arguments to get:

$$R_{e,No}(k_e, \tau_e, T_e, G_e) = \underset{(0)}{\psi_0} + \underset{(0)}{\psi_k} k_r + \underset{(0)}{\psi_F} F_r + \underset{(0)}{\psi_T} \Gamma_r = \mathbf{x}_e' \boldsymbol{\psi}. \tag{6.3}$$

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:

$$\text{Prob}[Sale_e] = \frac{e^{\mathbf{x}_e'\boldsymbol{\beta}}}{e^{\mathbf{x}_e'\boldsymbol{\beta}} + e^{\mathbf{x}_e'\boldsymbol{\alpha}} + e^{\mathbf{x}_e'\boldsymbol{\psi}}}, \quad \text{Prob}[Entry_e] = \frac{e^{\mathbf{x}_e'\boldsymbol{\alpha}}}{e^{\mathbf{x}_e'\boldsymbol{\beta}} + e^{\mathbf{x}_e'\boldsymbol{\alpha}} + e^{\mathbf{x}_e'\boldsymbol{\psi}}}. \tag{6.4}$$

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 (6.3) identifies vectors $\boldsymbol{\beta}$ and $\boldsymbol{\alpha}$ from (5.2) and (5.3).

In Table 6.1, we show the results from estimating (6.4) 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).[27] 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

under bidding competition.

What if the invention is drastic so that the possessor obtains a monopoly? Let π^m denote the monopoly profit where $\pi_A(i) = \pi_E(e) = \pi^m$ for $k = k^{mon}$. The net value for of an acquisition from (3.1) is then $v_{il} - v_e = G - \Gamma$ Hence, if the quality reaches $k = k^{\max}$ there will be commercialization by sale if $G > \Gamma$.

[27] 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 Section 7.2 which uses a duration analysis.

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 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), while identifying 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.[28] To check this we also estimated a probit model with selection, where the selection stage modelled the commercialization decision and the second stage the model of commercialization. This gave qualitatively the same results. We also found that the error terms on the two stages were uncorrelated.[29]

6.3. Acquisitions involve synergies

For expositional reasons, incumbents and the entrepreneur make symmetric use of the invention k. Let us now allow for synergies between incumbents' assets and the invention. Let $\tilde{k}(k,\kappa)$ be the effective size of the invention, where k is the "original" quality and $\kappa > 0$ is the level of synergies, with $\frac{\partial \tilde{k}(k,\kappa)}{\partial \kappa} > 0$. Let Definition 1 hold in terms of effective size of quality $\tilde{k}$. Let $\tilde{k}(e) \equiv \tilde{k}(k,1) = k$ and let $\tilde{k}(i) = \tilde{k}(k,\kappa) > \tilde{k}(e)$ for $\kappa > 1$ and $\tilde{k}(i) = \tilde{k}(k,\kappa) < \tilde{k}(e)$ for $0 < \kappa < 1$.

Assuming away exits of incumbents, and setting $\lambda(l) = 1$ in (3.1), (3.3) and (3.4) now take the form:

$$v'_{ie,k} - v'_{e,k} = \left[\frac{d\pi_A(i)}{d\tilde{k}}\frac{\partial \tilde{k}(k,\kappa)}{\partial k} - \frac{d\pi_E(e)}{d\tilde{k}}\right] - \frac{d\pi_{NA}(e)}{d\tilde{k}} \quad (6.5)$$

$$v'_{ii,k} - v'_{e,k} = \left[\frac{d\pi_A(i)}{d\tilde{k}}\frac{\partial \tilde{k}(k,\kappa)}{\partial k} - \frac{d\pi_E(e)}{d\tilde{k}}\right] - \frac{d\pi_{NA}(i)}{d\tilde{k}}\frac{\partial \tilde{k}(k,\kappa)}{\partial k} \quad (6.6)$$

where we have used the fact that $\frac{d\tilde{k}(e)}{dk} = 1$. It is straightforward to show that synergies must be sufficiently large in order to have an acquisition by an incumbent be profitable. Consider the case where true synergies arise, $\kappa > 1$. This is illustrated in Figure 6.2(i). The figure first illustrates ED-and PE-locuses without synergies, $\kappa = 1$. The dashed locuses then depicts the ED and PE conditions under synergies. Note that synergies shift the ED and PE conditions to the left, also making them steeper, which follows from comparing (6.2) with (6.5) and (6.6). Intuitively, when synergies arise this will increase incumbents' willingness to pay and makes bidding competition more prevalent. Inspecting the figure it also follows that Proposition 1 is immediately fulfilled. Moreover, Proposition 4 will test if commercialization occurs under bidding competition, that

[28] 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).

[29] Results available upon request from authors.

is, whether acquisition occurs in the light-gray areas (at price $S^* = v_e$), or under bidding competition in the dark-gray area (at price $S^* = v_{ii}$).

6.4. Incumbents are asymmetric ex-ante

We have also assumed that incumbents are symmetric ex-ante. This may be a reasonable assumption in some industries. Other industries are dominated by large incumbent firms, such as Microsoft and Intel in the computer industry. How would our results and identification strategy be affected if we allowed incumbents to be ex-ante asymmetric?

Incumbents will then have different valuations of the invention, and the auction game will be harder to solve with many possible orderings of valuations. While this complicates the analysis, there is no qualitative change in results. Let us illustrate using an example with two incumbent firms. The incumbents valuations are then $v_{ii}^1 = [\pi_{A_1}(i) - \pi_{NA_1}(i)]$ and $v_{ie}^1 = [\pi_{A_1}(i) - \pi_{NA_1}(d)]$ for Incumbent 1, whereas for Incumbent 2 we have $v_{ii}^2 = [\pi_{A_2}(i) - \pi_{NA_2}(i)]$ and $v_{ie}^2 = [\pi_{A_2}(i) - \pi_{NA_2}(e)]$. Furthermore, we make the following assumption:

Assumption A3: (i) $\frac{d\pi_{A_1}(i)}{dk} > \frac{d\pi_A(i)}{dk} > \frac{d\pi_{A_2}(i)}{dk} > 0$, (ii) $\frac{d\pi_E(e)}{dk} > 0$, and (iii) $\frac{d\pi_{NA_1}(l)}{dk} < \frac{d\pi_{NA}(l)}{dk} < \frac{d\pi_{NA_2}(l)}{dk} < 0$. $l = \{e, i\}$

Assumption A3 implies that Incumbent 1 generates the largest gain in profits from higher quality, but Incumbent 1 is also the firm facing the largest profit loss as a non-acquirer at increasing quality. We also make the gain (loss) for Incumbent 1 larger (smaller) than in the case of ex-ante symmetry between incumbents. The opposite holds for Incumbent 2. To simplify further, suppose that $\pi_{A_j}(i)\big|_{k=0} = \pi_{NA_j}(i)\big|_{k=0} = \bar{\pi}$ holds.[30]

Note that Assumption A3 implies that Incumbent 1 will always have the highest valuation of the domestic assets $v_{il}^1 > v_{il}^2$, which implies that if an acquisition occurs, Incumbent 1 will be the acquirer. The equilibrium commercialization pattern is shown in Figure 6.2(ii). In the figure the ED- and PE conditions are drawn as dashed curves for the case of ex-ante symmetry between incumbents. The ED- and PE conditions for the case of asymmetries are drawn as solid lines. Since the valuation of Incumbent 1 increases when compared to ex-ante symmetry $v_{ie}^1 > v_{ie}$, an entry deterring acquisition now occurs for a lower quality. However, preemptive acquisitions occur for a higher quality than under ex-ante symmetry. This occurs because bidding competition occurs only when $v_{ii}^2 > v_e$. From Assumption A3 it follows directly that a higher quality of the invention is needed for this to be fulfilled. Asymmetries will then expand the region of entry deterring acquisition. However, as shown by the figure, this does not invalidate Propositions 1 and 4. In particular, Proposition 4 can still be used to test whether commercialization occurs under bidding competition, that is, whether acquisitions occur in the light-gray area without bidding competition (at price $S^* = v_e$), or under bidding competition in the dark-gray area (at price $S^* = v_{ii}^2$). Consequently, the identification of bidding competition in the estimates of table 5.5 and table 5.8 are also consistent with a setting with asymmetric incumbents.

---

[30] Assumption A4 can be incorporated into the LC model by assuming that $k_i = \alpha_i k$, where $\alpha_1 = 1 > \alpha_2 > 0$.

