

Firm Size and the Quality of Entrepreneurs*

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June 12, 2004

Abstract

Founders of new firms tend to be experienced workers who pursue opportunities closely related to their previous employment. We propose a theory that studies the tango between individual workers' entrepreneurship decision and established firms' effort to keep their best workers and ideas. The main results are twofold. First, taking the firm size as given, larger firms tend to have less flexible wages and produce entrepreneurs of higher quality than smaller firms. Second, making firm size endogenous, we find that stronger property rights makes the optimal firm size larger (and the average quality of entrepreneurs higher). To illustrate the theory, we consider two sources of evidence: data on the quality of entrepreneurs from a survey of Stanford MBA alumnus, and evidence on the evolution of firm size in the U.S. Software Industry after a recent strengthening in software patent protection. Both hypotheses receive encouraging support.

Keywords: Entrepreneurship, Innovation, IPP, Private benefits, Property Rights, Spin-offs, Start-ups.

*Thanks to Manuel Amador, Tim Bresnahan, Denis Gromb, Thomas Hellman, Oliver Hart, Ed Lazear, Jim March, Espen Moen, Paul Romer, Jeff Zwiebel, and seminar audiences at Bergen, Zurich and Stanford for comments and suggestions. Special thanks to Stanford University Graduate School of Business for its hospitality and for providing access to their Master of Business Administration alumni data.

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1 Introduction

Due to their role in fostering employment opportunities and growth, entrepreneurs are viewed as essential to long-run economic performance. For example, the U.S. emphasis on the role of the entrepreneur has been viewed as a main reason for why the US outperformed Europe in the 20th century. In spite of the economic importance attached to entrepreneurs, we have surprisingly little systematic knowledge about them. Who become entrepreneurs? How are these individuals' ideas and human capital shaped and accumulated? What determines whether an entrepreneur becomes a success or a failure?

Empirical evidence indicates that founders of new firms tend to be experienced workers who pursue opportunities closely related to their previous employment. Entrepreneurs have several years of work experience (Hamilton, 2000), and according to Cooper (1985), 70 percent of the founders of new firms in a broad cross-section of U.S. industries were previously employed in the same industry. And, as frequently quoted, Bhidé (2000) reports that 71% of the entrepreneurs in his sample, "replicated or modified an idea encountered through previous employment". This evidence suggests that entrepreneurs do not come from out of the blue but build their human intellectual capital through work experience in established firms.

Established firms can be expected to respond actively to the possibility of key workers leaving, such as through no-compete clauses, longer-term employment contracts, and through patent rights enforcement. Still, there are several limitations to these measures; there are legal restrictions to the length of time an employee can commit to work for a firm; non-competition clauses must be of limited scope to be legally binding (e.g., Posner & Triantis, 2001), and even for established innovations, the effectiveness of patent protection can at best be said to vary considerably between industries (Cohen, 2000).

Firms can only to a limited extent can use formal contracts in order to appropriate the value created by employees. There are, however, other means. Firms can, for example, create bonus or options programs geared to keep the best workers. Or the firm may design a cautious R&D policy that focuses on easily protectable innovations, to reduce the rents left on the table for workers. Or, as we shall focus on, the firm may choose an organizational structure that makes it less vulnerable.

To address the interaction between the entrepreneurship decisions of workers and strategy decisions of firms, we construct a simple model. A principal (owner) hires a worker (specialist) to engage in a project. The output of this project is an idea of ex-ante uncertain quality, and with imperfect property rights attached to it, meaning that the firm to a limited extent can use sticks to keep the worker from leaving the firm and capture (a fraction of) the value of the idea. Instead, the firm must use an attractive continuation wage as a carrot.

The model considers two different possible firm organizations, "small" and "large". In a small firm, the principal is well-informed about the progress and content of the research project the worker is engaged in, and can therefore pay a wage that is fine-tuned to the worker's leaving option. As a result, workers leave a small firm to become entrepreneurs only to the extent that their private benefits, such as more flexible work hours or a sense of freedom and pride, from doing so are sufficiently high (relative to their productivity).¹ Compared to small firms, large firms are able to exploit returns to scale (or scope) better than small firms, but has inferior quality of information about the ideas and productivity of individual employees. Therefore, a large firm has a less fine-tuned wage policy than small firms, and as a result the best ideas tend to leave the firm. The theory therefore predicts that the ideas lost to a firm will depend on its size: large firms will lose the top end of the distribution, while workers leaving small firms will tend to have comparatively low-quality ideas.

To indicate whether entrepreneurs from large firms tend to do better than entrepreneurs from small firms, we consider data from a recent survey of Stanford University MBA alumni. Although clearly limited in size and scope, a unique feature of these data is that we can identify measures of the success of an entrepreneur (such as his salary at different

¹To let private benefits play a serious role in determining the entrepreneurship decision could sound overly ad-hoc. It might therefore be worth to point out it has an intellectual tradition going back at least to John Stuart Mill and Alfred Marshall: "Concerning the entrepreneur [J. S. Mill] was explicit when he stated that small producers often value so highly the feeling of being their own masters that they consume their small capital in an unsuccessful struggle for independence; 'they either sink into the condition of hired labourers, or become dependent upon others for support'." (Evans, 1949, p. 339) And Marshall wrote that "'Organizers of improved methods and appliances are stimulated by a noble emulation more than by any love of wealth for its own sake', and the entrepreneur 'often holds his own great tenacity even under considerable disadvantages; for the freedom and dignity of his position are very attractive to him.'" (op. cit., p. 339).

points in time of the start-up and the start-up size) conditional on both the entrepreneur's previous salary and the size of his previous employer. The analysis suggests an economically significant positive relationship between the size of an entrepreneur's previous employer and his success as an entrepreneur. We are not aware of alternative theories that can explain this finding.

In the second part of the paper, we ask which firm size is optimal, small or large, conditional on the worker having the option to leave. The central exogenous variable is the strength of property rights protection in the industry (or country) of the firm. Recall that the downside from being large is that the principal obtains inferior information about the value of individual employees (or projects). When property rights protection is weak, the value of information is high, since the worker leaving with the idea is more of a threat, and being small becomes more beneficial. On the other hand, when property rights protection is strong, the value of information is low, since the worker leaving is not a serious threat, and the principal can focus on technical efficiency and commercialization potential. The bottom line is that improved property rights makes a larger firm more likely to be optimal.

The strength of property rights protection a firm enjoys can be related to several other variables, such as the patentability of process or product innovations (OECD, 1998, Cohen et al., 2000), or simply the legal culture in its geographical region. For example, legal scholars argue that the Massachusetts courts are more "pro-firm" while the Californian courts are "pro-employee" (Hellmann, 2003). Our second main hypothesis, then, has resonance in Saxenian (1994), which argues that firms along Route 128 in Massachusetts are typically larger and more bureaucratic than in their counterparts in Silicon Valley. Another type of evidence consistent with this hypothesis is from Kumar et al. (2004), which considers differences in within-industry firm size across countries. Since regions and countries differ along several other dimensions than property rights protection, such as financial market conditions (Beck et al., 2002, 2003) and local labor market conditions (Landier, 2001), a stronger type of test of the theory would be to investigate whether firm size tends to increase following "exogenous" improvements in property rights protection. Fortunately, there exists something close to such a natural experiment; In the U.S. software industry patent protection increased significantly through landmark court cases in

the mid 90-ies (e.g., Burk & Lemley, 2002). Simple analysis of publicly available data indicates a strong increase in firm size within the U.S. software industry between the mid 90-ies and presently. For example, the average number of employees per firm *doubled*, from 21 to 42, between 1996 and 2001, a change that is hard to attribute to other factors than the regime shift in property rights. In sum, therefore, the main insights findings from the theory receive encouraging empirical support from independent sources.

2 Related literature

In a typical economic theory of business start-ups, the defining feature of the entrepreneur – a business idea of some novelty – is simply assumed to exist (e.g., Kihlstrom & Laffont, 1979, Evans & Jovanovic, 1989, Rajan & Zingales, 1998, 2001, Landier, 2001, and Gromb & Scharfstein, 2003). The process in which the entrepreneur obtains these ideas and his human capital is usually ignored.² There are some exceptions. Lazear (2003) models and finds empirical support for the idea that entrepreneurs are jacks-of-all-trades rather than specialists. Although Lazear (2003) emphasizes the background of the entrepreneur, he does not focus on the entrepreneur's previous employment relationship or the transition to entrepreneurship. Hellmann (2003) and Subramanian (2003) consider the multi-tasking problem that ensues if a worker can engage in "private activities" on the job with the intention of creating a start-up later. Hellmann (2003) shows that entrepreneurship may come about through the firm committing not to reward these private activities (even if they should be ex-post efficient to support it). Subramanian (2003) finds that the level of private activities inside the firm should be positively correlated with pay-for-performance contracts. In contrast to these papers, we assume that the principal can stop the worker from engaging in private activities, but cannot stop the worker from leaving with ideas that are generated through his legitimate work.³

²Shane (2000) argues that this point holds also for the Psychology and Management literature on entrepreneurship.

³Dunn & Holtz-Eakin (2000), among others, suggest that self-employed build their human capital through learning spillovers from their parents. Several papers, e.g., Evans & Jovanovic (1989), Evans & Leighton (1989) and Holtz-Eakin et al. (1994) find evidence that financial constraints are important in determining whether an individual becomes an entrepreneur. Gentry & Hubbard (2002) investigates the macro-level implications of the relation between savings and investments made by entrepreneurs. De Meza

Since we focus on the interaction between entrepreneurship and the organization of established firms, there is a related literature within Organizational Economics. Aghion & Tirole (1994) considers the management of innovations in a setting based on Grossman & Hart (1986). In their setting, there is no entrepreneurship in equilibrium due to ownership rights being fully contractible. In the same tradition, but with imperfect property rights, Rajan & Zingales (2001) considers a firm with an exogenously given "critical resource" controlled by an owner, and analyzes the optimal choice of organization to protect this resource from being stolen by employees. There is no start-up activity by workers in equilibrium due to information being complete. Further, in our setting the employee has informal control in that only he has the human capital necessary for the innovation. We obtain the same type of prediction as Rajan & Zingales (2001) on the relation between firm size and property rights regime. It is interesting that this insight seems valid in such markedly different frameworks. Pakes & Nitzan (1984) was the first to consider the problems that arise where agents can appropriate part of their output. In their setting, the principal always has complete information about the value of individual workers and therefore only efficient separations will occur. Anton & Yao (1994) considers the effects of weak property rights in a market for ideas. Anton & Yao (1995) builds on Anton & Yao (1994) to study whether an idea generated inside a firm leads to creation of one or two ventures. This question is eliminated in the current setting by assuming that the participation of the employee is essential to develop the idea.

3 The basic model

A principal (owner) identifies a research area, and hires a worker (specialist) at time 0 to generate ideas in that area. We shall assume that the firm has only this project and that the worker is hired from a homogenous pool of risk neutral agents with reservation utility $\bar{U} = 0$. The latter assumption means that we can safely assume that the worker waives any formal ownership rights for future output.

Upon signing the contract, the agent is paid a fixed wage F and supplies one unit of

& Southey (1996), Amador & Landier (2003) and Landier & Thesmar (2003) study the role of entrepreneurial overconfidence, while Bates (1985, 1990) studies the link between education and entrepreneurship.

effort. Inelastic effort supply is meant to capture a situation where it is easier to monitor the input of the agent in terms of time spent and effort exerted than assessing his output. At time 1, he produces an idea with value x , where x is stochastic and non-negative (a really bad idea can always be viewed as no idea, i.e., $x = 0$). The distribution of x follows $G(x)$ with density $g(x)$ and support on $[0,1]$. For convenience, we assume that $G(\cdot)$ is twice differentiable and with $g(1) = 0$. Although we refer to x as the quality of an idea produced by the agent, one might prefer to think of x as the value of the worker's human capital if employed by the firm after time 1.

We assume that x is known to the worker upon its realization at time 1, while the principal receives a signal $s \in S$ about x . The precision of the signal is inversely related to the firm size in a particularly simple manner; in a small firm $s = x$ and in a large firm s is uninformative. The role of this assumption is discussed later. Conditional upon s , the firm makes a continuation wage offer B to the agent. Whether the firm can commit to a continuation wage offer $B(s)$ at time 0 or not is immaterial to the analysis as long as $\bar{U} = 0$, but we shall speak as if commitments were not possible.⁴ Agents are protected by limited liability so that both F and B must be non-negative.

The agent may accept or reject the offer B . Accepting B is synonymous to signing an extension of the employment contract, and the final (time 2) payoffs become $x - B$ to the firm and B to the agent, respectively.⁵ If the worker rejects the offer B , he quits the firm and develops a start-up based on x at time 1. We let "an entrepreneur" be such an individual. The time 2 payoff from becoming an entrepreneur, $U(x, \cdot)$ depends on the fixed costs (or benefits) from starting up a firm and the degree to which the idea generated is possible to carry away. We formalize this as the entrepreneurial payoff being equal to,

$$U(x) = \max\{0, \eta x - c\} \tag{1}$$

⁴If $\bar{U} > 0$ then under pre-commitment there will be an indeterminacy in the optimal contract, as in Pakes & Nitzan (1984), since F and B will be substitutable, but that will have no impact on the results. By the assumption $\bar{U} = 0$, then $F = 0$ in optimum, and the optimal $B(s)$ schedule is uniquely determined.

⁵One might ask why the firm would not write a longer contract in the first place, to avoid many problems. However, contracts of unbounded duration would not be acceptable according to labor laws in most countries, and for any contract with finite length, the problems the paper discusses can occur.

Since this is the key equation of the model setup, let us discuss it in some detail. The parameter c is meant to capture the sum of financing costs and the private benefits the agent enjoys from being entrepreneur. For example, if a start-up requires a high investment cost (think of a pharmaceutical lab) or is located in region with a dearth of venture capitalists, then the financing costs are high.⁶ Private benefits, on the other hand, is the monetary equivalent the entrepreneur is willing to sacrifice in order to start a venture (be his own boss, a sense of pride etc.) The parameter c will be taken as determined by forces exogenous to the model (Both this assumption and the linearity assumption inherent in (1) is discussed in 4.3). Since empirical evidence indicates that private benefits can be substantial (Hamilton, 2000), we analyze both the cases $c > 0$ and $c < 0$. For simplicity we assume that c is known to both the worker and the employer at time zero, and constant across all workers in the labor pool.⁷

The parameter η reflects the degree to which the idea generated by the agent has value to him if he leaves; the higher η the higher fraction of value the agent can carry with him. Our focus is on how the strength of property rights protection affects η (how technological complementarities can affect η is discussed in Section 8). There are at least two ways in which η depends on the legal environment; through non-compete clauses, and through patenting. Let us discuss these two mechanisms in turn.

Non-compete clauses impose a direct restriction on the worker's legal ability to start up a business whose activities are close or similar to those engaged in at his previous employer. The ease to which non-compete clauses can be enforced varies between industries, one reason being that what is meant by a related business can be much harder to define in say the management consulting industry than in the electronics industry (Posner & Triantis, 2000). Varying η can also reflect differences in strength of patent protection. If

⁶Evidence from Hellmann & Puri (2002) suggests that venture capitalists may boost the gross entrepreneurial payoff $U(x)$, in addition to providing funding. As long as the firm has the option to hire the venture capitalist as a consultant, or a person with similar expertise it seems unlikely that this possibility would change our results qualitatively.

⁷Since c does not interact with x , letting c be unknown to both parties prior to contracting (but learned at time 1) would give the same type of results. Letting c be privately known to the worker prior to signing the employment contract, would open for the firm screening for workers with a high c . When precommitment to $B(s)$ is not possible, such screening is not possible, since all worker types will prefer a high F . When precommitment to $B(s)$ is possible such screening contracts would give an advantage to small firms relative to large firms, but apart from that make no qualitative difference to our results.

the innovation lies close to the firm's previously issued patents, this can be interpreted as η being lower. Patentability varies considerably between industries; for example, evidence from Cohen et al. (2000) indicates that innovations in the drugs (pharmaceutical), computers and chemicals industries are easier to patent than innovations in the food or steel industry. It therefore seems reasonable to assume that η varies considerably between different industries for technological reasons that can be taken as exogenous in the model, and that this variable therefore is well-suited for comparative statics exercises.

We assume that the worker after accepting B can reveal x to the principal. This is a fairly innocuous assumption, as the agent would have no incentives to misrepresent x at this point and even (non-verifiable) cheap talk would be credible. As a consequence, the quantity x can be interpreted as the value of the idea given its best use by the firm, either through development inside or through a spin off (creation of a new division organized as a separate firm). This interpretation will be explained further in Subsection 4.3. Since a spin-off plausibly can imitate a start-up along all technical dimension (recall the assumption that the worker has committed to work for the firm), and there will be no deadweight loss associated with legal costs or other hassles, we shall assume throughout that η is greater than zero but less than unity.

The last thing to specify in the model is the payoff to the firm if the worker decides to leave. There are at least two counteracting effects that can be taken into account. First, the employee leaving could involve some loss in profits for the firm due to increased product market competition. Second, the employee starting up a firm based on x could open up for the possibility of suing the agent, with some positive payoff if successful. To simplify the analysis, we assume that these effects are small, or counteract, and that the employee leaving is from the firm's perspective equivalent to the employee leaving the workforce. In Subsection 4.3 we argue that altering this assumption is unlikely to seriously affect the results.

4 Quality of entrepreneurs

In this section, we look at the interplay between the entrepreneurship decision made by workers and the optimal wage offers made by firms, taking firm size as given. We first

analyze the small firm case and then the large firm case. In the next section we analyze evidence relating to the hypotheses obtained.

4.1 Small firm

As a metaphor for a small firm, we consider the case where there are only two agents employed in the firm, the owner and the worker, and where the owner knows x , i.e., $s = x$.

If $c > 0$ then $U(x) < x$, it will be efficient that the worker stays, and the firm will offer a bonus that is sufficient to retain the worker. If $c < 0$, however, then $U(x) > x$ for sufficiently low x . Without loss of generality, let us assume that the worker stays in the firm if $B_S = U(x)$. Since there is no reason to leave rents on the table, the optimal bonus offer by the firm will be,

$$B_S^* = \begin{cases} 0 & \text{if } U(x) < 0 \text{ or } U(x) > x \\ \eta x - c & \text{if } 0 < U(x) < x \end{cases} \quad (2)$$

The leaving option of the agent implies that the bonus payment to the agent will be equivalent to a call option on (a fraction of) the value of the project. Incidentally, this payment scheme resembles pay structure in small technologically oriented firms, which commonly pay their workers with stocks or options.⁸

Having derived the optimal bonus offer by the firm, we have the following result on the quality of entrepreneurs from a small firm.

Proposition 1 *There will be entrepreneurs emerging from small firms only when private benefits from a start-up outweigh the financing costs ($c < 0$). The entrepreneurs will be of low quality.*

Proof. For $c > 0$ then $U(x) < x$ and the firm will always pay a sufficient amount to keep the worker. When $c < 0$, the worker leaves in equilibrium if $\eta x - c > x$, or in other

⁸Oyer & Schaefer (forthcoming) provides evidence that firms issue stock options to employees in order to retent them, rather than to elicit effort. There will be free-rider problems associated with option pay, but such free-rider problems will be smaller for smaller firms.

words if $x < P$, where $P \equiv -\frac{c}{(1-\eta)} > 0$. Hence from a small firm workers with ideas on the interval $[0, P]$ will become entrepreneurs. ■

We can note that there will be a socially optimal level of separations in equilibrium, since the firm extracts all the surplus created when it sets the separation treshold through B_S^* .

Assuming that $c < 0$, the comparative statics properties on the quality and quantity of entrepreneurs emerging from a small firm are straightforward.

Remark 1 *The quality and quantity of entrepreneurs from a small firm, decreases in c and increases in η*

Proof. The remark follows from differentiating P with respect to c and η . ■

An increased financing cost or decreased private benefit, i.e., an increased c , makes entrepreneurship less efficient and only workers with ideas of very low quality will leave to start-up their own firm. In a similar vein, weaker property protection makes entrepreneurship less inefficient, and the quality of entrepreneurs goes up.

To sum up, this section has two main results, both conveyed in Proposition 1. First, in a small firm there cannot be entrepreneurship unless there are private benefits associated with entrepreneurship. Second, entrepreneurs from small firms will tend to have low quality ideas, i.e., the value of their ideas are not a random sample from the distribution of x , but a random sample below some treshold.

Let us complete the section with some comparative statics properties of the expected bonus and profits in a small firm.

Remark 2 *In a small firm, the expectation and the variance of the bonus payment increases in η . The expected bonus decreases in c . The expectation and the variance of the profits increase in η .*

Proof. See Appendix A. ■

Inferior property rights imply that the firm has to pay the worker a higher bonus to make him stay, and since the worker in this case gets a higher fraction of the risky cash flows, the variance of the bonus increases. The results on the firm's profits are the mirror images of the results on the worker's bonus. Since $x = B_S^* + \Pi_S^*$ and therefore

$E(x) = E(B_S^*) + E(\Pi_S^*)$, a reduction in the expected bonus must be counteracted by an increase in the expected profits. On the other hand, the total variance of cash flows, $Var(x)$, must be beared by the two parties and since an increased η leads to the worker bearing more risk, then the effect on the firm's risk must be negative.

4.2 Large firm

As a metaphor for a large firm, we consider a setting with two divergent characteristics from a small firm. The first is that, for a given quality of an idea, the large firm can develop an idea more effectively than a small firm, due to e.g., returns to scale in production or marketing. We will formalize this idea by assuming that if the worker stays, a large firm can boost the value of the idea by a factor $\alpha > 1$: An idea of quality x is worth x to a small firm and αx to a large firm.⁹ Second, we assume that organizing as a large firm weakens the information flow to the owner, so that the owner of a large firm knows less about x than the owner of a small firm. We formalize this by assuming that the principal in a large firm only knows the prior distribution of x . This should be contrasted with a small firm, where the principal learns x .

One way of justifying the distinction we make between small and large firms is that "large" means hiring a bureaucrat, or middle manager, in addition to a worker. The upside of hiring a bureaucrat is that he can boost the value of the project through e.g., facilitating commercialisation. The downside of hiring a bureaucrat is that he acts as a veil between the agent and the owner, either because of lack of competence in assessing x or perhaps more realistically because of having a private agenda. For example, the bureaucrat cannot be trusted to make true announcements about x due to private benefits from keeping the project alive.¹⁰ An alternative justification is to interpret a large firm as one with a larger number of workers employed on projects than a small firm: the upside

⁹To assume that the "boosting factor" α is a constant makes the analysis more convenient but is not necessary. The same type of results go through as long as $\alpha(x)x > x$ for all x .