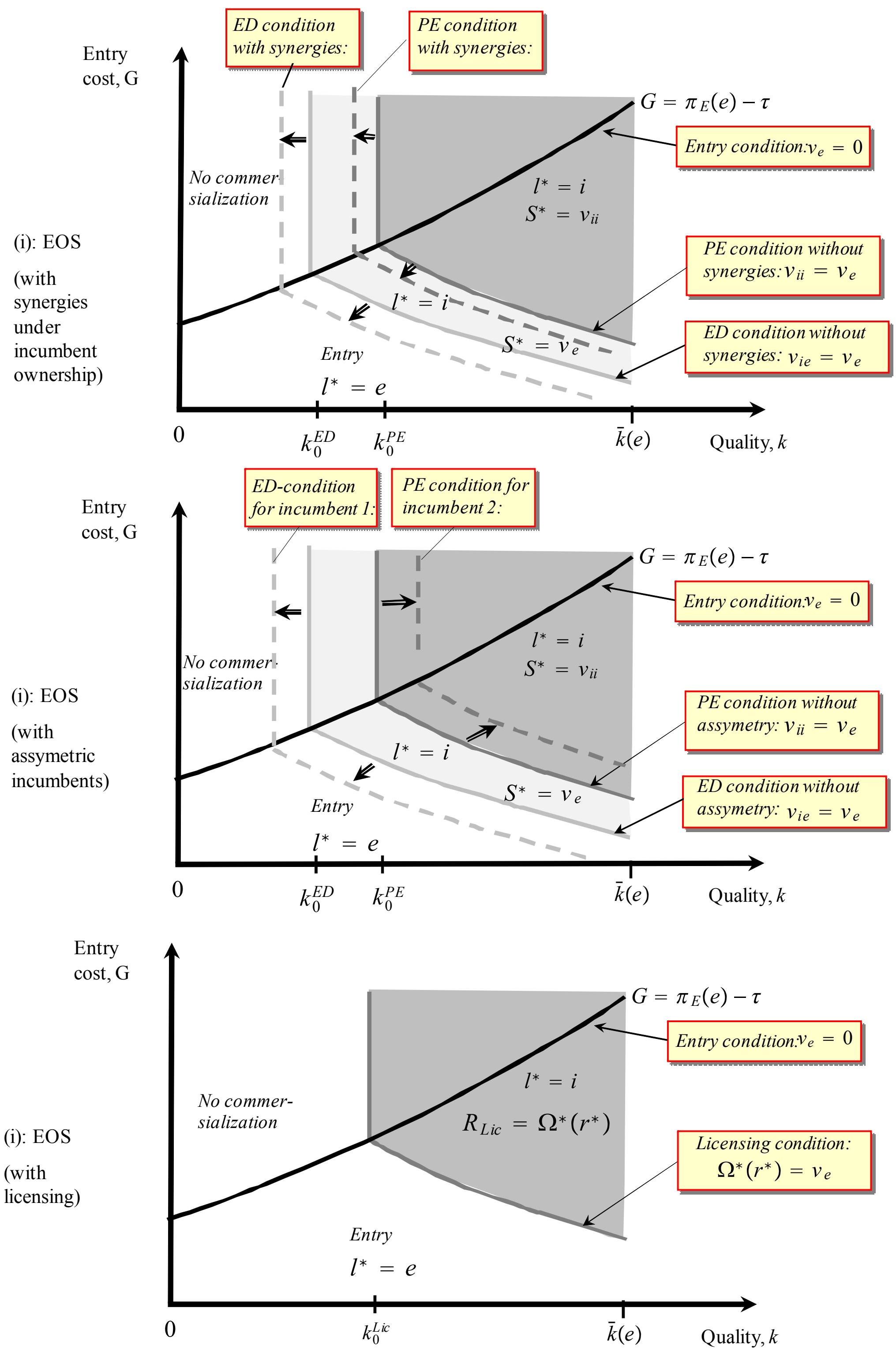

Figure 6.2: The Equilibrium Ownership Structure (EOS) when allowing for (i) synergies, (ii) assymetric incumbents and (iii) multi-firm licensing.

6.5. Multi-Firm Licensing

In the analysis, we have also assumed that the seller can only sell the innovation (or the innovative firm) exclusively to one buyer. In many cases, the "innovation" consists of a combination of assets in terms of capital, intellectual capital, and human capital, which cannot be used by many firms simultaneously. Indeed, in the data there are only 2 out of 48 licensed inventions have multiple licences.

Let us nevertheless set aside the exclusive single buyer scenario and examine how the results would be affected if we allowed several buyers to hold a licence to utilize the innovations. Allowing the seller to commit to the number of licences to sell, Katz and Shapiro (1986) show that there exists an equilibrium where some potential buyers are left without a licence. Consider a setting where the entrepreneur can decide on how many licences r to licence if not entering. Let $\pi_A(i,r)$ denote the profit of a buyer of a licence when there are r licenses for sale. Let $\pi_N(i,r)$ be the profit of a firm not buying a licence. Licensing by the entrepreneur gives the profit $\Omega = r\left[\pi_A(i,r) - \pi_N(i,r)\right]$. For simplicity treating r as continuous, the optimal number of licenses is:

$$\Omega'_r = \underbrace{\left[\pi_A(i,r) - \pi_N(i,r)\right]}_{(+)} + r\left[\pi'_{A,r}(i,r) - \pi'_{N,r}(i,r)\right] = 0 \tag{6.7}$$

In the Linear Cournot model it can be shown that $\pi'_{A,r}(i,r) - \pi'_{N,r}(i,r) < 0$, $\pi'_{A,r}(i,r) < 0$ and $\pi'_{N,r}(i,r) < 0$, since more licenses increase aggregate output and lower the product market price, which affects a larger firm more adversely. Assuming that $\Omega''_{rr} < 0$ and m is sufficiently large, there exists an optimal $r^* < m$.

How does an increase in quality then affect the choice between licensing and entry? Define $\Omega^*(r^*) \equiv r^*\left[\pi_A(i,r^*) - \pi_N(i,r^*)\right]$ This gives:

$$\begin{aligned} \frac{d\Omega^*}{dk} &= \Omega'_r \frac{dr^*}{dk} + \frac{\partial \Omega^*}{\partial k} \\ &= r^*\left[\frac{d\pi_A(i,r^*)}{dk} - \frac{d\pi_N(i,r^*)}{dk}\right] \end{aligned} \tag{6.8}$$

since $\Omega'_r = 0$ from (6.7). So, we may have it that $\frac{d\Omega^*}{dk} > \frac{dv_e}{dk} > 0$ since $\frac{d\pi_N(i,r^*)}{dk} < 0$. Thus, also in a setting with multiple licences, higher quality is conducive to innovation for sale. Noting that $R_{Lic} = \Omega^*(r^*)$ and $R_{Entry} = v_e$, we can still use Prop 4(iii) to test if higher quality of an invention will lead to the entrepreneur choosing licensing over entry. This is illustrated in Figure 6.2(iii).

6.6. Endogenous quality of inventions:

Our results would also hold 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 $k^{Sale} = \arg\max_k\left[v_{ii} - C(k)\right] > k^{Entry} = \arg\max_k\left[v_e - C(k)\right]$. Thus, our theory would also predict that entrepreneurs choosing commercialization by sale will have a stronger incentive to develop inventions of 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(iii) to identify preemptive acquisitions, irrespective of whether the quality of an innovation is exogenously given for the entrepreneur, or if the entrepreneur could affect the quality prior to commercialization.

7. Extensions

In this section, we undertake two major extensions of the analysis. In Section 7.1, we extend the basic model to include information asymmetries between the incumbents and the entrepreneur. In Section 7.2, we examine the duration to commercialization to control for differences in transaction or information costs between the two modes of commercialization.

7.1. Asymmetric information and entry as verification

So far, we have assumed away information problems. However, the inventor may have an informational advantage by better knowing the quality of the invention. The entrepreneur can then mitigate such information problems by verifying the value or quality of the invention by entering the market and revealing high profits, low costs or high sales, prior to selling the invention. This verification motive may explain the pattern in our data were 30 out of the 91 sold patents where first commercialized by entry and then sold at a later stage.

Entry should be a credible verification in most countries since mandatory disclosure laws and different type of auditing systems are built up to certify that information about firms' revenues, cost and profits are accurately reported.[31],[32] These disclosure laws and auditing systems also imply that firms' cannot easily signal in the product market interaction.

Consider the following extension of the baseline model:

Stage 1 Initially, all players know what type of R&D project (k) the entrepreneur has undertaken, and assign an exogenous probability of success of the entrepreneur's invention $\theta \in [0, 1]$. At the end of the research stage, only the entrepreneur learns if the project was a failure ($k = 0$) or a success ($k > 0$).

Stage 2 In the commercialization stage, the entrepreneur can sell the invention under asymmetric information, where the incumbents still assign the probability of success of the entrepreneur's invention $\theta \in [0, 1]$. If an incumbent obtains the invention, only the acquiring incumbent learns the quality of the invention after the purchase.

Stage 3 In the product market interaction at the beginning of stage 3, information is asymmetric since non-acquiring incumbents can only estimate quality of the invention from the prior θ. However, at the end of stage 3 profits are public information and non-acquiring incumbents can infer the quality of the invention from them. It is assumed that firms' cannot signal in the product market interaction.

[31] There is a small literature on costly disclosure and debt financing (see Townsend (1979) and Gale and Hellwig (1985)).

[32] Note that we abstract from appropriation problems since the entrepreneur has a patent.

Stage 4 Given that the entrepreneur has entered in stage 2 and competed in the product market in stage 3, she can sell the invention under perfect information in this stage.

Stage 5 Given the commercialization mode of the invention in stage 2, firms compete in the product market under perfect information.

If the invention is not commercialized in stage 2, all incumbents are symmetric and interact under full information in stages 3 and 5. If there is no entry in stage 2, the commercialization decision from stage 2 is unaltered. We now proceed to solve the game by backward induction:

7.1.1. Stage 5: Product market interaction under full information.

Suppose that the invention is commercialized in stage 2, and then used in the product market in stage 3. Firms will then have inferred the true quality of the invention $t = s, f$, where $s = success$ and $f = failure$ denote the outcomes for the entrepreneur in stage 1. The Nash-equilibrium is given from (2.1) and here denoted $\mathbf{x}^*(l,t) = (x_j^*(l,t), x_{-j}^*(l,t))$. Let $\pi_h(l,t) \equiv \pi_h(x_h^*(l,t), x_N^*(l,t), l, t)$ be the reduced-form profit the possessor for a firm of type $h = A, E, NA$. Since $\pi_h(l,s) \equiv \pi_h(l)$, Definition 1 applies for a successful invention ($t = s$), whereas $\frac{d\pi_h(l,f)}{dk} \equiv 0$ since $k = 0$ under a failed invention ($t = f$). If the invention is not commercialized, there is a symmetric Nash-equilibrium where incumbents make profits $\pi_N(0)$.

7.1.2. Stage 4: Post entry acquisition game

We assume the entrepreneur has commercialized by entry in stage 2, and competed in the product market in stage 3. From the product market profit in stage 5, the entrepreneur's reservation price in stage 4 is:

$$v_e(t) = \pi_E(e,t) - \tau \tag{7.1}$$

where we note that the entry cost G is sunk from stage 2 and hence not included in the reservation price.

An incumbent's valuations of the invention in stage 4 is:

$$v_{il}(t) = \pi_A(i,t) - \pi_N(l,t) - \Gamma \tag{7.2}$$

We will assume that acquisitions driven solely by market power are not profitable, $v_{il}(f) < v_e(f)$. To examine the commercialization pattern for a successful invention, (7.1) and (7.2) gives:

$$v'_{il,k}(s) - v'_{e,k}(s) = \left[\frac{d\pi_A(i,s)}{dk} - \frac{d\pi_E(e,s)}{dk}\right] - \frac{d\pi_{NA}(l,s)}{dk}. \tag{7.3}$$

Since $\pi_h(l,s) \equiv \pi_h(l)$, Assumption A2 implies the net gain of an acquisition $v_{il}(s) - v_e(s)$ is increasing in quality k, as shown in Figure 7.1(i). Applying the reasoning behind Lemma 3, we have the following proposition:

Proposition 5. ***(Late sale):*** *Suppose that $\check{k}^{ED}$ defined from $v_{ie}(s) = v_e(s)$ and $\check{k}^{PE}$ defined from $v_{ii}(s) = v_e(s)$ exist. Then, from Assumption A3:(i) commercialization by entry takes* *place if the quality of the invention is sufficiently low, $k \in (0, \breve{k}^{ED})$, (ii) commercialization by sale occurs at sales price $S_4^* = v_e(s)$ if the quality of the invention is of intermediate size, $k \in [\breve{k}^{ED}, \breve{k}^{PE})$, and (iii) commercialization by sale occurs at sales price $S_4^* = v_{ii}(s)$ if the quality of the invention is sufficiently high, $\breve{k} \in [\breve{k}^{PE}, \bar{k}(i))$.*

In sum, if the entrepreneur has verified the quality choosing commercialization by entry in stage 2 and competed in the product market in stage 3, she will sell the invention in stage 4 if the quality is high. For sufficiently high quality a sale will take place under bidding competition. This is shown in Figure 7.1(ii).

7.1.3. Stage 3: Product market interaction under asymmetric information

Let us now formalize how verification of quality takes place. Suppose that the invention is commercialized in stage 2, either by entry or sale. Since only the possessor of the invention (the entrepreneur or the acquiring incumbent) knows the true quality of the invention, the product market interaction takes place under asymmetric information. We will then assume a Bayesian-Nash-equilibrium in the firms' product market actions x_j. Non-acquiring incumbents assign a probability θ that the possessor of the invention has a successful invention and probability $1-\theta$ that the possessor has a failed invention. The possessor knows how rivals infer quality, and rivals know that the possessor knows how they infer quality. A possessor $h = A, E$ of an invention of type t maximizes her direct profit $\pi_h(x_h(t), x_{-h}, l, t)$ choosing an action $x_h(t)$, given the vector of actions of non-acquiring incumbents, $x_{-h} = \mathbf{x}_N$. A non-acquiring incumbent chooses an action x_N to maximize her expected profit based on the prior θ, $\bar{\pi}_h = \theta\pi_h(x_N, x_{-N}(s), l, s) + (1-\theta)\pi_h(x_N, x_{-N}(f), l, f)$, where $x_{-N}(s) = (x_h(s), x_N, ..., x_N)$, $x_{-N}(f) = (x_h(f), x_N, ..., x_N)$ are the action of her rivals. The Bayes-Nash equilibrium can then be written $\mathbf{x}^*(l,t,\theta) = (x_h^*(l,s,\theta), x_h^*(l,f,\theta), \mathbf{x}_N^*(l,\theta))$, where $x_h^*(l,s,\theta)$ for $h = A, E$ is the optimal action taken by a possessor of a successful invention, $x_h^*(l,f,\theta)$ for $h = A, E$ is the optimal action taken by a possessor of a failed invention, while $\mathbf{x}_N^*(l,\theta)$ is the vector of (symmetric) actions by non-acquiring incumbents (who do not know the true quality t and thus cannot condition their optimal action on the type of invention). Let $\pi_h(l,t,\theta) \equiv \pi_h(\mathbf{x}^*(l,t,\theta), l, t)$ be the reduced-form profit for a firm of type $h = A, E, N$.

We will make the following assumptions on reduced-form profits, which are shown to hold for the LC model in the Appendix.

Assumption A4 Let $\theta \in [0,1]$. For $h = A, E$: (i) $\frac{d\pi_h(l,s,\theta)}{dk} > 0 \geq \frac{d\pi_N(l,s,\theta)}{dk}$, and $\frac{d\pi_h(l,f,0)}{dk} = \frac{d\pi_N(l,f,0)}{dk} = 0$, (ii) $\pi_j(l,s,\theta) > \pi_j(l,f,\theta) > \pi_N(l,f,\theta) > \pi_N(l,s,\theta) > 0$, $j = A, E$.

Proof. See the Appendix. ■

Assumption A4(i) implies that Definition 1 holds for a successful invention. If the invention has failed and incumbents are certain that the invention has failed, quality will not affect firms' profits. To ensure that firms assign a positive value to the invention, Assumption A4(ii) states that the possessor of the invention has a higher reduced-form profit when the invention is successful than when it is unsuccessful. In turn, these profits are higher than the profits of a non-acquiring incumbent when the invention has failed, which in turn is higher than the profit of an

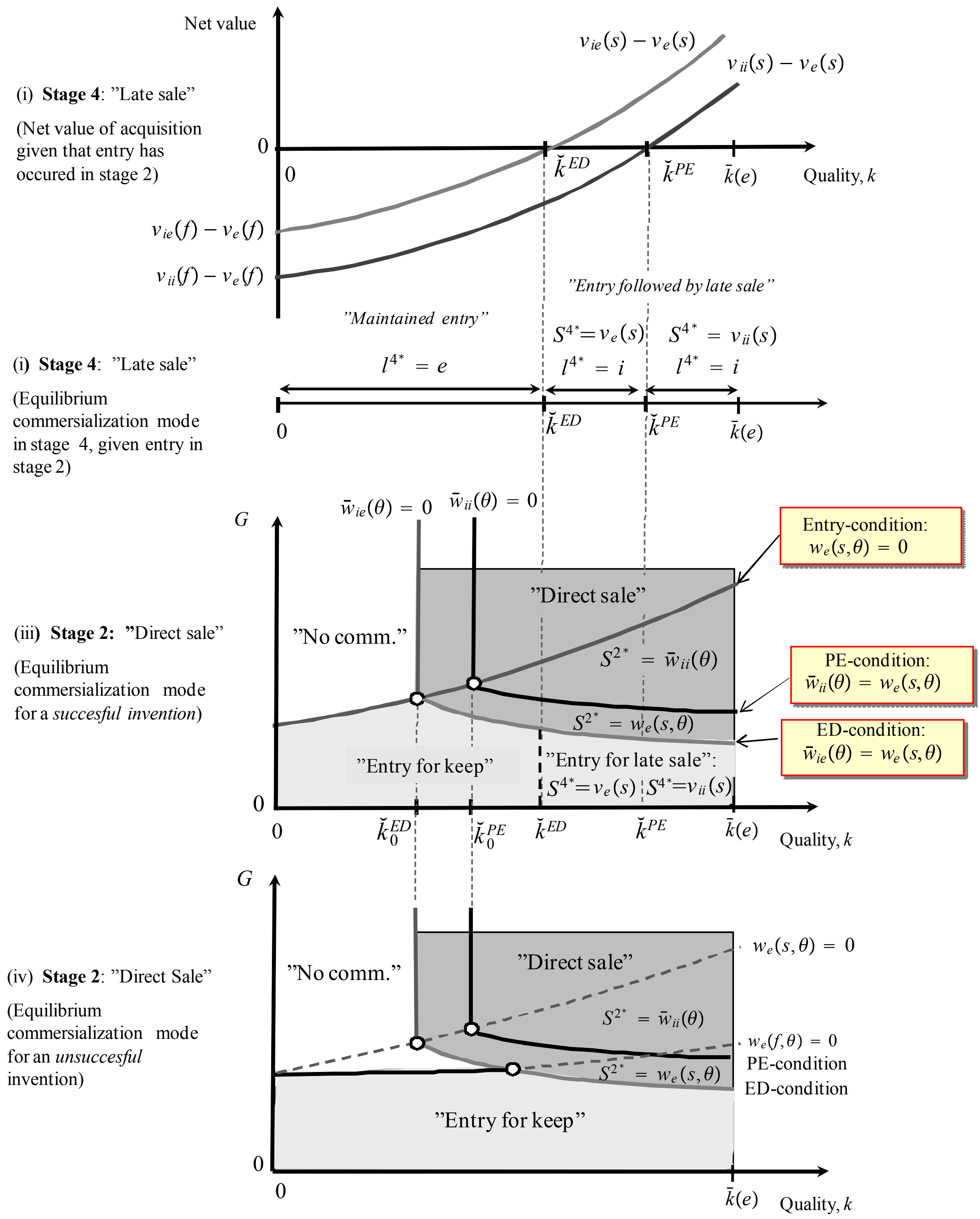

Figure 7.1: Figures (i) and (ii) solve for the entrepreneur’s decision to sell given commercialization by entry in stage 1. Figures (iii) and (iv) solve the entrepreneurs commercialization decision in stage 1 in the case that incumbents have a high prior on the quality of the invention.

acquiring incumbent when the invention is successful. Assuming that the latter profit is strictly positive, a non-acquiring incumbent's expected profit $\bar{\pi}_N(l,\theta) = \theta\pi_N(l,s,\theta) + (1-\theta)\pi_N(l,f,\theta)$ is then strictly positive. The Appendix gives more details on these profits for the LC-model.

Since profits are public information at the end of stage 3, firms can infer the quality of the invention $t = s, f$ from their own or rivals' reduced-form profits $\pi_h(l,s,\theta)$, and we can state the following corollary:

Corollary 1. *If the invention is commercialized in stage 2, the reduced-form profits in stage 3 reveal the type of the invention.*

7.1.4. Stage 2: Commercialization under asymmetric information

Let us now solve for the commercialization decision in stage 2. To determine the firms' valuations in stage 2 we need take into account how the game proceeds from stages 3 to 5.

The reservation price for the entrepreneur Note that the value of entry arising from stage 5 profits is defined from $v_e(t)$ in (7.1). The value of entry from stage 3 profits for the entrepreneur is

$$v_e(t,\theta) = \pi_E(e,t,\theta) - \tau - G \tag{7.4}$$

where we note that the entry cost G is paid in stage 2.