¹⁰Stein (2002) formalizes a similar idea. In his setting, a principal decides whether to continue a project or not after hearing the report of a middle manager. The middle manager has some private benefits from continuation of the project, and a project with x lower than some threshold should be shut off. Because of the private benefits, the middle manager reports a high x whatever the true x is, and can therefore not be trusted.

of employing more workers is to exploit scale advantages or complementarities between the worker's skills, and the downside being that with more workers it becomes harder to evaluate a particular worker's marginal contribution to projects, which it is plausible to assume is strongly correlated with the value of his entrepreneurship option.

Since the principal in a large firm only knows the prior distribution of x , he must make a fixed bonus offer. Let us denote the optimal offer by B_L^* . We confine ourselves to the case $B_L^* > 0$, which occurs when $|c|$ is not too large (if $c \ll 0$ then all workers become entrepreneurs and when $c \gg 0$, no workers become entrepreneurs even for $B_L = 0$, neither case being very interesting). Given an offer $B_L > 0$, then a worker leaves iff $U(x) = \eta x - c > B_L$, or in other words if x exceeds a cutoff z , where

$$z = \frac{B_L + c}{\eta} \quad (3)$$

Taking into account worker's best response, and viewing z as the choice variable for the firm, the profit function equals,

$$\Pi_L = \int_0^z [\alpha x - \eta z + c]g(x)dx \quad (4)$$

(Note that for a positive B_L^* to be optimal, it must be that $z > 0$). The firm's profit maximization problem can be written as finding the optimal cutoff z^* , where

$$z^* = \arg \max_{z \in [0,1]} \left\{ \int_0^z [\alpha x - \eta z + c]g(x)dx \right\} \quad (5)$$

The first order derivative of Π_L equals,

$$\Pi'_L = [\alpha z - \eta z + c]g(z) - \eta G(z) \quad (6)$$

This equation reflects the trade-off faced when deciding upon a cutoff z . Setting a higher z will decrease leaving at the margin, but also increase the wage payment to all worker types that stay.¹¹ To see that $z^* < 1$, observe that $\Pi'_L(1) = [\alpha - \eta + c]g(1) - \eta G(1) = -\eta < 0$.

¹¹The second order condition for profit maximum is,

$$\Pi''_L = [\alpha - 2\eta]g(z^*) + [\alpha z^* - \eta z^* + c_E]g'(z^*) < 0$$

We then have the following result.

Proposition 2 *There will always be entrepreneurs emerging from a large firm, and the entrepreneurs will be of high quality.*

Proof. This result follows directly from $z^* \in (0, 1)$ and (3). ■

The underlying reason for why entrepreneurs from large firms are from the top of the distribution of x is that $U(x)$ slopes upwards in x and therefore workers with the best ideas reject the fixed bonus offer.

Let us assume for convenience that $\Pi'_L = 0$ has a unique solution (some conditions for uniqueness are considered in Appendix C). In that case, the first order condition (5) implicitly defines a function $z^*(\alpha, \eta, c)$. Differentiating $z^*(.)$ implicitly gives comparative statics properties on the equilibrium quality and quantity of entrepreneurs.

Remark 3 *The quality (quantity) of entrepreneurs from a large firm,*

Increases (decreases) in α

Increases (decreases) in c

Decreases (increases) in η

Proof. We find the derivatives of $z^*(\alpha, c, \eta)$ by implicitly differentiating the first order condition for profit maximum to obtain,

$$\begin{aligned} \frac{dz^*}{d\alpha} &= -\frac{z^*g(z^*)}{\Pi''_L} > 0 \\ \frac{dz^*}{dc} &= -\frac{g(z^*)}{\Pi''_L} > 0 \\ \frac{dz^*}{d\eta} &= \frac{z^*g(z^*) + G(z^*)}{\Pi''_L} < 0 \end{aligned} \tag{7}$$

■

These results are intuitive. Increased technical efficiency α makes the marginal employee more valuable to the firm without affecting the entrepreneurship option and the firm increases z (by increasing B_L). This reduces the probability of entrepreneurship, but

increases the average quality of entrepreneurs. An increased financing cost or decreased private benefit, i.e., an increased c , makes it cheaper for the firm to keep the marginal employee, and z increases. Finally, a decreased property rights protection makes it more expensive for the firm to keep the marginal employee, and the entrepreneurial cutoff decreases.

To sum up, a large firm is constrained by low quality on the information about the value of the ideas generated, and therefore has a rigid wage policy. As a consequence, the workers with the best ideas will tend to leave the firm to start their own venture (a result that holds independently of the sign of c). Therefore, entrepreneurs from large firms do not carry with them a random draw from the distribution of x , but the distribution of x above some threshold.

4.3 Some interpretational issues

We have assumed that the firm has the formal ownership rights to the project. This is an innocuous assumption given that the reservation utility of a worker is zero ($\bar{U} = 0$), since the worker makes rents and therefore will be willing to waive any formal ownership rights at the time of employment. If $\bar{U} > 0$, however, then conceivably it would be optimal to sign contract that gives some ownership rights of the project to the agent. To see why this would not be the case, suppose that contracts on formal ownership can be written to induce any η on the interval $[\eta_L, 1]$. Then we would have that the agreed upon η would equal the minimum point η_L . The reason is simple; if the agent's expected utility needs to be increased to ensure participation, it will be more efficient to increase it via increasing the fixed wage F rather than increasing η , since a higher η means a greater efficiency loss (due to an increased probability of entrepreneurship). Therefore, the only consequence of $\bar{U} > 0$ in the model would be to increase the fixed wage F paid by the firm. This is convenient because it means that the model can be encompassed in a general equilibrium type of framework (with endogenous \bar{U}) without any of the basic results being reversed.

Second, the spin-off option has been implicit in the firm's production function. Let us look more into this possible venue of developing ideas, by considering the case of a small firm (the case of a large firm is practically speaking identical). A reasonable feature of spin-

offs is that they have higher fixed costs than internal development. For spin-offs to occur at all, there must be consequently be some technological advantage to it, such as negative synergies between the project and other existing projects of the firm (a spin-off occurs if the innovation does not fit existing business areas, or it might be easier to incentivize the agent in a separate unit). We can formalize this by assuming that developing an idea with "intrinsic" quality y in-house gives it economic value equal to py , while developing it through a spin-off gives it value $\theta y - f$, where $f > 0$, and $\theta > p$. Conditional on the firm developing ideas optimally, we then have that $x = \max\{py, \theta y - f\}$. It follows immediately that.

Remark 4 *Only innovations of sufficiently high quality will be developed through a spin-off.*

This result is consistent with evidence of a positive stock market reaction to spin-off decisions (e.g., Desai & Jain, 1999 for US evidence and Veld & Veld-Merkoulova, 2002, for European evidence).

Third, since the principal may not know when the agent learns about x it can be more realistic to assume that the worker makes a wage demand, and then leaves the firm if the demand is not met. That formulation, which appears in Appendix D, opens up for the interesting possibility that the agent through his demand can reveal information about x , and is shown to yield qualitatively the same results as the current formulation where the firm makes the offer.

Fourth, we have stressed the interpretation of η as reflecting the extent to which property rights are enforceable. The flexibility of the model allows for other interpretations. If we choose to interpret x as the human capital the agent acquires from working on the project, one interpretation of η is the extent to which this human capital is firm-specific; where a high degree of firm specificity implies that η is low. Although a firm may be able to affect the firm specificity of human capital acquisition when designing training projects, it does not seem unreasonable to assume that firm specificity in the human capital acquired from working on a research project to a large extent is driven by technological factors outside the decision sphere of the firm. This justifies treating η as exogenous also under this interpretation of x .

Finally, while η is a constant in (1), we can generalize our findings to when η is a function of x , so that,

$$U(x) = \max\{0, \eta(x)x - c\} \tag{8}$$

where the only restriction put on $\eta(x)$ is that $\frac{dU}{dx} = \eta'(x)x + \eta > 0$. This means that the agent prefers a higher x to a lower x . This more flexible formalization allows for complementarities that can vary upon the quality of the idea. Also it covers, for example, cases where it is easier for firms to enforce property rights when x becomes bigger.

5 Evidence

The previous section outlined differences between the optimal wage policies of small and large firms, and showed how the optimal wage policy interacts with the entrepreneurial decisions made by workers of those firms. We argued that the self-selection of workers to become entrepreneurs follows a systematic pattern conditional on firm size. Since smaller firms can design a more flexible pay policy than large firms, entrepreneurs from small firms will carry with them ideas from the lower end of the quality distribution, and entrepreneurs from large firms will carry with them ideas from the upper end of the distribution. From this analysis, we expect the wage dispersion to be higher in smaller firms than in larger firms, and that *start-ups originating from large firms to be of higher quality than start-ups from small firms*. In this section we relate to evidence.¹²

While many empirical studies investigate differences in average wages between firms of different size categories, we are aware of only one study that considers differences in second moments, or wage dispersion, broken down on firm size. Davis & Haltiwanger (1996) considers wages at firm level for a broad sample of US manufacturing firms, and finds evidence that, in particular for non-production workers, small plants have a more variable pay structure, or a higher wage dispersion, than larger plants, controlling for

¹²A more general comment on the paper's strategy of assessing evidence. In the current section, we implicitly assume that firm size is given exogenously. In the next section, we determine the optimal firm size, and relate the theoretical results to evidence from the software industry. Evidence where we could evaluate all the main predictions of the model simultaneously would arguably be more fitting, but is to our knowledge not available. The advantage with a stepwise procedure of assessing evidence is that we are forced to assess several independent sources of evidence.

worker observable characteristics. Moreover, the empirical results on wage dispersion are particularly strong for the upper tail of the wage distribution, which fits well with our theory since it seems reasonable to think that the pull towards entrepreneurship would be the strongest in this end of the distribution.

Hamilton (2000) contains a large-scale investigation on the returns to entrepreneurship/ self-employment for American workers on the 1984 panel of Survey of Income and Program Participation. Interestingly, Hamilton's study indicates that the unconditional returns to entrepreneurship has a distribution that is bimodal or with a thick right tail (see figure on p. 613). Our model suggests that this pattern may be caused by entrepreneurs originating from small firms (and, of course, failures from large firms) constituting the lower "hump" of the returns distribution and the entrepreneurs from large firms constituting the thick right tail, and that the conditional returns to entrepreneurship may have a more standard unimodal distribution. Hamilton's study does not have access to work histories, and can therefore not be taken as more than indirect evidence in favor of the model.¹³

Gompers et al. (2004) analyze the propensity of publicly listed firms to "spawn" venture backed startups. One of their interesting findings is that larger firms are more likely to spawn new firms than smaller firms. For example, the "spawners" in their sample (firms that spawn one firm or more) are almost 30 times as large as the "non-spawners", measured in the median number of employees. Since start-ups financed by venture capitalists are typically very promising ones, this result is consistent with our theory. Other findings from Gompers et al. (2004) also seem consistent with the present theory. For example, their findings indicate that firms with lower growth rates (larger firms) are more likely to spawn entrepreneurs, which is interpreted as "... the results appear to be consistent with the view that employees leave firms not at the peak of their growth rates, but instead when growth rates have fallen, i.e., employees pursue entrepreneurial opportunities outside their firms when the rents from staying at the firm are diminished." A shortcoming with the data from Gompers et al. (2004) for evaluating the present theory more closely is that it does not contain evidence on start-ups that did

¹³A perhaps lesser concern is that to be able to relate our theory more closely to Hamilton's evidence, we would need a more continuous version of the model with many different firm sizes.

not receive venture capitalists funding, nor on whether a start-up was encouraged by the spawning firm or not.

To further assess whether entrepreneurs from large firms do better than entrepreneurs from small firms (controlling for observable features of the entrepreneur's ability), we consider data collected by Stanford University on its MBA alumnus. This dataset, described more in detail by Dobrev & Barnett (2004) and Lazear (2003) contains information on the jobs held by Stanford MBAs in their careers up to a point in the end of the 90-ies (the response rate was 42%, in total about 5000 individuals), with an emphasis on start-up activity. Although the sample is of limited size and scope, it has the attractive feature of containing measures of the size of an entrepreneur's previous employer, what type of firm he started (industry code, and whether the entrepreneur made an "organization change", the latter is useful for separating start-ups from spin-offs), and measures of entrepreneurial success.

The data is constructed as a panel where each individual has one row for each job spell. For example, an individual who had 8 jobs would have eight rows of data, one for each employer. The firm size and the individual's salary at the beginning of each job is provided, in addition to other information about the firm and the worker, such as industry codes and position codes. The salary data comes in categories (that are not inflation adjusted). The lowest category (1) covers 0-50.000\$ yearly salary and the highest category (12) covers above 2.000.000\$.¹⁴ The main finding from the analysis is that the theory squares well with evidence for workers that are highly paid in their previous employment, or whose start-up is not a family business, while the confirmation seems weaker for workers not in these two categories.¹⁵

We define entrepreneur as an individual that at some point works more than 50% of his time in a company that he founded. To avoid oversampling individuals with multiple entrepreneurial spells, we focus on the first time an individual becomes entrepreneur. This also avoids problems with individuals that are moving from one entrepreneurial spell to another (i.e., moving from a firm they own). Restricting attention to entrepreneurs

¹⁴Category 1=less than \$50.000, 2=50K-75K, 3=75K-100K, 4=100K-150K, 5=150K-200K, 6=200K-300K, 7=300K-400K, 8=400K-500K, 9=500K-750K, 10=750K-1M, 11=1M-2M, 12=over 2M.

¹⁵We present the evidence in the form of tables. This insight was also confirmed by a variety of regressions that can be provided by the author on request.

that report both previous salary and previous firm size leaves us with about 850 entrepreneurs.¹⁶ Furthermore deleting entrepreneurs older than 65 years (a high fraction in the 65+ group are susceptible to be essentially retiring) gives a sample size of around 750.¹⁷ The average entrepreneur is 46 years old, has 13 years of experience after the MBA degree, founds 1.8 firms (including later and earlier startups than the one we focus on), and the start-up is his 4,5 work history role.¹⁸

The dataset contains several possible measures of entrepreneurial success, in particular salary and size figures at the beginning and the end of the venture. Since many of the entrepreneurs are still active (the average start-up year in the sample is 1987), we focus primarily on success in the beginning of the venture measured by salary. We denote this variable for "Salbeg".

We first look at the raw relation between Salbeg and previous size, grouping previous firm size into four categories.¹⁹ Standard deviations in parentheses.

Table 1. Average Salbeg by previous size (in \$1,000).

Size cat	No workers	Mean	%
1	≤60	85 (219)	25
2	61-300	80 (102)	26
3	301-5000	101 (184)	23
4	>5000	117 (243)	26

Table 1 indicates a positive relation between previous firm size and the entrepreneur's success (the correlation coefficient is 0,07). Translated to percentages, the average increase in yearly salary from moving up one size category is about 8%.

Since previous firm size and previous wage are positively correlated ($\rho = 0.10$) the

¹⁶Less than 100 respondents started out as entrepreneurs immediately after their degree. These individuals are skipped unless they move into a firm owned by somebody else and then becomes entrepreneurs again.

¹⁷More precisely, an individual is included if one or more of his entrepreneurial spells satisfy two criteria: i)salary and size data are reported, including in his previous job, and ii)he came from a firm owned by somebody else, iii)age<65, and iv)not age>55 and retirement from previous job. We then picked the first entrepreneurial spell that satisfied i), ii), iii), and iv).

¹⁸See Lazear (2003) for theory and evidence on how the number of previous roles in a person's work history affects on the probability of that person becoming entrepreneur.

¹⁹In the following table, we assume that the distribution of salaries inside each salary category is symmetrically distributed. The average wage in the \$2.000.000+ category is tabulated to be \$2.500.000. Setting it higher would give stronger results.

positive relation between size of previous employer and entrepreneurial performance in Table 1 could reflect that workers in smaller firms are observably less able. To mitigate this problem, we therefore classify the entrepreneurs into 12 groups, according to the wage earned previously and the size of the firm they were previously employed in. We employ the same size categories as above, and create three categories of previous wage in a manner that keeps these categories of equal size. This means that previous wage group 1 contains category 1 (0-\$50K), previous wage group 2 contains category 2 and 3 (\$50-100K), and previous wage group 3 contains all other categories (\$100K+).²⁰

Table 2. Average Salbeg by previous size and previous wage groups (in \$1,000)

$n = 747$	Previous wage group		
Previous size group	1	2	3
1	34 (19)	61 (39)	193 (408)
2	54 (1124)	57 (31)	126 (119)
3	38 (24)	58 (43)	178 (272)
4	35 (19)	58 (36)	234 (369)

Table 2 suggests a weak to moderate trend towards entrepreneurs that previously worked in large firms doing better than entrepreneurs that previously worked in small firms. While a positive trend is slight for wage group 1, non-existent for wage group 2, it seems quite strong for entrepreneurs in wage group 3. Here, moving up one size category gives a 13% wage increase on average.²¹ Across the three columns, the unweighted average

²⁰**No of entrepreneurs in each subgroup**

$n = 747$	Previous wage			
Previous size	1	2	3	sum n_i
1	73	65	49	187
2	49	71	64	184
3	39	67	70	176
4	58	68	74	200
sum n_j	219	271	257	747

²¹One may suspect that this result is an artifact of many previous wage categories being grouped together in the previous wage 3 group, and therefore not controlling for the correlation between previous wage and previous size inside this group. This is not the case though, as the weakly negative correlation (-.0023) between previous size and wage category inside this group indicates. Also, we split up group 3 into 4 different subgroups to see whether the trend was different between these subgroups. Nothing indicated that these subgroups are different.

wage increase from moving one size category up equals about 6% (the average weighted by size of the subgroups is slightly higher).

The data contains a dummy variable on whether the start-up is a family business or not. One may suspect that a significant fraction of family ventures are means to transfer wealth from one generation to the next, either by subsidies to the entrepreneur from the family (it seems fair to guess that the families of MBAs are well above median wealth on average), or transfers from the entrepreneurs to his children, rather than being promising business opportunities. To avoid the influence of such tax or inheritance motives from the analysis, we perform the same type of analysis as in Table 2 on Salbeg but family businesses excluded.

Table 3. Average Salbeg salary for non-family ventures by previous size and previous wage groups. (in \$1,000)

$n = 511$	Previous wage group		
Previous size group	1	2	3
1	35 (21)	48 (35)	227 (469)
2	38 (37)	58 (33)	130 (131)
3	34 (26)	51 (38)	156 (238)
4	39 (24)	63 (36)	270 (413)

Table 3 suggests positive relation between previous firm size and entrepreneurial success for non-family businesses, controlling for previous wage. On average across the three columns, the wage increase from moving one size category upwards equals about 10%, and the difference in average wages between previous size group 1 and previous size group 4 is statistically significant for all previous wage groups. We can also note that the trend seems uniform across the three previous wage groups, in contrast to in Table 2 where the effect was largest for the highest wage group.²² Also, the standard deviations are more stable across columns compared to Table 2.

Overall, the tables suggest that entrepreneurs emerging from larger firms perform better than entrepreneurs emerging from smaller firms, controlling for the previous wage

²²This might suggest that MBA that do not do particularly well in their careers are more likely to be subsidized by their families through a start-up.

of the entrepreneur.²³ While this is the kind of relation predicted by the theory, there could also be alternative explanations. One could be that if entrepreneurs start up businesses related to their previous employer, entrepreneurs emerging from larger firms would for technological reasons have to invest more up front to make their business running, and therefore can be expected to generate a higher gross returns. There does not seem much support for this interpretation in the data, however, since the size of the start-up and size of the previous employer seem unrelated.²⁴

The theory suggests that entrepreneurs that form companies in the same industry as the one they left should be more successful than entrepreneurs that start up companies in unrelated industries. Individuals with high private benefits and a low x are reasonably more likely to leave the industry and form a venture in a different industry than persons with a high x .²⁵ To get an idea whether such a relation holds, let us consider the following

²³An entrepreneur facing financing constraints may sacrifice salary to be able to exploit growth opportunities, particularly in the beginning of the venture. It is therefore useful to consider measures of entrepreneurial success that capture growth rather than salary levels. Analysis of firm growth gave a similar picture to the salary analysis, one example being the following table which tabulates average yearly growth rates (in terms of number of employees) for the 12 different categories.

Table 4. Average yearly growth rates by previous size and previous wage groups.

$n = 650$	Previous wage group		
Previous size group	1	2	3
1	21,6	32,8	34,6
2	21,0	41,2	46,7
3	39,9	49,2	38,7
4	42,4	31,4	25,0

Table 4 suggests a positive (and concave) relation between firm growth and the size of the entrepreneur's previous employer. Also for this measure of entrepreneurial success excluding family businesses gives stronger results.

Another way to capture the success of entrepreneurs that are financially constrained would be to consider salary growth. However, here the data are not very suitable, as we only have salary data for two points in time, "beginning" and "end", and there is not a very clear definition given to the respondents of what is meant by these concepts. In particular "beginning salary" could mean something very different to a person that started up his business 20 years ago and a person that started up his business 5 years ago. Since timing is less of a concern when comparing Salbeg across firm size categories, we do not believe these interpretational problems seriously affect our conclusions based on Table 1-3.

²⁴The Spearman- ρ between size of previous employer and size of startup in the beginning (end) is .0288 (-0.007) with p -value 0.42 (0.86).

²⁵The model can easily be extended to encompass this idea, by allowing the to start-up occur in one of n different industries, with some distribution of private benefits across these industries, and the possibility of the largest private benefit occurring in a different industry than present employment. This would imply, for example, that a person working in the computer hardware industry with no creative ideas for a start-up within that industry will be more likely to start up a French restaurant than a person with a

table.

Table 5. Average Salbeg by previous wage groups and industry change (in \$1,000)

$n = 746$	Previous wage			n_i
	1	2	3	
Start-up industry equals previous industry	41 (72)	58 (31)	71 (38)	252
Start-up industry different from previous industry	37 (23)	50 (38)	62 (38)	494

Table 5 indicates that entrepreneurs that form start-ups in the same industry as they were previously employed do considerably better than entrepreneurs that do not. On average across the three previous categories, the Salbeg difference across these two groups of entrepreneurs is 14%, which is evidence in favor of the theory.²⁶

6 Endogenous firm size

We have so far let firm size be exogenous. In this section we study how property rights regime affects the trade-off between technical efficiency and quality of information.