The full reservation price in stage 2 for the entrepreneur with a successful invention, denoted $w_e(s,\theta)$, can then be written:

$$w_e(s,\theta) = \begin{cases} 0, \text{ for }, \; v_e(s,\theta) + \max\{v_e(s), v_{ii}(s)\} < 0 \\ v_e(s,\theta) + v_e(s), \text{ for } v_e(s,\theta) + v_e(s) > 0, \; k \in [0, \breve{k}^{PE}), \\ v_e(s,\theta) + v_{ii}(s), \text{ for } v_e(s,\theta) + v_{ii}(s) > 0, \; k \in [\breve{k}^{PE}, k^{\max}). \end{cases} \tag{7.5}$$

In (7.5), $v_e(t,\theta)$ is the value arising from product market entry in stage 3. Since entry reveals the true quality, the term $\max\{v_e(s), v_{ii}(s)\}$ is the value from optimally choosing to keep the invention or to sell it under full information in stage 4. Note finally that if the reward from entry is negative, the entrepreneur has a zero reservation price.

If the entrepreneur has a failed invention, this will be revealed by the firms profits in stage 3 as shown in Corollary 1. Since incumbents have no incentive to buy a failed invention, the entrepreneur's reservation price for a failed invention is:

$$w_e(f,\theta) = \begin{cases} 0, \text{ for } v_e(f,\theta) + v_e(f) < 0, \\ v_e(f,\theta) + v_e(f) \text{ for } v_e(f,\theta) + v_e(f) > 0. \end{cases} \tag{7.6}$$

Incumbents valuations The value of the invention for an incumbent arising from stage 5 profits is $v_{il}(t)$ and defined in (7.2). The value for an incumbent arising from stage 3 profits can be written:

$$v_{il}(t,\theta) = \pi_A(i,t,\theta) - \bar{\pi}_N(l,\theta) \tag{7.7}$$

since only the possessor will know the type of the invention when entering into the product market competition in stage 3. To avoid double-counting the transaction cost Γ which is included in $v_{il}(t)$, we do not include Γ in (7.7).

When determining the value of the invention in stage 2, incumbents will need to estimate the type of the invention using the prior θ. Let $\bar{w}_{il}(\theta)$ denote the expected valuation of the invention. This can be written:

$$\bar{w}_{il}(\theta) = \begin{cases} \theta[v_{il}(s,\theta) + v_{il}(s)] + (1-\theta)[v_{il}(f,\theta) + v_{il}(f)], \text{ for } \bar{w}_{ie}(\theta) > w_e(s,\theta) \\ v_{il}(f) + v_{il}(f), \text{ for } \bar{w}_{ie}(\theta) < w_e(s,\theta) \end{cases} \tag{7.8}$$

In (7.8), the first line tells us incumbents will only value the invention according to its expected value if the value of deterring commercialization by entry is higher than the reservation price of an entrepreneur with a successful invention, $\bar{w}_{ie}(\theta) > w_e(s,\theta)$. The second line tells us that if this condition is not met, incumbents will rationally expect that only failed inventions will be for sale, following Akerlof's (1970) classic "lemons problem".

It is now straightforward to solve for the equilibrium commercialization pattern. This is illustrated in Figure 7.1(iii) and (iv), where we again depict the equilibrium ownership structure (EOS) in the space of the quality of the invention k and the entry cost G.

Commercialization of a successful invention Consider first the EOS for a successful invention in Figure 7.1(iii). Note that the locus of the Entry-condition $w_e(s,\theta) = 0$ is upward-sloping from Assumption A4(i), since $v_e(s,\theta) + \max\{v_e(s), v_{ii}(s)\}$ must increase in quality k. Since Assumption A4(i) also implies that the term $v_{il}(s,\theta) + v_{il}(s)$ in (7.8) increases in quality, an incumbent's valuation $\bar{w}_{il}(\theta)$ also increases in quality.[33] When entry is not profitable, $w_e(s,\theta) < 0$, the ED and PE locuses then becomes the vertical lines $\bar{w}_{il}(\theta) = 0$, at $\breve{k}_0^{ED} < \breve{k}_0^{PE}$. The latter inequality follows from the concentration effect of an acquisition, i.e. $\bar{w}_{ie}(\theta) > \bar{w}_{ii}(\theta)$, so that the ED-locus is again located to the left of the PE-locus. A direct acquisition of the entrepreneur's invention occurs at price $S^{2^*} = w_e(s,\theta) = 0$ for $k \in [\breve{k}_0^{ED}, \breve{k}_0^{PE})$, and $S^{2^*} = \bar{w}_{ii}(\theta)$ for $k \in [\breve{k}_0^{PE}, k^{\max})$. For $k \in (0, \breve{k}_0^{ED})$ the invention is not commercialized since $\bar{w}_{il}(\theta) < 0$.

Focus now on the region below the EC-condition $w_e(s,\theta) = 0$, where the ED-condition does not hold, i.e. where $\bar{w}_{ie}(\theta) < w_e(s,\theta)$. In this region, the market for successful inventions initially breaks down, and the entrepreneur will commercialize by entry, an action that will reveal the true quality of the invention from Corollary 1. The pattern of commercialization in stage 4 is then given by Proposition 5, as shown in Figure 7.1(i) and (ii).

Focus finally on the middle region between the EC-condition and the ED-condition in Figure7.1(iii). In the region between the ED- and PE locuses (where $\bar{w}_{ie}(\theta) > w_e(s,\theta) > \bar{w}_{ii}(\theta)$) there is sale at the reservation price $S^{2^*} = w_e(s,\theta)$, and in the region above the PE-locus (where $\bar{w}_{ii}(\theta) > w_e(s,\theta)$) there will be bidding competition, leading to the sales price $S^{2^*} = \bar{w}_{ii}(\theta)$. What then is the effect of higher quality on the entrepreneur's commercialization decision in

[33] Assumption A4 does inform us how the term $v_{il}(f,\theta)$ in (7.8) behaves in quality k. Under reasonable assumptions, however, $v_{il}(f,\theta)$ terms are non-decreasing in quality. This is also shown in the Appendix for the LC model.

this region? Differentiate the ED and PE-conditions in k and G to obtain:

$$\frac{dG^{ED}}{dk} = \frac{\bar{w}'_{ie,k}(\theta) - w'_{e,k}(s,\theta)}{w'_{e,G}(s,\theta)}, \qquad \frac{dG^{PE}}{dk} = \frac{\bar{w}'_{ii,k}(\theta) - w'_{e,k}(s,\theta)}{w'_{e,G}(s,\theta)} \tag{7.9}$$

Since $w'_{e,G}(s,\theta) < 0$, whether higher quality still leads to commercialization by sale and bidding competition, depends on whether the net value of an early acquisition increases in quality. As illustrated in Figure 7.1(iii), if $\bar{w}'_{ie,k}(\theta) - w'_{e,k}(s,\theta) > 0$ holds the ED and PE locuses are downward sloping, and higher quality leads to commercialization by sale and bidding competition. However, if $\bar{w}'_{ie,k}(\theta) - w'_{e,k}(s,\theta) < 0$ the opposite holds. Without knowledge of the prior θ we cannot determine whether the net value for a direct acquisition increases or decreases in quality. This follows from the fact that incumbents valuations $\bar{w}_{il}(\theta)$ in (7.8) are weighted by the prior θ, whereas this is not the case for the reservation price of entrepreneur $w_e(f,\theta)$ in (7.5). If incumbents are "optimistic" their willingness to pay is high for high quality, and the entrepreneur can get a reward from selling high quality inventions. But if incumbents are "pessimistic" about the true quality (θ is low) their willingness to pay in a direct acquisition is low. It will then be worthwhile for the entrepreneur to keep a successful invention, enter the product market in stage 3 and then - given that the quality is high - sell the invention at a high price by exploiting the bidding competition.

We have the following proposition which is proved in the Appendix:

Proposition 6. ***(Direct sale)*** *Let $\theta \in [0,1]$. When entry is profitable for a successful invention , $w_e(s,\theta) > 0$, higher quality of a successful invention will lead to commercialization by sale under bidding competition $S^{2^*} = \bar{w}_{ii}(\theta) > w_e(s,\theta)$ only if incumbents' prior that the invention is successful is sufficiently high.*

Proof. See the Appendix. ■

Commercialization of a failed invention Turning to entrepreneurs with failed inventions, such entrepreneurs will sell their inventions whenever $\bar{w}_{il}(\theta) > w_e(s,\theta)$ holds. From (7.8) incumbents know that only failed inventions are for sale when $\bar{w}_{ie}(\theta) < w_e(s,\theta)$. As shown in Figure 7.1(iv), entrepreneurs with failed invention will then enter if entry is profitable $w_e(f,\theta) > 0$. Otherwise, no commercialization occurs.

7.1.5. Estimating the model with asymmetric information

It is straightforward to extend the empirical analysis to the asymmetric information model.

Late sale Start with the choice to sell late in stage 4. With commercialization by entry in stage 2, Corollary 1 implies that a late sale occurs under full information. We can apply the identification strategy in Proposition 4 with some adjustments. Since $\pi_h(l,s) = \pi_h(l)$, Proposition 5 (ii) implies we should observe $\gamma_k = \beta_k - \alpha_k > 0$ when estimating (5.4). However, since entry costs G are sunk when a late sale occurs, $\gamma_G = \beta_G - \alpha_G = 0$. The estimates are shown in Table 7.1**,** where $LATEALE = 1$ for the 30 patents which are first commercialized by entry and then are sold, and $LATEALE = 0$ for the remaining 273 patents which are commercialized by entry and remain in the inventor's ownership. Thus, the 61 patents sold directly are removed. As expected, the citation variable W_CIT is positive and significant, while the measure of entry costs, $SMALL$ and $MICRO$, are insignificant. This pattern remains true in all specifications. Consequently, we find support for the verification model that shows how entry can remove information problems and lead to a late sale under bidding competition.

Direct sale Now let's turn to the entrepreneur's choice of whether to sell the invention directly instead of entering the market in stage 2. To estimate this choice we can use the multinomial logit model (6.4) derived in Section 6.2, with the difference that patents which are first commercialized by entry and then sold will be treated as commercialization by entry. Under Assumption A4(i), it follows that if the entrepreneur has a successful invention a higher quality k will encourage entry and direct sale over non-commersialzation, i.e. $\beta_k > 0$ and $\alpha_k > 0$.[34] However, we also know from Proposition 6 that without knowledge of the prior θ, we cannot know whether higher quality increases the probability of direct sale, or the probability of entry when the entrepreneur has a successful invention, and so $\beta_k - \alpha_k$ is ambiguous in sign. We cannot measure this prior in the data, so we will need to use the estimates to infer it.