To solve for the optimal firm size, we need to calculate the difference in expected profits between organizing as a large firm and organizing as a small firm,

$$\begin{aligned} \Delta^*(\alpha, c, \eta, z(\alpha, c, \eta)) &= \Pi_L^* - \Pi_S^* = \alpha \int_0^{z^*} xg(x) - G(z^*)B_L^* - \Pi_S^* \\ &= (\alpha - 1)E(x) - \alpha \int_{z^*}^1 xg(x) + \int_0^{I(c)P} xg(x) - [G(z^*)B_L^* - E(B_S^*)] \end{aligned}$$

The first term gives the (hypothetical) productivity difference between a large and a small firm if there were no entrepreneurship, the second term gives the reduction in

solid computer-oriented business plan.

²⁶About 1/3 of the entrepreneurs form up a start-up in the same industry as they were previously employed. This is a smaller fraction than in the samples of Cooper (1984) and in Bhide (2000), and may to some extent reflect overlap of industrycodes in our data. For example, a person employed in the pharmaindustry that starts up a management consulting business serving the pharmaindustry would turn up as a person that switched industries. On the other hand, evidence from Gompers et al. (2004) indicate that firms with a high level of spawning on average spawn to less related fields. Although it is not obvious how to interpret this finding, it will be interesting to see whether future work by Gompers et al. can reveal differences in entrepreneurial performance conditional on whether the start-up occurs in the same industry or not in their data.

productivity for large firms due to workers leaving, and the third term gives the reduction in productivity in small firms due to workers leaving, where $I(c)$ is an indicator function which equals 1 if $c < 0$ and 0 otherwise. The final term gives the difference in expected wage bill for a large and a small firm. The Δ^* -function is continuous since both Π_L^* and Π_S^* are continuous.²⁷

We can immediately note the following results,

Remark 5 *When (i) α is sufficiently high or (ii) η is sufficiently small, then a large firm dominates.*

Proof. To prove (i) we show that for $\alpha \geq \frac{E(x) + \eta - c}{E(x)}$ then a large firm dominates for all (c, η) . The argument is simple. Suppose that the large firm pays a bonus equal to $\eta - c$ to all workers. It would then retain all and have profits equal to $\alpha E(x) - \eta + c$. A small firm can never make a profit higher than $E(x)$. Hence the difference in profits between a large firm and a small firm must be at least $(\alpha - 1)E(x) - \eta + c$. This expression is greater than zero for $\alpha > \frac{E(x) + \eta - c}{E(x)}$. To prove (ii), there are two cases to consider, $c < 0$ and $c > 0$. For $c < 0$, let us consider the limit case $\eta = 0$. In that case it is either optimal to pay all agents c (in which case all stay) or to pay them all zero (in which all leave). Assuming that $E(x) - c > 0$, paying all agents c is optimal. The profits of a large firm then equals $\alpha E(x) - c$, and the profits of a small firm equals $E(x) - c$. Therefore $\Delta^* = (\alpha - 1)E(x) > 0$ for $c < 0$ and $\eta = 0$. By continuity, there must exist an interval $[0, \bar{\eta}]$ such that a large firm is optimal for any $\eta \in [0, \bar{\eta}]$. For $c > 0$, the worker stays even when $B_L = 0$ if $\eta \in [0, c]$. It follows directly that $\Delta^* > 0$ for $\eta \in [0, c]$. ■

Let us now move to the more interesting cases where the conditions behind these results are not met. We have the following main result.

Proposition 3 *For any c , then for α not too large there exists a cutoff η^* such that a large firm dominates for $\eta < \eta^*$ and a small firm dominates for $\eta > \eta^*$.*

Proof. See Appendix B. ■

Recall that the optimal firm size is a trade-off between technical efficiency (parameterized by α) and the quality of information. The proposition shows how this trade-off is

²⁷That Π_S^* is continuous in the point $c = 0$ is shown in Appendix B.

affected by property rights. When property rights are strong (η low) the leaving option is less of a threat, information about the quality of individual projects therefore of relatively small value, and a large firm is optimal. On the other hand, when property rights are weak (η high), the leaving option is more of a threat, the value of information high, and a small firm becomes optimal. Hence worsened property rights makes a small firm more likely to be optimal.²⁸

Given this result, we expect a positive relation between property rights protection, firm size, and the quality of entrepreneurs. Since we are aware of no evidence that relate all these variables, we assess pairwise relations. In the previous section we analyzed the relation between firm size and the quality of entrepreneurs. In the next section, we assess evidence on the relation between property rights protection and firm size.

Let us first derive some additional comparative statics results.

Remark 6 *A large firm is more likely to be optimal the higher α . For the absolute value of c sufficiently small, a large firm is less likely to be optimal the higher c .*

Proof. See Appendix B. ■

While the first result is intuitively rather obvious, the second result essentially says that increasing c will be more beneficial to the profits of small firms than to the profits of large firms. The intuition behind this result is that a higher c benefits a small firm for all (or approximately all) workers, while it benefits large firms only for workers with $x \in [0, z]$.

7 Empirical evidence on firm size

In the first subsection we discuss evidence from Kumar et al. (2004) on the relation between judicial system quality and firm size, based on a comparison of firm size within industries between different countries. This evidence is suggestive of a positive relation

²⁸There is a qualification to this result. When the property rights are very weak (η close to 1), the surplus that can be extracted from the worker is low, and information can become of little value. Hence the relationship between weakened property rights protection and the value of information can be non-monotonic. Proposition 3 excludes this possibility to have an impact on the optimal firm size for α sufficiently close to 1. Restricting η to be bounded away from 1 will have the same effect.

between property rights protection and firm size, but is somewhat hard to interpret due to the judicial system quality plausibly affecting both property rights and financial market conditions, such as creditor rights, in a complex interaction.

To lessen concerns about financial markets interactions, a useful type of evidence would be from an industry that has undergone a "natural" change in the strength of property right protection. The U.S. software industry experienced something close to such a natural experiment, through substantially increased patent protection in the mid 1990-ies, and in the second part of the section we present some evidence on firm size from this industry.

7.1 International evidence

Kumar et al (2004) consider the relation between firm size and the quality of the judicial system for different industries in a sample of European countries. Their main finding is that countries with stronger property rights have larger firms than countries with weaker property rights, controlling for the fact that different countries have a different distribution of firms across industries. This finding is clearly consistent with our theoretical arguments. In addition, Kumar et al. (2004) find that "... the efficiency of the judicial system has the strongest relationship with firm size in industries with low physical capital intensity." (p. 1, abstract). This result squares well with our theory, since our theory is plausibly more applicable to industries where human or intangible capital rather than physical capital is more important.²⁹

Can alternative arguments these findings? If a weak judicial system is associated with poorly developed financial markets, as indicated by e.g., the empirical findings of Beck et al. (2002), then firms located in countries with weaker judicial systems may find it hard to grow above a certain size because of lack of access to well-functioning national financial markets. Such a mechanism, which is clearly different from the one in the present paper, can also explain why industries with more intangible capital relative to physical capital find it harder to grow in a country with a weak judicial system: If a weak financial system would primarily hurt industries where financiers to a lesser extent can collateralize their

²⁹While Kumar et al (2004) have access to aggregate industry data in each country they consider, Beck et al (2003) has data from financial reports on firm level from 44 countries. The findings of Beck et al (2003) confirm those of Kumar et al (2004).

lendings (i.e., non physical capital intensive industries), or other contracting measures that can substitute for a poor creditor rights, then a positive relation between firm size and the quality of the judicial system might as well run via the financial system rather than via the quality of property rights.³⁰ There are also other problems that makes a positive relation between property rights and firm size open to multiple explanations, such as a weak judicial system being associated with a threat of being expropriated by the government or the military or the mafia for that matter. It seems fair to say, therefore, that the international evidence on the relation between property rights protection and firm size is not conclusive.

An alternative source of evidence to assess the theory with would be from inter-industry firm size comparisons within a country. A serious problem with such comparisons, however, is to account for differences in technology and cost structures. For example, if property rights such as patents are more easily enforced in physical capital intensive industries with high fixed costs, then a positive relation between property rights and firm size may be spurious. To illustrate this problem, the drugs (pharmaceuticals), computers and chemicals industries enjoy relatively strong patent protection according to Cohen et al. (2000), and we could therefore expect firm size within these industries to be large, a hypothesis that receives support in data from the U.S. Small Business Administration (2003).³¹ However, these industries are all at or near the top when it comes to traditional measures of R&D intensity such as R&D/sales (NSF, 2001), which makes it seem reasonable that the differences in firm size are mainly technology or cost-driven.

³⁰The argument of Beck et al. (2003) is somewhat different. According to them, larger firms have to a greater extent access to internal capital markets, and viewing this effect in isolation we can therefore expect a worse judicial system to make the optimal firm size larger. ["Firms size is positively related to the size of the banking system, and the efficiency of the legal system. Thus, we find no evidence that firms are larger in order to internalize the function of the banking system or to compensate the general inefficiency of the legal system."] However, Beck et al. (2003) lacks a theory of how it is possible to become a large firm in a country with a poorly developed financial system. It seems fair to say, therefore, that which relation to expect between financial system development and firm size is not obvious.

³¹These industries have 79%, 73% and 73% of workers employed in firms with 500+ workers, the average across all industries being 50%. These data are easily available at <http://www.sba.gov/advo/about.html>.

For computers, we use NAIC code 334, computer & electronic manufacturing. For drugs, we used NAIC code 3254 Pharmaceutical & medicine manufacturing, and for Chemicals, we used NAIC code 325, Chemical manufacturing. Cohen et al. (2000) are based on (an aggregated version) the older SIC industry codes and are not directly comparable.

7.2 Evidence from the Software Industry

Currently, the software industry is engaged in a lively patenting activity, counting around 20,000 issued patents a year (Bessen & Hunt, 2004). While this high activity might seem as a natural state of affairs now, matters were not so up to the 1980-ies, when software innovations were not considered proper inventions, and were generally speaking not patentable.³² However, landmark court decisions in the mid 90-ies, such as *In Re Alappat* in 1994 and an appeal case in 1995 where IBM obtained the right to patent "computer programs embodied in a tangible medium, such as floppy diskettes" (*In re Beauregard*, 53 F.3d 1583), dramatically improved the scope of patenting software (Cohen & Lemley, 2001). Legal literature (e.g., Burk & Lemley, 2002) suggests that the legal shift came unexpected to both legal experts and industry actors, and that the court responsible for it did not have a very good understanding of its consequences.

If there was truly a legal shift, one would expect the number of software patents to increase following it. Since the U.S. Patents Office does not have an isolated software category, it is difficult to measure the number of software patents granted before and after this. The following table with estimates of patenting activity, with figures from Bessen & Hunt (2004), indicates that the number of software patents issued in the U.S. increased dramatically from the first to the second half of the 1990-ies.

³²Software patents were unpatentable unless they were embedded in hardware like pizza ovens.

Table 6. # of Software patents issued in the U.S. 1990-1999	
Year	#patents
1990	4704
1991	5347
1992	5862
1993	6756
1994	8031
1995	9000
1996	11359
1997	12262
1998	19355
1999	20355
2000	21065
Source: Bessen & Hunt (2004)	

Table 6 indicates that the number of software patents issued increased quite dramatically between the first half of the 1990-ies to the second half of the 1990-ies. Since a weakened legal requirement (particularly an unexpected one) would at least take a couple of years to come into effect on the number of patents issued, this table strongly confirms the idea of an important regime shift towards stronger patent protection for software innovations during the mid 1990-ies.

Have there been any effects of this regime shift on firm size? Let us consider the firm size trend in an industry where the regime shift plausibly had the strongest effects on property rights, Software Publishing (SIC 7372/ NAICS 5112). The following figures are based on comparing employment figures from the U.S. Small Business Administration (2003).³³

From 1996 to 2001, the total employment in SIC 7372 experienced a 14% yearly growth, from 180,000 in 1996 to 350,000 in 2001, while the number of firms decreased slightly (8278 to 8057). Accordingly, the average number of employees per firm doubled from 22 employees to 44 employees, accounting to a 15% yearly growth. Different measures

³³Employment figures are not the only way to measure firm size. Kumar et al. (2004) contains a useful discussion of this point.

of the evolution of firm size confirms this picture. For example, the fraction of employees in the industry employed by 100+ firms increased from 0,65 to 0,76. The average number of employees per firm in the three firm size classes 0-100 employees, 100-500 employees, and 500+ employees, has grown annually by 8%, 2% and 9%, respectively.

Let us consider alternative explanations. First, it is possible that the evolution of firm size in SIC 7372 merely continued a trend that was in motion before 1996. There is little support for this interpretation in the data; the average number of employees per firm fell slightly (from 23 to 22) between 1990 and 1996.³⁴ Second, the trend in software may have picked up a trend specific in the computer firms, due to e.g., a change in taxation or trade conditions. There is little or no support of such an interpretation. To illustrate, a useful benchmark industry to Software Publishing is Custom Computer Programming (SIC 7371/NAICS 541511), which produces custom software solutions for specific customers, and is less prone to patenting than Software Publishing (Bessen & Hunt, 2004, Table 4). If the theory is correct, one would expect the firm size growth to be smaller in Computer programming than in Software Publishing between 1990 and 1996. This supposition is rather strongly suggested by the data, as indicated by Figure 1.

³⁴Likewise, the trend in software might have picked up some economywide trend towards greater firm size between 1996 and 2001. There is very little support also of such an interpretation, as the average firm size across all industries increased by a mere 1,7% in that period.

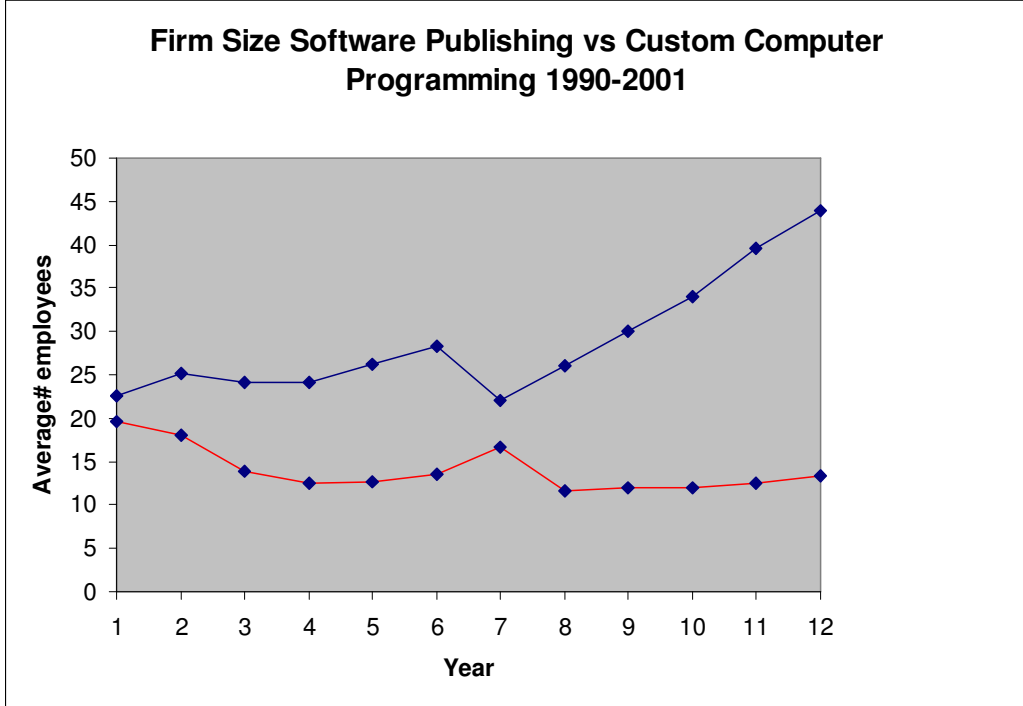


Figure 1

The figure depicts the development in average firm size in the Software Publishing Industry (upper line) and the Custom Computer Programming Industry (lower line) from 1990 to 2001. In the first half of the 1990-ies, these two industries are fairly similar both with respect to the initial absolute level and evolution in firm size. Around 1996 (the 7th year in the figure) a strong upward trend in Software Publishing kicks in, while there is no apparent shift in the firm size trend for Computer Programming. Comparing Software Publishing with other industries within computers reinforces the message: Software Publishing had a sharp and seemingly idiosyncratic movement towards larger firm size after 1996. For example, the average firm size in the industry NAICS 3571 Electronic Computers fell from 171 to 141 from 1996 to 2001 (4%).

Third, one can imagine that the trend towards greater firm size in the software industry was caused by a merger wave that increased firm size but had little effect on establishment level. Although there is some evidence of mergers by large establishments through this period, this can account for only a modest fraction of the increased firm size (there was growth in average number of employees at establishment level for this firm class).

Finally, it could be that industries with strong demand and employment growth tend

to have firm growth through established firms rather than through entry. We are not aware of strong evidence in favor of such a proposition. As indicated by the graph in Figure 1, a counter-example would be the software industry itself: In the period 1990-1996, the software industry experienced a similar growth rate in employment as in the period 1996-2001 (15%). However, in the early period the growth came primarily through growth in the number of firms; the average firm size dropped from 23 to 22 employees and the number of firms increased by almost 150%.³⁵ So overall the evidence from the software industry seems suggestive of a rather strong link between property rights protection and firm size.³⁶

8 Discussion of modelling assumptions

The main message of the paper is twofold. When ownership rights are strong, established firms are large, principals lack crucial information about project quality and wages are inflexible, and entrepreneurs are of high quality. On the other hand, ownership rights being weak implies small firms being optimal, well-informed principals and flexible wages, and low-quality entrepreneurs. Empirical evidence from multiple sources lean favorably in favor of the theory. In this section, we return to the model, and discuss some of its limitations.

First, the (fixed) cost of becoming an entrepreneur, c , has been taken as exogenous and independent of the type of firm an entrepreneur emerges from. This feature of the model can be modified and yield some additional insights. Suppose that a start-up obligates an investment cost that requires funding externally, and eventual repayment according to some contracting arrangement, excluding the use collaterals independent of the project. Also, let the project quality be unobservable to the financier, but the financier knows the background of the entrepreneur, in particular whether he arrives from a large or from a

³⁵Kumar et al. (2004) reviews the relation between market growth and firm size one would expect from theoretical work.

³⁶The pharmaceutical industry experienced a similar shift in patent protection in the mid 90-ies, although the changes here were less dramatic. This industry experienced a decrease in the average firm size in the first half of the 90-ies, and then a marked increase in the second half of the 90-ies, evidence that also fits well with the theory.

small firm. If financiers are risk averse or there is some cost of bankruptcy, entrepreneurs from small firms will then have worse financing conditions than entrepreneurs from large firms. The reason is simple: entrepreneurs from small firms carry (more) credit risk, and financiers will only be willing to tolerate this if they are compensated through a higher effective interest rate. There are two implications of this insight. The first is that since we held c constant across firm types in the main analysis, this analysis overstates the quantity and quality of entrepreneurs emerging from small firms. Second, if c is higher for entrepreneurs from small firms than from large firms, this will make it more profitable, all else equal, to establish as a small firm in the first place. At a more formal level, this will shift the Δ function to the left but apart from that have no qualitative impact.

Second, we have let firm size be synonymous to the firm being more bureaucratic or hiring more workers, keeping the number of projects inside the firm constant at one. Another notion of firm size is to increase the number of projects. First, if the firm has several projects but these projects are independent in the sense that the number of projects does not affect η then our analysis carries through in the same manner as in the text. More reasonably, however, there may be technological complementarities between the projects, so that the existence of one project may boost the α of other projects. There is some empirical evidence for this view, e.g., Henderson & Cockburn (1996) find empirical support that larger research efforts are more productive, attributed to knowledge spillovers between divisions in firms that are more diversified. To a certain extent, the model already captures this effect in reduced form through α . A different possibility is that some projects are initiated to protect other projects rather than to contribute with a positive NPV viewed in isolation. An example here may be from the software industry, where there is currently concerns about "patent thickening", which can be understood as patenting activity that is driven by protecting existing innovations rather than independent value. In terms of the model, the effect of adding such projects would be to decrease the effective η . At a formal level, this would have the rather harmless effect of shifting the Δ -function to the right.

Third, we have assumed that the information advantage of a small firm relative to a large firm is independent of the strength of property rights protection η . It is worth, however, to think more about what causes property rights to be weak. Presumably, this

occurs due to information inside the firm being weak (leading to unverifiability), so that we can expect a positive correlation between the strength of property rights and the extent to which small firms would have an information advantage. This argument is complementary to our model, in that there would be even greater reasons to choose a large firm if both ownership rights are strong and information is good, and, vice versa, there would be even greater reason to organize as a small firm if both ownership protection is weak and the informational advantage versus large firms becomes greater.³⁷

Finally, we have assumed that the principal can monitor the input (effort, time) of agents in a perfect manner. What if (a portion of) effort had to be induced via incentives? Since a small firm can condition its pay on a less noisy measure of x than a large firm can, it can link pay and performance in a more direct fashion, and therefore elicit effort more easily than a large firm. Modeling such a consideration would tend to shift the Δ -function to the left in the model.

9 Conclusion

Understanding the determinants of entrepreneurship is a key question to the profession. Still progress in the area has been limited; for example, textbooks' notion of an entrepreneur is synonymous to an exogenously given production possibility frontier, and business school courses on entrepreneurship are largely case-based and normatively tilted, and commonly taught by practitioners rather than academics. This state of affairs justifies an aggressive research effort towards a better understanding of entrepreneurship.

The starting point of the perspective on entrepreneurship developed in the current paper is the stylized fact that entrepreneurs are experienced workers who follow start-up opportunities closely related to their previous work experience. From this, we suggested an imperfect property rights framework that attempts to capture the tango between the

³⁷Related, we assumed that the principal knows x in a small firm and knows nothing about x in a large firm (except its distribution). Allowing for an informative signal received by the principal in a large firm will open up for the possibility that the set of entrepreneurs in a large firm will be a non-connected set. This can mean a lower quality of entrepreneurs from a large firm than presently, but it will still be true that the average quality of entrepreneurs will be higher from a large firm than from a small firm, as long as principals in small firms have better information.

worker's leaving decision and an established firm's innovation strategy. We arrived at two main insights. First that entrepreneurs from small firms can be expected to be of less quality than entrepreneurs from small firms, and second that optimal firm size increases in the protection of property rights. Confronted with evidence on entrepreneurs from the Stanford University MBA alumni survey and evidence on recent firm size evolution in the U.S. software industry, both results received empirical support.