Specification A uses the citation variable W_CIT, whereas specification B uses the citation dummy D_W_CIT. The estimates in Table 7.2 reveals that Wald tests for specification A reject $\boldsymbol{\beta} = 0$ and $\boldsymbol{\alpha} = 0$, with lower significance for direct sale. A Wald test also rejects $\boldsymbol{\beta} = \boldsymbol{\alpha}$ which suggest that direct acquisitions are preemptive in nature. The citation variable W_CIT is neither significant for direct sale nor direct entry, $\beta_k > 0$ and $\alpha_k > 0$. The estimates suggests that $\beta_G = \alpha_G$ can be rejected, whereas $\beta_k = \alpha_k$ cannot. A problem is that we cannot distinguish patents which are failed and successful in the data. An imperfect way to do this is to use the citation dummy D_W_CIT, assuming that patents that receive zero citations are more likely to be patents for which $k = 0$, whereas patents with forward citations are more likely to be successful, $k > 0$. We see that specification B leads to sharper estimates. Wald tests again reject $\boldsymbol{\beta} = \boldsymbol{\alpha}$ so direct acquisitions are preemptive in nature. We can also see that both $\beta_k = 0$ and $\alpha_k = 0$ can be rejected, while a Wald test shows that $\beta_k = \alpha_k$ cannot be rejected. While entrepreneurs do receive a premium for sold inventions, this premium is not further increased by higher quality. This suggests that the prior θ is low enough to dampen incumbents willingness to pay. In short, there is evidence of asymmetric information in direct sales.

Some additional evidence of information problems comes from the variable PVC which measures the involvement by venture capitalists. It is now positive and marginally significant in specification A. In addition, there is some evidence that lower fixed costs of entry leads the entrepreneur not to commercialize the invention. Such an outcome can be rationalized from Figure 7.1(iv), where an entrepreneur with a failed invention will not commercialize when entry costs are medium high for a large region of perceived invention qualities.

[34] This assumption implies that $\frac{d\pi_h(l,s,\theta)}{dk} > 0 \geq \frac{d\pi_N(l,s,\theta)}{dk}$ holds. In the Appendix, it is also shown that $\frac{d\pi_h(l,f,\theta)}{dk} > 0 \geq \frac{d\pi_N(l,f,\theta)}{dk}$ if $\theta \in (0,1]$ in the LC-model,

7.1.6. Incumbents have the information advantage

Finally, it is useful to discuss the opposite case where incumbents have an information advantage over the entrepreneur, assuming that the entrepreneur does not know the true quality of the invention. It then follows that if the invention fails, entry is not profitable and incumbents do not provide any bids. If the invention is a success, incumbents will have a positive value of acquiring the invention. Then, if the incumbents place positive bids below the reservation price of a successful invention, the entrepreneurs will infer that the invention is successful and reject these bids. Consequently, we are back in the base model and our main analysis is valid.

7.2. Time to commercialization

The preceding section demonstrates why asymmetric information is costly for the entrepreneur. The reward in a direct sale will be lower when incumbents are uncertain of the value of the invention. Removing the information problem is costly since the entrepreneur needs to enter the market to prove the quality of the invention. In this section, we try to control for differences in information and transaction costs between entry modes by examining the time dimension in the data. In particular, since commercialization by sale is associated with asymmetric information, it is likely that it takes a longer time for a sale to occur.

To illustrate, the hazard function of the events of commercialization by entry and sale is shown in Figure 7.2; these events are measured in years from the application date, and commercialization by sale also includes patents that were initially commercialized by entry and then sold "subsequent".[35] The hazard function, $h_m(t)$, shows the conditional probability of a patent being 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 commercialize through entry more quickly than inventors who try to sell or license their patents. In the latter case, inventors may again 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 inherent uncertainty regarding the scope of the patent protection for the acquiring firm. Acquisition and licensing contracts may then be delayed until the grant date.[36]

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

[35] 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.

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

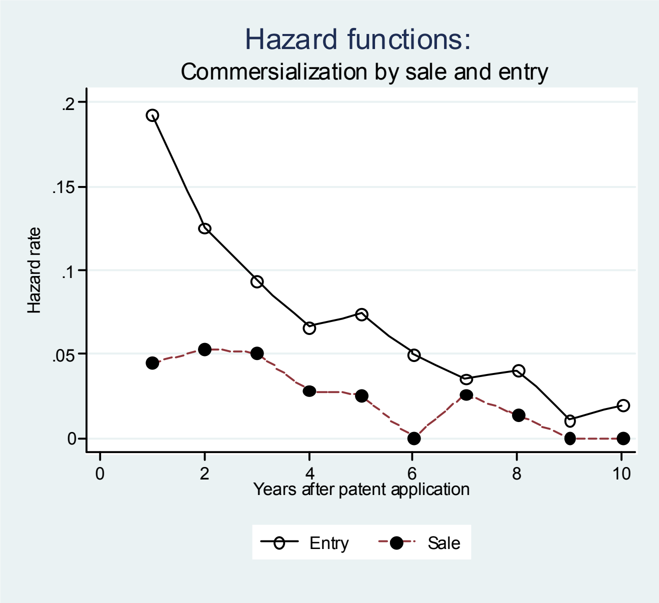

Figure 7.2: Illustrating the hazard rates for commercialization by entry and sale.

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.[37] The accelerated failure time (AFT) model is then the appropriate statistical model (Allison, 1995):

$$\log(T_{Sale,e}) = \mathbf{X}_e' \boldsymbol{\zeta}^{Sale} + \sigma^{Sale} \varepsilon_{e,Sale} \tag{7.10}$$
$$\log(T_{Entry,e}) = \mathbf{X}_e' \boldsymbol{\zeta}^{Entry} + \sigma^{Entry} \varepsilon_{e,Entry}, \tag{7.11}$$

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 (7.10) and (7.11) are estimated by Maximum Likelihood. When estimating the sale event in (7.10), we treat commercialization by entry ($m = Entry$) as right-censored. Likewise, when estimating the entry event in (7.11), 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 ζ^{Sale} and ζ^{Entry} in (7.10) and (7.11) for the full sample of 624 observations are

[37] 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.

shown for the log normal distribution in Table 5.10.[38] Regardless of specification or measure, as shown by W_CIT in Table 7.3 or D_W_CIT in Table 7.4, forward citations within the same technology class have a negative and highly significant impact on the time until commercialization by sale occurs. Quantifying this effect in Specification C in Table 5.10, if a patent receives one more forward citation within technologies (during a five-year period), the time until sale occurs decreases by around 28 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.[39] 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 time 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 (6.3). It then follows that when increasing the quality of an invention, commercialization by sale will become more profitable – irrespective of whether a comparison is made to entry or to no commercialization. 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 (6.3), 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.[40]

8. Concluding remarks

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

[38] 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 assumptions are available upon request.

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

[40] As noted, a direct Wald test whether $\boldsymbol{\beta} = \boldsymbol{\alpha}$ is not possible to undertake with the AFT model. However, if the survival model instead is estimated by the Cox proportional hazard model, it is possible to test if $\boldsymbol{\beta} = \boldsymbol{\alpha}$. Such a test shows that $\boldsymbol{\beta} = \boldsymbol{\alpha}$ can be rejected both when only the core variables are included in the model and when both the core variables and the dummy variables for technologies and regions are included. This gives additional evidence for preemptive bidding competition in the market for entrepreneurial inventions.

undertaking preemptive acquisitions. However, we have shown that the possibility of such acquisitions creates stronger incentives for entrepreneurs to develop high-quality inventions. Consequently, it may at present and in the future, be the combination of "creative destruction and productive preemption" which together matters for sustained growth.

Our theory predicts that the reward function for selling inventions when there is bidding competition (preemptive acquisitions) will be more sensitive to quality improvements as compared to selling without bidding competition (entry deterring acquisitions). The reason is that the selling price under bidding competition not only increases due to the increased profit for the buyer but also due to the decreased profits for the non-acquirers. In our empirical analysis, we find evidence of preemptive acquisitions using detailed patent data on the commercialization process.

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 be even more important than the role of de-novo entrant. Preemptive acquisitions give 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.

These results suggests that industry policies supporting growth of small innovative firms through subsidies and tax exemptions may be counterproductive, by in effect reducing their incentive to discover high quality inventions. Policies improving the M&A market would be preferred such as for example making the tax system neutral between keeping and selling a firm or improving the legal system to reduce the transaction cost to ensuring bidding competition for target firms. On the contrary, the existing EU-policies to a large extent focus exclusively on stimulating growth of small firms, but lack policies stimulating the ownership transfers to large established firms.[41]

References

[1] Acs, Z. J. and Audretsch D. B., 2005, "Entrepreneurship, Innovation and Technological Change", *Foundations and Trends in Entrepreneurship*, Vol 1(4), pp. 149-195.

[2] Aghion, P. and Howitt, P., 1992, "A Model of Growth through Creative Destruction", *Econometrica*, Vol. 60(2), pp. 323–351.

[3] Akerlof, G.A., 1970, "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism", *Quarterly Journal of Economics*, Vol. 84(3), pp. 488-500.

[4] Allison, P.D., 1995, *Survival Analysis Using SAS – A Practical Guide*, SAS Institute Inc., Cary, NC.

[41] The Small Business Act for Europe by Directorate-General for Enterprise and Industry applies to all indepentent companies having fewer than 250 employees: roughly 99% of all European businesses. http://ec.europa.eu/enterprise/policies/sme/small-business-act/index_en.htm

[5] Anton, J.J. and Yao, D.A., 1994, "Expropriation and Invention: Appropriable rents in the absence of property rights", *American Economic Review*, Vol. 84(1), pp. 190-209.

[6] Arrow, K.J., 1962, "Economic Welfare and the Allocation of Resources for Innovation", in Nelson (ed.), *The Rate and Direction of Inventive Activity.*

[7] Baumol W.J., 2004, "Entrepreneurial Enterprises, Large Established Firms and Other Components of the Free-Market Growth Machine", *Small Business Economics*, Vol. 23(1), pp. 9-21.