While there are several possible extensions of the present work in theoretical direction, for example to capture aspects the established firm's choice of R&D strategy (such as project choice and the extent to which workers are delegated decisions at project level) and labor market competition for workers, an important direction for future research on entrepreneurship lies on the empirical side. Existing data are either too broad, focusing on self-employed, or too narrow by focusing on successes or on highly select group of workers, to get a precise conception of the importance of and determinants of entrepreneurship. One would wish to have data resembling the Stanford MBA dataset, but for a broader set of workers and covering the innovation practices of entrepreneurs' previous employers more closely. The current project is in the process of collecting data on Norwegian entrepreneurs, covering their labor market history, performance, and ownership fraction in their start-up engagements, in addition to information on product markets where they operate. This data collection process will hopefully end up in a dataset with qualities that makes testing of alternative theories of entrepreneurship possible, and spur future cross-fertilization of theoretical and empirical work.

10 Appendix A. Proofs small firm

Proof of Remark 1. We start out with the proofs for the case $c > 0$ and then sketch the proof for the case $c < 0$. Throughout we skip the *-notation. ■

Case a): $c > 0$. If the ownership rights of firms are weak, i.e., $\eta < c$, then $U(.) < 0$ for all x , and therefore $B_S = 0$. For $\eta > c$ the optimal bonus is zero for $x < \frac{c}{\eta}$ and equal

to $\eta x - c > 0$ for $x < \frac{c}{\eta}$. The expected bonus therefore equals,

$$E(B_S) = \int_A^1 (\eta x - c)g(x)dx \quad |\eta > c \quad (10)$$

where $A = \frac{c}{\eta}$ and $A' = \frac{\partial A}{\partial \eta} = -\frac{A}{\eta} < 0$. From this equation, $E(B_S)$ can be written as $f(\eta, c, A(\eta, c))$. Noting that

$$\frac{dE(B_S)}{d\eta} = \frac{\partial E(B_S)}{\partial \eta} + \frac{\partial E(B_S)}{\partial A} \frac{\partial A}{\partial \eta} \quad (11)$$

where $\frac{\partial E(B_S)}{\partial A} = (\eta A - c)g(A) = 0$, we get,

$$\frac{dE(B_S)}{d\eta} = \frac{\partial E(B_S)}{\partial \eta} = \int_A^1 xg(x) > 0 \quad (12)$$

Let us now look at the variance of B_S , where

$$Var(B_S) = E(B_S^2) - E(B_S)^2.$$

Since $E(\cdot)$ is a linear operator, $\frac{dE(B_S^2)}{d\eta} = 2E(B_S B_S')$ and $\frac{dE(B_S)^2}{d\eta} = 2E(B_S) \frac{dE(B_S)}{d\eta}$, where $B_S' = x$. Hence,

$$\begin{aligned} \frac{dVar(B_S)}{d\eta} &= \frac{dE(B_S^2)}{d\eta} - \frac{dE(B_S)^2}{d\eta} = 2E(B_S B_S') - 2E(B_S) \frac{dE(B_S)}{d\eta} \Leftrightarrow \\ \frac{dVar(B_S)}{2d\eta} &= \int_A^1 xBg(x)dx - E(B_S) \int_A^1 xg(x) = \int_A^1 x[B_S - E(B_S)]g(x)dx \end{aligned} \quad (13)$$

Define $C = \frac{E(B_S) + c}{\eta}$. Note that since $x \in [0, 1]$, there exist constants $k_1(\alpha, \eta)$ and $k_2(\alpha, \eta)$ where $0 < k_1 < C < k_2 < 1$, such that

$$\int_A^1 x[B_S - E(B_S)]g(x)dx = k_1 \int_A^C [B_S - E(B_S)]g(x)dx + k_2 \int_C^1 [B_S - E(B_S)]g(x)dx \quad (14)$$

By construction, the first integral is negative and the second integral is positive. Hence,

$$\int_A^1 x[B_S - E(B_S)]g(x)dx > k_1\left\{\int_A^C [B_S - E(B_S)]g(x)dx + \int_C^1 [B_S - E(B_S)]g(x)dx\right\} \quad (15)$$

since $k_1 < k_2$. But, therefore,

$$\begin{aligned} \frac{dVar(B_S)}{2d\eta} &= \int_A^1 x[B_S - E(B_S)]g(x)dx \\ &> k_1\left\{\int_A^C [B_S - E(B_S)]g(x)dx + \int_C^1 [B_S - E(B_S)]g(x)dx\right\} \\ &= k_1 \int_A^1 [B_S - E(B_S)]g(x)dx = k_1[E(B_S) - (1 - G(A))E(B_S)] = k_1G(A)E(B_S) > 0 \end{aligned} \quad (16)$$

Moving to the effect of increasing c ,

$$\frac{dE(B_S)}{dc} = \frac{\partial E(B_S)}{\partial c} = G(A) - 1 < 0 \quad (17)$$

Let us now consider profits. For $\eta < c$ the expected profits just equals $E(x)$. For $\eta > c$ it equals,

$$\begin{aligned} \Pi_S &= \int_0^1 [x - \max\{0, \eta x - c\}]g(x)dx \quad |\eta > c \\ &= E(x) - E(B_S) \end{aligned} \quad (18)$$

It follows directly that $\frac{d\Pi_S}{d\eta} = -\frac{dE(B_S)}{d\eta} = -\int_A^1 xg(x) < 0$.

Let us now consider the variance of profits, where $Var(\Pi_S) = E(\Pi^2) - E(\Pi)^2$. Since $E(\cdot)$ is a linear operator, $\frac{dE(\Pi^2)}{d\eta} = 2E(\Pi\Pi')$ and $\frac{dE(\Pi)^2}{d\eta} = 2E(\Pi)\frac{dE(\Pi)}{d\eta}$, where $\Pi =$

$x(1 - \eta) + c$ and $\Pi' = \frac{d\Pi}{d\eta} = -x$.

$$\begin{aligned} \frac{dVar(\Pi)}{d\eta} &= \frac{dE(\Pi^2)}{d\eta} - \frac{dE(\Pi)^2}{d\eta} = 2E(\Pi\Pi') - 2E(\Pi)\left(-\frac{dE(B_S)}{d\eta}\right) \Leftrightarrow \quad (19) \\ \frac{dVar(\Pi)}{2d\eta} &= -\int_A^1 x\Pi g(x)dx - E(\Pi)\left[-\int_A^1 xg(x)\right] \\ &= \int_A^1 xE(\Pi)g(x) - \int_A^1 x\Pi g(x)dx \\ &= \int_A^1 x(E(\Pi) - \Pi)g(x) \end{aligned}$$

This expression is negative, by the same type of argument showing that $\frac{dVar(B_S)}{d\eta} > 0$.

■

Case b): $c < 0$. Recall that the optimal bonus equals,

$$B_S = \begin{cases} 0 & \text{if } x < P \\ \eta x - c & \text{if } x \geq P \end{cases} \quad (20)$$

where $P = -\frac{c}{1 - \eta}$. Therefore, the expected bonus equals,

$$E(B_S) = \int_P^1 (\eta x - c)g(x)dx \quad (21)$$

Note that $P' = \frac{dP}{d\eta} = -\frac{c}{(1 - \eta)^2} > 0$. The effect of worsened property rights on the expected bonus is,

$$\frac{dE(B_S)}{d\eta} = -P'(\eta P - c) + \int_P^1 xg(x) > 0 \quad (22)$$

The profits of the small firm conditional on offering an optimal bonus therefore equals,

$$\Pi_S = \int_P^1 [(1 - \eta)x + c]g(x)dx \quad (23)$$

Differentiating, we obtain,

$$\frac{d\Pi_S}{d\eta} = P'[(1 - \eta)P + c] - \int_P^1 xg(x) = -\int_P^1 xg(x) < 0 \quad (24)$$

That the variance of bonus payment and profits increase in η follows from a same type of argument as for $c > 0$ and is skipped. ■

11 Appendix B. Proofs on $\Delta(\cdot)$.

We start out by proving Proposition 4 in several steps. For brevity we skip the * notation, and throughout the Appendix we assume interior solutions to the large firm's profit maximization, i.e., $z \in (0,1)$. To be able to prove the proposition for both $c < 0$ and $c > 0$ we first define,

$$\Omega(c, \eta) = \begin{cases} P & \text{if } c < 0 \\ A & \text{if } c \geq 0 \end{cases} \quad (25)$$

where $P \equiv -\frac{c}{(1-\eta)}$ and $A \equiv \frac{c}{\eta}$, as before. Clearly the function $\Omega(c, \eta)$ slopes downward in c for $c < 0$ and upwards in c for $c > 0$. $\Omega(\cdot)$ decreases in η since $\frac{dP}{d\eta} = -\frac{c}{(1-\eta)^2} < 0$ and $\frac{dA}{d\eta} = -\frac{c}{\eta^2} < 0$. $\Omega(\cdot)$ is continuous in c since $\lim_{c \rightarrow 0^+} A = 0 = \lim_{c \rightarrow 0^-} P$.

Recall that,

$$\Delta(\alpha, c, \eta, z(\alpha, c, \eta)) = \Pi_L - \Pi_S = \alpha \int_0^z xg(x) - G(z)B_L - \Pi_S \quad (26)$$

We start out with the following useful application of the envelope theorem.

Lemma 1

$$\frac{d\Delta}{d\eta} = \frac{\partial\Delta}{\partial\eta} = \int_{\Omega}^1 xg(x) - G(z)z \quad (27)$$

Proof. Recall that $\Delta = \alpha \int_0^z xg(x) - G(z)B_L - \Pi_S$, where $B_L = \eta z - c$. Therefore,

$$\frac{d\Delta}{d\eta} = \frac{\partial\Delta}{\partial\eta} + \frac{\partial\Delta}{\partial z} \frac{\partial z}{\partial\eta} \quad (28)$$

But by the construction of Δ , we have that $\frac{\partial\Delta}{\partial z} = 0$. Recall that $B_L = \eta z - c$ and

$\frac{\partial B_L}{\partial \eta} = z$. Therefore,

$$\frac{d\Delta}{d\eta} = \frac{\partial \Delta}{\partial \eta} = -G(z)\frac{\partial B_L}{\partial \eta} + \frac{\partial \Pi_S}{\partial \eta} = \int_{\Omega}^1 xg(x) - G(z)z.$$

■

Our next lemma is also on a property of Δ .

Lemma 2 Δ is convex in η .

Proof. Write for brevity $\frac{d\Omega}{d\eta} = \Omega'$ and recall that $\Omega' < 0$. Using the envelope theorem again, we have that,

$$\begin{aligned} \frac{d^2\Delta}{d\eta^2} &= \frac{\partial^2\Delta}{\partial \eta^2} + \frac{\partial^2\Delta}{\partial z\partial \eta} \frac{\partial z}{\partial \eta} \\ &= -\Omega'\Omega g(\Omega) - (g(z)z + G(z))\frac{\partial z}{\partial \eta} > 0 \end{aligned} \tag{29}$$

Since $\frac{\partial z}{\partial \eta} < 0$. ■

Let us now define,

$$\Delta^1(\cdot) = \Delta(\eta = 1, \cdot) \tag{30}$$

Since Δ is convex in η from the previous lemma, the following obvious but very useful observation follows directly.