[8] Bianchi, M. and Henrekson M., 2005, "Is Neoclassical Economics Still Entrepreneurless?", *Kyklos*, Vol. 58(3), pp 353-377.

[9] Bloningen, B.A. och Taylor, C.T., 2000, "R&D Intensity and Acquisitions in High-Technology Industries: Evidence from the US Electronic and Electrical Equipment Industries", *Journal of Industrial Economics*, Vol. 48(1), pp. 47-70.

[10] Bond, E.W, 1982, "A Direct Test of the "Lemons" Model: The Market for Used Pickup Trucks", *American Economic Review*, Vol. 72(4), pp. 836-840.

[11] Breschi, S., Lissoni, F. and Malerba, F., 2004, "The Empirical Assessment of Firms' Technological Coherence: Data and Methodology", in Cantwell, J., Gambardella, A. and Granstrand, O. (eds.), *The Economics and Management of Technological Diversification*, Routledge, London.

[12] Chen, Y., 2000, "Strategic Bidding by Potential Competitors: Will Monopoly Persist?", *Journal of Industrial Economics,* 48(2), pp. 161-75.

[13] Gale, D., and M. Hellwig, 1985, "Incentive-compatible debt contracts:the one-period problem" *The Review of Economic Studies*, 52, 647-63.

[14] Gans, J.S., Hsu, D.H. and Stern, S., 2002, "When does Start-Up Innovation Spur the Gale of Creative Destruction?", *RAND Journal of Economics,* Vol. 33(4), pp. 571-586.

[15] Gans, J.S., Hsu, D.H. and Stern, S., 2007, "The Impact of Uncertain Intellectual Property Rights on the Market for Ideas: Evidence from Patent Grant Delays", Discussion paper.

[16] Gans, J.S. and Stern, S., 2000, "Incumbency and R&D Incentives: Licensing the Gale of Creative Destruction", *Journal of Economics and Management Strategy*, Vol. 9(4), pp. 485-511.

[17] Genesove, D., 1993, "Adverse Selection in the Wholesale Used Car Market", *Journal of Political Economy*, Vol. 101(4), pp. 644-665.

[18] Gilbert, .R., 2006, "Looking for Mr. Schumpeter: Where Are We in the Competition-Innovation Debate?", in Jaffe, A.B., Lerner, J. and Stern, S. (eds.), *Innovation Policy and the Economy*, Vol. 6, pp. 159-215, MIT Press, Cambridge and London.

[19] Gilbert, Richard, and Newbery, D. M. G., 1982, "Preemptive Patenting and the Persistence of Monopoly." *American Economic Review,* 72, pp. 514-26.

[20] Gilligan, T.W., 2004, "Lemons and Leases in the Used Business Aircraft Market", *Journal of Political Economy*, Vol. 112(5), pp. 1157-80.

[21] Granstrand, O. and Sjölander, S., 1990, "The Acquisition of Technology and Small Firms by Large Firms", *Journal of Economic Behavior and Organization,* Vol. 13, pp. 367-386.

[22] Griliches, Z., 1990, "Patent Statistics as Economic Indicators: A Survey", *Journal of Economic Literature*, Vol. 28(4), pp. 1661-1707.

[23] Grossman, G.M. and Helpman, E. 1991, *Innovation and Growth in the Global Economy*, MIT Press, Cambridge, MA.

[24] Hall, B.H., 1990, "The Impact of Corporate Restructuring on Industrial Research and Development", *Brookings Papers on Economic Activity,* Special issue 1990, pp. 85-124.

[25] Hall, B.H., Jaffe, A.B. and Trajtenberg, M., 2005, "Market Value and Patent Citations", *RAND Journal of Economics*, Vol. 36(1), pp. 16-38.

[26] Harhoff, D., Narin, F., Scherer, F.M. and Vogel, K., 1999, "Citation Frequency and the Value of Patented Inventions", *Review of Economics and Statistics*, Vol. 81(3), pp. 511-515.

[27] Howitt, P., 2008, Endogenous Growth, In *The New Palgrave Dictionary of Economics*, 2nd Edition, edited by Steven Durlauf and Lawrence Blume, Palgrave Macmillan, New York.

[28] Jehiel, P. and Moldovanu, B, 1995, "Cyclical Delay in Infinite Horizon Bargaining with Externalities", *Review of Economic Studies*, 62 (4), pp. 619-639.

[29] Jehiel, P. and Moldovanu, B, 2006, "Allocative and Informational Externalities in Auctions and Related Mechanisms", (joint with Jehiel, P.), in *The Proceedings of the 9th World Congress of the Econometric Society*, edited by Richard Blundell, Whitney Newey, and Torsten Persson, Cambridge University Press.

[30] Jehiel, P., Moldovanu, B., and Stacchetti, E., 1996, "How (Not) to Sell Nuclear Weapons," *American Economic Review*, Vol. 86, pp. 814-829.

[31] Jehiel, P, Moldovanu, B. and Stacchetti, E., 1999, "Multidimensional Mechanism design for auctions with externalities." *Journal of Economic Theory*, 85, pp. 258-293.

[32] Kamien, M.I., 1992, "Patent Licensing", in *Handbook of Game Theory with Economic Applications*, Volume 1, pp. 331-354, North-Holland, New York.

[33] Kamien, M.I. and Tauman Y., 1986, "Fees versus Royalties and the private value of a patent", *Quarterly Journal of Economics*, Vol. 101(3), pp. 471-491.

[34] Katz, M.L. and Shapiro, C., 1986, "How to Licence Intangible Property", *Quarterly Journal of Economics*, Vol. 101(3), pp. 567-89.

[35] Lanjouw, J.O. and Schankerman, M., 1999, "The Quality of Ideas: Measuring Innovation with Multiple Indicators", NBER Working paper No. 7345, Cambridge, MA.

[36] Lerner, J. and Merges, R., 1998, "The Control of Strategic Alliances: An Empirical Analysis of the Biotechnology Industry", *Journal of Industrial Economics,* Vol. 46(2), pp. 125-156.

[37] Morgan, R.P., Kruytbosch, C. and Kannankutty, N., 2001, "Patenting and Invention Activity of U.S. Scientists and Engineers in the Academic Sector: Comparisons with Industry", *Journal of Technology Transfer*, Vol. 26(1-2), pp. 173-183.

[38] Norbäck, P and Persson, L, 2009, "The Organization of the Innovation Industry: Entrepreneurs, Venture Capitalists and Oligopolists", *Journal of European Economics Association* 7(6) pp. 1261-1290.

[39] Norbäck, P., Persson, L., and Svensson, R., 2009, "Creative Destruction and Productive Preemption", Working Paper No. 799, Research Institute of Industrial Economics.

[40] Schumpeter, J., 1942, *Capitalism, Socialism and Democracy*, Harper & Brothers, London.

[41] Segerstrom, P.S., Anant, T.C.A. and Dinopoulos, E., 1990, "A Schumpeterian Model of the Product Life Cycle", *American Economic Review*, Vol. 80(5), pp. 1077–1091.

[42] Svensson, R., 2007, "Commercialization of Patents and External Financing during the R&D-Phase", *Research Policy*, Vol. 36(7), pp. 1052-1069.

[43] Townsend, R.M., 1979, "Optimal contracts and competitive markets with costly state verification", *Journal of Economic Theory*, 21, pp. 265-93.

[44] Trajtenberg, M., 1990, "A Penny for your Quotes: Patent Citations and the Value of Innovations", *RAND Journal of Economics*, Vol. 21(1), pp. 172-187.

[45] Van de Ven, Wynand P. M. M. & Van Praag, Bernard M. S., 1981. "The demand for deductibles in private health insurance : A probit model with sample selection", *Journal of Econometrics*, Vol. 17(2), pp. 229-252.

9. Appendix

9.1. 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 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 incumbent $w \neq e$ is the incumbent that has posted the highest bid and obtains the assets, and that 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 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.

9.2. Deriving the Bayes-Nash equilibrium in the LC-model

Let us solve the for the Bayes-Nash equilibrium in the product market interaction in stage 3. Let $P(l,t) = a - Q(l,t)$ be the inverse demand, where $Q(l,t) = \sum_{j=1}^{N(l)} q_j(l,t)$. In the Bayes-Nash equilibrium firms maximize the following direct profits :

$$\begin{aligned} \pi_h(\cdot, l, s) &= [P(l,s) - (c-k)]\, q_h(l,s) && (9.1)\\ \pi_h(\cdot, l, f) &= [P(l,f) - c]\, q_h(l,f) && (9.2)\\ \bar{\pi}_N(l) &= \theta\,[P(l,s) - c]\, q_N(l) + (1-\theta)\,[P(l,f) - c]\, q_N(l) && (9.3) \end{aligned}$$

where again non-acquiring incumbents do not know the true quality of the invention.

The first-order conditions are:

$$\begin{aligned} \frac{\partial \pi_h(\cdot, l, s)}{\partial q_h(l,s)} &= [P(l,f) - c]\, q_h(l,f) - q_h(l,s) = 0 && (9.4)\\ \frac{\partial \pi_h(\cdot, l, f)}{\partial q_h(l,f)} &= [P(l,f) - c] - q_h(l,f) = 0 && (9.5)\\ \frac{\partial \bar{\pi}_N(l)}{\partial q_N(l)} &= \theta\,[P(l,s) - c] + (1-\theta)\,[P(l,f) - c] - q_N(l) = 0 && (9.6) \end{aligned}$$

The Bayes-Nash equilibrium can then be solved as:

$$\begin{aligned} q_h^*(l,s,\theta) &= \tfrac{\Lambda + k - (N(l)-1) q_N^*(l,\theta)}{2} && (9.7)\\ q_h^*(l,f,\theta) &= \tfrac{\Lambda - (N(l)-1) q_N^*(l,\theta)}{2} && (9.8)\\ q_N^*(l,\theta) &= \tfrac{\Lambda - \theta k}{N(l)+1} && (9.9) \end{aligned}$$

Note that (9.1) and (9.4) implies a reduced-form profit $\pi_h(l,s,\theta) = [q_h^*(l,s,\theta)]^2$ for $h = A, E$ and (9.2) and (9.5) implies a reduced-form profit $\pi_h(l,f,\theta) = [q_h^*(l,f,\theta)]^2$ for $h = A, E$.

From (9.7) and (9.8) it then follows that $\pi_h(l,s,\theta) > \pi_h(l,f,\theta)$ for $h = A, E$.

Let $P(l,t,\theta) = a - Q^*(l,t,\theta)$ and note that $P(l,s,\theta) - P(l,f,\theta) = -\frac{k}{2}$. Note that $\pi_N(l,s,\theta) = [P(l,s,\theta) - c)]q_N^*(l,\theta)$ and that $\pi_N(l,f,\theta) = [P(l,f,\theta) - c]q_N^*(l,\theta)$. It follows that $\pi_N(l,f,\theta) - \pi_N(l,f,\theta) = [P(l,f,\theta) - P(l,s,\theta)]q_N^*(l,\theta) = \frac{k}{2} q_N^*(l,\theta) > 0$. Also for $h = A, E$, $\pi_h(l,f,\theta) - \pi_N(l,f,\theta) = [P(l,f,\theta) - c]\,[q_h^*(l,f,\theta) - q_N^*(l,f,\theta)] > 0$, since $q_h^*(l,f,\theta) - q_N^*(l,\theta) = \frac{\theta k}{2} \geq 0$.

Hence, we have shown that

$$\pi_h(l,s,\theta) > \pi_h(l,f,\theta) > \pi_N(l,f,\theta) > \pi_N(l,s,\theta) \text{ for } h = A, E$$

Note that (9.7) and (9.8) implies, $\frac{d\pi_h(l,t,\theta)}{dk} > 0$ for $h = A, E$. Moreover, we have that

$$\frac{dP(l,s,\theta)}{dk} = -\frac{1}{2}\left[1 - \theta\frac{N(l)-1}{N(l)+1}\right] < 0 \tag{9.10}$$

$$\frac{dP(l,f,\theta)}{dk} = \frac{\theta}{2}\frac{N(l)-1}{N(l)+1} > 0 \tag{9.11}$$

Then, $\frac{d\pi_N(l,s,\theta)}{dk} = \frac{dP(l,s,\theta)}{dk}q_N^*(l,\theta) + [P(l,s,\theta) - c]\frac{dq_N^*(l,\theta)}{dk} < 0$, since $\frac{dq_N^*(l,\theta)}{dk} < 0$ and $\frac{dP(l,s,\theta)}{dk} < 0$.
It also follows that $\frac{d\pi_h(l,t,\theta)}{dk} - \frac{d\pi_N(l,t,\theta)}{dk} = \frac{dP(l,f,\theta)}{dk}[q_h^*(l,f,\theta) - q_N^*(l,\theta)] + [P(l,s,\theta) - c]\left(\frac{dq_h^*(l,f,\theta)}{dk} - \frac{dq_N^*(l,\theta)}{dk}\right) > 0$ since $\frac{dP(l,f,\theta)}{dk} > 0$, $q_h^*(l,f,\theta) > q_N^*(l,\theta)$ and $\frac{dq_h^*(l,f,\theta)}{dk} > \frac{dq_N^*(l,\theta)}{dk}$ from (9.11), (9.8) and (9.9).

9.3. Proof of Proposition 6

Note that if incumbents are certain that the invention is successful ($\theta = 1$), Assumption A2 implies:

$$\bar{w}'_{il,k}(1) - w'_{e,k}(s,1) = v'_{il,k}(s,1) - v'_{e,k}(s,1) + v'_{il,k}(s) - v'_{e,k}(s) > 0, \tag{9.12}$$

since $v'_{il,k}(s,1) - v'_{e,k}(s,1) = v'_{il,k}(s) - v'_{e,k}(s) > 0$.

If incumbents are certain that the invention is unsuccessful ($\theta = 0$), we have:

$$\bar{w}'_{il,k}(0) - w'_{e,k}(s,0) = \begin{cases} -[v'_{e,k}(s,0) + v'_{e,k}(s)] < 0 \text{ for } k \in [0, \breve{k}_0^{PE}) \\ -[v'_{e,k}(s,0) + v'_{ii,k}(s)] < 0 \text{ for } k \in [\breve{k}_0^{PE}, k^{\max}) \end{cases} \tag{9.13}$$

noting that $v'_{e,k}(s) > 0$ and $v'_{ii,k}(s) > 0$ while $\bar{w}'_{il,k}(0) = 0$ and $v'_{e,k}(s,0) > 0$ from Assumption A4. Since the prior $\theta \in [0,1]$ is continuous, there must exist a cut-off prior $\tilde{\theta}$ such that $\bar{w}'_{il,k}(\tilde{\theta}) - w'_{e,k}(s,\tilde{\theta}) = 0$ for $k \in [\breve{k}_0^{PE}, k^{\max})$. For any $\theta = \tilde{\theta} + \varepsilon$ we then have $\bar{w}'_{il,k}(\theta) - w'_{e,k}(s,\theta) > 0$ and for any $\theta = \tilde{\theta} - \varepsilon$, $\bar{w}'_{il,k}(\theta) - w'_{e,k}(s,\theta) < 0$.

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	Year when patent was filed			1995	1.7	1995	1.7

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
Differences between means, t-test	Entry – No comm. Sale - No comm.. Sale - Entry	1.86 * 1.73 * 1.17		
Average No. of citations per patent and 5 year period	0.30	0.45	0.63	0.42
Differences between means, t-test	Entry – No comm. Sale - No comm.. Sale - Entry	2.15 ** 1.92 * 1.05		

Note: ***, ** and * indicate significance at the 1, 5 and 10 percent level

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		
	Specification A	Specification B	Specification 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 *	-0.315	-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
Wald, χ^2	42.8 **	43.5 **	44.2 **
Wald, χ^2 (Core var.)	20.5 ***	20.8 ***	21.8 ***

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. The Wald χ^2 tests the hypothesis $\boldsymbol{\gamma} = \mathbf{0}$ in (5.4). The Wald χ^2 test in the last row 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		
	Specification A	Specification B	Specification 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
Wald, χ^2	40.9 **	41.9 **	45.1 **
Wald, χ^2 (Core var.)	19.4 ***	19.4 ***	21.3 ***

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

Table 6.1. Results of the multinomial logit model

Explanatory variables	Multinomial logit model with "No commercialization" as the base alternative					
	Specification A (Quality measured with W_CIT)			Specification B (Quality measured with D_W_CIT-dummy)		
	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 FE	Yes			Yes		
Regional FE	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. Wald test II tests $\beta = 0$ and $\alpha = 0$ in (5.8), respectively, under the assumption of $\psi = 0$. Wald test III repeats this for the core variables *W_CIT, SMALL, MICRO* and *PVC* all being zero. The Wald χ^2 (diff) given in columns four and six test first tests if individual parameter estimates differ between equations. Columns four and six for Wald tests II and III test $\beta = \alpha$ for the full specification and then repeat this for the core variables for *W_CIT, SMALL, MICRO* and *PVC.*

Table 7.1. Results of the probit model with late sale

Explanatory variables	Dependent variable = *LATE SALE*		
	Statistical model: Binomial probit model		
	Specification A	Specification B	Specification C
W_CIT	0.229 **	0.249 **	0.248 **
	(0.108)	(0.110)	(0.109)
SMALL	-0.197	-0.196	-0.176
	(0.288)	(0.289)	(0.281)
MICRO	0.151	0.189	0.189
	(0.262)	(0.265)	(0.264)
PVC	-4.5 E-3	-4.6 E-3	5.2 E-3
	(8.5 E-3)	(8.5 E-3)	(8.6 E-3)
B_CIT		-0.436	-0.444
		(0.472)	(0.481)
APPLY			0.027
			(0.068)
Technology FE	Yes	Yes	Yes
Region FE	Yes	Yes	Yes
Log Likelihood	-84.8	-84.5	-84.4
Wald χ^2 I	26.5 **	29.4 **	29.8 *
Wald χ^2 II	5.81	6.54	6.53
Wald χ^2 III	1.52	2.51	2.48

Note: The number of observations is 303. *LATESALE* equals 1 for 30 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. The Wald χ^2 I test tests the hypothesis $\gamma = \mathbf{0}$ in (5.4). The Wald χ^2 II test repeats this for the core variables *W_CIT, SMALL, MICRO* and *PVC* and Wald $\chi2$ III test for *SMALL, MICRO* and *PVC*.

Table 7.2. Results of the multinomial logit model with direct sale

Explanatory variables	Multinomial logit model with "No commercialization" as the base alternative					
	Specification A			Specification B		
	DIRECT SALE	*DIRECT ENTRY*	Wald χ^2 (diff)	*DIRECT SALE*	*DIRECT ENTRY*	Wald χ^2 (diff)
W_CIT	0.418	0.275	1.94			
	(0.260)	(0.228)				
D_W_CIT				1.16 ***	0.862 ***	0.74
				(0.373)	(0.236)	
SMALL	-2.01 *	1.24 ***	9.64 ***	-2.12 **	1.16 ***	10.02 ***
	(1.08)	(0.36)		(1.06)	(0.363)	
MICRO	0.415	1.36 ***	5.31 **	0.263	1.26 ***	5.83 **
	(0.470)	(0.35)		(0.472)	(0.353)	
PVC	0.015	-1.5 E-4	2.97 *	0.013	-2.5 E-3	2.73
	(9.4 E-3)	(8.9 E-3)		(9.5 E-3)	(8.8 E-3)	
Technology FE	Yes			Yes		
Regional FE	Yes			Yes		
Log likelihood	442.1			-436.9		
I. Wald χ^2	83.1 ***			99.9 ***		
II. Wald χ^2	25.7 *	44.7 ***	36.5 ***	38.9 ***	53.3 ***	38.1 ***
III, Wald χ^2 (core)	9.9 **	28.1 ***	18.4 ***	17.6***	36.3 ***	18.6 ***

Note : The number of observations equals 527, of which *MODE*=1 (Direct Entry) for 303 observations and *MODE*=2 (Direct sale) for 61 observations. 163 observations classified as No commercialization (*MODE*=0), 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. Wald test II tests $\beta = 0$ and $\alpha = 0$ in (5.8), respectively, under the assumption of $\psi = 0$. Wald test III repeats this for the core variables *W_CIT, SMALL, MICRO* and *PVC* all being zero. The Wald χ^2 (diff) given in columns four and six test first tests if individual parameter estimates differ between equations. Columns four and six for Wald tests II and III test $\beta = \alpha$ for the full specification and then repeat this for the core variables for *W_CIT, SMALL, MICRO* and *PVC.*

Table 7.3. Results of the survival model with competing risks, part I (cont.)

Explanatory variables	Accelerated failure time model with competing risks – log-normal model					
	Specification A			Specification B		
	ENTRY	*SALE*	Diff. χ^2	*ENTRY*	*SALE*	Diff. χ^2
W_CIT	-4.1 E-3	-0.30***	3.60 *	-4.0 E-3	-0.33***	4.33 **
	(0.11)	(0.11)		(0.12)	(0.11)	
SMALL	-1.33***	0.97**	23.18 ***	-1.33***	0.94**	22.52 ***
	(0.26)	(0.40)		(0.26)	(0.40)	
MICRO	-1.05***	-0.073	6.78 ***	-1.04***	-0.11	6.15 **
	(0.23)	(0.29)		(0.24)	(0.29)	
PVC	2.6 E-3	-6.5 E-3	0.83	2.6 E-3	-6.4 E-3	0.81
	(7.1 E-3)	(7.0 E-3)		(7.1 E-3)	(7.0 E-3)	
B_CIT				-0.11	0.69	0.95
				(0.43)	(0.70)	
σ	1.93	1.73		1.93	1.73	
Technology FE	Yes	Yes		Yes	Yes	
Region FE	Yes	Yes		Yes	Yes	
Log likelihood	-882.5	-404.4		-882.5	-403.9	

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

Table 7.3. part II (cont.)

Explanatory variables	Accelerated failure time model with competing risks – log-normal model		
	Specification C		
	ENTRY	*SALE*	Diff. χ^2
W_CIT	-2.1 E-3	-0.33 ***	4.22 **
	(0.12)	(0.11)	
SMALL	-1.32***	0.93 **	22.29 ***
	(0.26)	(0.40)	
MICRO	-1.04***	-0.11	6.11 **
	(0.22)	(0.29)	
PVC	3.0 E-3	-6.3 E-3	0.88
	(7.1 E-3)	(6.9 E-3)	
B_CIT	-0.10	0.69	0.95
	(0.42)	(0.70)	
APPLY	-0.064	-0.030	1.18
	(0.056)	(0.066)	
σ	1.92	1.72	
Technology FE	Yes	Yes	
Region FE	Yes	Yes	
Log likelihood	-881.8	-403.8	

Table 7.4. Results of the survival model with competing risks, part I (cont.)

Explanatory variables	Accelerated failure time model with competing risks – log-normal model					
	Specification A			Specification B		
	ENTRY	*SALE*	Diff. χ^2	*ENTRY*	*SALE*	Diff. χ^2
D_W_CIT	-0.012	-0.65***	4.04**	-0.015 E-3	-0.69***	4.27**
	(0.20)	(0.25)		(0.20)	(0.25)	
SMALL	-1.33***	1.03**	23.86***	-1.33***	1.02**	23.67***
	(0.26)	(0.41)		(0.26)	(0.41)	
MICRO	-1.05***	0.028	7.97***	-1.05***	0.016	7.78**
	(0.24)	(0.30)		(0.24)	(0.30)	
PVC	2.6 E-3	-5.6 E-3	0.67	2.6 E-3	-5.4 E-3	0.63
	(7.1 E-3)	(7.1 E-3)		(7.1 E-3)	(7.1 E-3)	
D_B_CIT				-0.020	0.31	0.27
				(0.33)	(0.44)	
σ	1.93	1.74		1.93	1.74	
Technology FE	Yes	Yes		Yes	Yes	
Region FE	Yes	Yes		Yes	Yes	
Log likelihood	-882.5	-404.8		-882.5	-404.5	

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 7.4. part II (cont.)

Explanatory variables	Accelerated failure time model with competing risks – log-normal model		
	Specification C		
	ENTRY	*SALE*	Diff. χ^2
D_W_CIT	-6.8 E-3	-0.68***	4.36 **
	(0.20)	(0.25)	
SMALL	-1.33***	1.02**	23.56 ***
	(0.26)	(0.41)	
MICRO	-1.05***	0.016	7.76 ***
	(0.24)	(0.30)	
PVC	2.9 E-3	-5.4 E-3	0.68
	(7.1 E-3)	(7.1 E-3)	
D_B_CIT	-0.034	0.30	0.24
	(0.33)	(0.44)	
APPLY	-0.064	-0.011	0.37
	(0.056)	(0.066)	
σ	1.92	1.74	
Technology FE	Yes	Yes	
Region FE	Yes	Yes	
Log likelihood	-881.9	-404.5	

Appendix

Table A1. Results of the logit model.

Explanatory variables	Dependent variable = *SALE*		
	Statistical model: Binomial logit model		
	Specification A	Specification B	Specification C
W_CIT	0.232 **	0.265 **	0.264 **
	(0.118)	(0.127)	(0.129)
SMALL	-1.62 ***	-1.61 ***	-1.62 ***
	(0.466)	(0.466)	(0.463)
MICRO	-0.548 *	-0.494 *	-0.498 *
	(0.331)	(0.337)	(0.333)
PVC	0.010	9.9 E-3	0.010
	(8.7 E-3)	(8.7 E-3)	(8.6 E-3)
B_CIT		-0.773	-0.771
		(0.723)	(0.713)
APPLY			-0.046
			(0.085)
Technology FE	Yes	Yes	Yes
Region FE	Yes	Yes	Yes
Log Likelihood	-185.9	-185.3	-185.1
Wald, χ^2	38.1 **	38.5 **	40.0 **
Wald, χ^2 (Core var.)	18.1 ***	18.3 ***	19.0 ***

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

Table A2. Results of OLS estimations.

Explanatory variables	Dependent variable = *SALE*		
	Statistical model: Ordinary Least Squares		
	Specification A	Specification B	Specification C
W_CIT	0.043 **	0.048 **	0.047 **
	(0.020)	(0.214)	(0.021)
SMALL	-0.242 ***	-0.238 ***	-0.239 ***
	(0.058)	(0.058)	(0.058)
MICRO	-0.101 *	-0.095 *	-0.095 *
	(0.058)	(0.058)	(0058)
PVC	2.3 E-3	2.2 E-3	2.3 E-3
	(1.8 E-3)	(1.8 E-3)	(1.8 E-3)
B_CIT		-0.093	-0.093
		(0.072)	(0.073)
APPLY			-6.6 E-3
			(0.015)
Technology FE	Yes	Yes	Yes
Region FE	Yes	Yes	Yes
R^2	0.10	0.10	0.10
F-test	2.11 ***	2.08 ***	2.09 ***
F-test (Core var.)	6.10 ***	6.22 ***	6.29 ***

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. The F-test tests the hypothesis $\boldsymbol{\gamma} = \mathbf{0}$ in (5.4). The F-test in the last row repeats this for the core variables for *W_CIT, SMALL, MICRO* and *PVC*.

Table A3. Results of probit model with extra covariates.

Explanatory variables	Dependent variable = *SALE*		
	Statistical model: Binomial probit model		
	Specification A	Specification B	Specification C
W_CIT	0.158 **	0.149 **	0.133 *
	(0.075)	(0.075)	(0.071)
SMALL	-1.01 ***	-0.842 ***	-0.883 ***
	(0.246)	(0.258)	(0.265)
MICRO	-0.361 *	-0.202	-0.215 *
	(0.193)	(0.207)	(0.208)
PVC	5.1 E-3	7.6 E-3	7.5 E-3
	(5.3 E-3)	5.1 E-3)	(5.2 E-3)
B_CIT	-0.470	-0.416	-0.417
	(0.375)	(0.380)	(0.389)
APPLY	-0.020	0.022	-0.024
	(0.048)	(0.048)	(0.048)
UNIV	-0.819	-0.623	-0.734
	(0.632)	(0.663)	(0.681)
SEX	-1.63 **	-1.69 **	-1.78 **
	(0.641)	(0.666)	(0.72)
PCT		0.012	0.013 ***
		(4.9 E-3)	4.9 E-3
KOMPL			0.300
			(0.191)
Technology FE	Yes	Yes	Yes
Region FE	Yes	Yes	Yes
Log Likelihood	-180.5	-177.2	-176.0
Wald, χ^2	52.2 ***	54.8 ***	56.1 ***
Wald, χ^2 (Core var.)	23.1 ***	17.7 ***	17.5 ***

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

Table A4. Results of the probit model. Large sample.

Explanatory variables	Dependent variable = *SALE*		
	Statistical model: Binomial probit model		
	Specification A	Specification B	Specification C
W_CIT	0.140 **	0.164 **	0.164 **
	(0.067)	(0.073)	(0.074)
SMALL	-0.976 ***	-0.968 ***	-0.978 ***
	(0.197)	(0.198)	(0.199)
MICRO	-0.396 **	-0.366 **	-0.370 **
	(0.180)	(0.181)	(0.181)
PVC	1.9 E-3	1.4 E-3	1.6 E-3
	(4.6 E-3)	4.7 E-3)	(4.6 E-3)
B_CIT		-0.496	-0.501
		(0.371)	(0.369)
APPLY			-0.036
			(0.045)
Technology FE	Yes	Yes	Yes
Region FE	Yes	Yes	Yes
Log Likelihood	-210.4	-209.6	-209.3
Wald, χ^2	50.0 ***	51.6 ***	51.9 ***
Wald, χ^2 (Core var.)	29.6 ***	30.0 ***	30.4 ***

Note: The number of observations is 449. *SALE* equals 1 for 99 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. The Wald χ^2 I tests the hypothesis $\boldsymbol{\gamma} = \mathbf{0}$ in (5.4). The Wald χ^2 test II repeats this for the core variables *W_CIT, SMALL, MICRO* and *PVC*.