Lemma 3 $\Delta^1(\cdot) < 0$ implies both existence and uniqueness of η^* .

Recall that,

$$\Delta^1(\cdot) = \alpha \int_0^z xg(x) - G(z)B_L - \Pi_S \tag{31}$$

Now define $\bar{\alpha}$ as a value of α which makes $\Delta^1(\cdot) = 0$. Since $\frac{d\Delta^1(\cdot)}{d\alpha} > 0$ there is at most one $\bar{\alpha}$ for each c , and hence there exists a function f such that $\bar{\alpha} = f(c)$, whose graph demarcates the values of (c, α) where $\Delta^1(\cdot) < 0$ from values of (c, α) where $\Delta^1(\cdot) > 0$. The area north of the graph would have $\Delta^1(\cdot) > 0$ and the area south of the graph would have $\Delta^1(\cdot) < 0$ since $\frac{d\Delta^1(\cdot)}{d\alpha} > 0$. So one way of completing the proof is to show that

$f(c) > 1$ for all c . It turns out, however, that there is a simpler way to complete the proof. Specifically, set $\Delta^1(\cdot) = 0$ and rearrange to form a fixed-point definition of $\bar{\alpha}$,

$$\bar{\alpha} = h(\bar{\alpha}, c, z(\bar{\alpha}, c)) = \frac{G(z)B_L + \Pi_S}{\int_0^z xg(x)}$$

It is sufficient to prove the proposition to show that any solution to this equation must have $\bar{\alpha} > 1$ for any c . Note first that $h(\cdot)$ converges to $(1 - c) + \Pi_S$ when $\bar{\alpha}$ goes to infinity, since z converges to 1 and B_L converges to $1 - c$. The reason is simple; when α becomes large, the large firm maximizes profits by keeping all workers, and must pay them $1 - c$. It is therefore sufficient for existence and uniqueness of a fixed point above 1 that $h(1, c, z(1, c)) > 1$. But this is trivial to see. Recall that $\Pi_L = \int_0^z xg(x) - G(z)B_L$. We therefore have that,

$$h(\bar{\alpha} = 1) = \frac{\int_0^z xg(x) + \Pi_S - \Pi_L}{\int_0^z xg(x)} \quad (32)$$

But the right hand side of this expression exceeds 1, since a small firm must make weakly higher profits than a large firm for any c when $\alpha = 1$.³⁸ Therefore $h(1, c, z(1, c)) > 1$, and the proposition is proved. We should note that this result does not depend on the firm getting nothing if the worker leaves, since if $\eta = 1$ then the firm gets nothing anyway, given that Δ is convex.

Proof. of Remark 5. Let us first prove the second statement. We have that,

$$\frac{d\Delta}{dc} = \frac{\partial\Delta}{\partial c} + \frac{\partial\Delta}{\partial z} \frac{\partial z}{\partial c} \quad (33)$$

³⁸Recall that the large firm pays the same wage to all agents that stay in the firm. The small firm can replicate whatever wage policy the large follows but pay less to the agents with a low x (it can do even better but that is beside the point). Therefore $\Pi_S - \Pi_B > 0$ when $\alpha = 1$ and $\eta = 1$, and $c < 1$. When $c = 1$, the profits of both types of firm equals $E(x)$, in which case the only solution to the fixed point equation is for $\bar{\alpha} = 1$. Therefore the curve defined by the function $f(c)$ can hit the c axis only in the point $c = 1$.

But by the construction of Δ , the envelope theorem gives $\frac{\partial \Delta}{\partial z} = 0$. Therefore

$$\frac{d\Delta}{dc} = \frac{\partial \Delta}{\partial c} = -G(z) \frac{\partial B_L}{\partial c} - \frac{\partial \Pi_S}{\partial c} = G(z) - \int_{\Omega}^1 xg(x)dx = G(z) + \int_0^{\Omega} xg(x)dx - 1 \quad (34)$$

Using the envelope theorem and the implicit function rule,

$$\frac{d\eta^*}{dc} = -\frac{\Delta_c^*}{\Delta_{\eta}^*} = \frac{1 - G(\Omega) - G(z)}{\Delta_{\eta}^*}. \quad (35)$$

Note that by uniqueness of η^* then $\Delta_{\eta}^* < 0$. For c close to zero, then $G(\Omega)$ is close to zero, and therefore $\frac{d\eta^*}{dc} < 0$. To find $\frac{d\eta^*}{d\alpha}$, we use the same method to obtain,

$$\frac{d\eta^*}{d\alpha} = \frac{\partial \eta}{\partial \alpha} = -\frac{\Delta_{\alpha}^*}{\Delta_{\eta}^*} = -\frac{\int_0^z G(x)}{\Delta_{\eta}^*} \quad (36)$$

■

12 Appendix C. Uniqueness of z^*

The analysis does not rely on the firm's first order condition yielding a unique interior solution (see the end of this Appendix for a discussion). However, it is of some interest to have a set of assumptions that ensure uniqueness. The following remark provides such. We abbreviate by writing $G(x) = G$, $g(x) = g$, $g'(x) = g'$, and $g''(x) = g''$, and denote by Z the set of values on the interior of $(0,1)$ that satisfies the first order condition (6).

Remark 7 For distribution functions satisfying $g'' < \frac{2G(g')^2 - g^2 g'}{Gg}$, $\forall x$ then Z has a unique element.

Proof. Note that z^* can be defined by the fixed point equation derived from the first order condition (we skip the *-notation)

$$z = -\frac{c}{\alpha - \eta} + \frac{\alpha}{\alpha - \eta} \frac{G(z)}{g(z)} \quad (37)$$

Now define $\Psi(z) = \frac{G(z)}{g(z)}$. Note that $\Psi(0) < 0$ and that $\Psi(\cdot)$ tends to infinity as $z \rightarrow 1$. It is therefore sufficient for a fixed point on the interior of $(0,1)$ to be unique that $\Psi(\cdot)$ is increasing and convex in z . Differentiating $\Psi(\cdot)$,

$$\Psi' = \frac{g^2 - Gg'}{g^2} \quad (38)$$

Differentiating once more,

$$\begin{aligned} \Psi'' &= \frac{(2gg' - gg'' - Gg'')g^2 - 2gg'(g^2 - Gg')}{g^4} = \frac{g^2(gg' - Gg'' - 2gg') + 2gg'Gg'}{g^4} \\ &= \frac{2G(g')^2 - g(Gg'' + gg')}{g^3} \end{aligned} \quad (39)$$

This expression is positive for all x whenever $g'' < \frac{2G(g')^2 - g^2g'}{Gg}$, $\forall x$. ■

The remark ensures uniqueness for distributions that are not too convex. Uniqueness is satisfied for a constant hazard rate, and several other tractable examples, as shown in the following.

Example 1 $g = 2(1 - x)$

In this case, $G = 2x(1 - \frac{x}{2})$, $g' = -2$, $g'' = 0$, and we get $g^3\Psi'' = 2G(g')^2 - g(Gg'' + gg') = 2G(g')^2 - gg' > 0$.

The next example illustrates that increasing functions may also satisfy uniqueness.

Example 2 $g = 2x$

In this case, $G = x^2$, $g' = 2$, $g'' = 0$ (note that this example violates the assumption $g(1) = 0$). Substituting in, we get $g^3\Psi'' = 2G(g')^2 - g(Gg'' + gg') = 2G(g')^2 - g^2g' = 2x^2 \cdot 4 - 4x^2 \cdot 2 = 0$. In other words, $\Psi'' = 0$. Since $\Psi(0) < 0$, then Z must have zero elements (i.e., no interior solutions) or one element. The latter case occurs if $-\frac{c}{\alpha - \eta} + \frac{G(1)}{g(1)} \frac{\alpha}{\alpha - \eta} > 1$, or in other words if $\alpha < 2(\eta - c)$.

The next example, the exponential distribution, shows that a constant hazard rate implies uniqueness. This distribution is often used in reliability analysis and in the patent race literature.

Example 3 $g = \lambda e^{-\lambda x}$

Define $\beta = e^{-\lambda x}$. Then $G = 1 - \beta$, $g' = -\lambda^2 \beta < 0$, $g'' = \lambda^3 \beta > 0$. It follows that $g^3 \Psi'' = 2G(g')^2 - g(Gg'' + gg')$ $= 2(1 - \beta)(\lambda^2 \beta)^2 - \lambda \beta [(1 - \beta)\lambda^3 \beta - \lambda \beta \lambda^2 \beta] = \lambda^4 \beta^2 [2(1 - \beta) - (1 - \beta) + \beta] = \lambda^4 \beta^2 > 0$.

Let us now consider a symmetric version of the triangular distribution,

Example 4 $g = 4x$ for $x < \frac{1}{2}$ and $g = 4(1 - x)$ for $x > \frac{1}{2}$

This gives $G = 2x^2$, $g' = 4$, $g'' = 0$ on the lower interval and $G = \frac{1}{2}[1 - (2x - 1)(2x - 3)]$, $g' = -4$, $g'' = 0$ on the upper interval. But recall that $\Psi' = \frac{g^2 - Gg'}{g^2}$. Therefore on the lower interval we have $\Psi' = 1 - \frac{2x^2 4}{16x^2} = 1 - \frac{1}{2} = \frac{1}{2}$. Since $\Psi' < 1$, then Z cannot have an element that is below $\frac{1}{2}$. We therefore just need to check that Ψ is convex for $x > \frac{1}{2}$. Substituting in, we get that on the upper interval, $g^3 \Psi'' = 2G(g')^2 - gg' = (1 - (2x - 1)(2x - 3))16 + (1 - x)16$, which can easily be verified to be positive on $[\frac{1}{2}, 1]$.

Relating these examples to hazard rates, in Example 1 the hazard rate is not monotonic, since $H(x) = \frac{g}{1 - G} = \frac{2(1 - x)}{1 - 2x(1 - x)}$ first increases and then decreases. In example 2, $H(x) = \frac{2x}{x^2} = \frac{2}{x}$, which decreases in x . In Example 3, the hazard rate is constant. In Example 4, on the lower interval $H(x)$ equals $\frac{4x}{1 - 2x^2}$, which increases in x . On the upper interval, $H(x)$ equals $\frac{4(1 - x)}{1 - \frac{1}{2}(1 - (2x - 1)(2x - 3))}$, which also increases in x .

Let us briefly discuss the case where the first order condition for profit maximum may have multiple elements. The $z(\cdot)$ function then need not be continuous, and we must to qualify the results. The source of discontinuity is as follows. For given exogenous parameters (α, c, η) the $\Pi_L(z)$ function may have multiple local maxima, where each of these maxima can be characterized by a function $z_i(\alpha, c, \eta)$. $z(\cdot)$ picks the $z_i(\cdot)$ function of the global maximum. However, changes to (α, c, η) may change the i that determines the global maximum, and therefore lead to a discontinuous $z(\cdot)$. Since such discontinuity can only prevail at particular points, we have that the derivatives above will exist (and be

identical to the expressions above) almost everywhere. Economically speaking, however, these points of discontinuity can be important if we wish to consider more than incremental changes in the exogenous variables.

13 Appendix D: Alternative bargaining formulation

In the main analysis, the firm makes a take-it or leave-it offer to the agent at time 1. Let us now consider the opposite formulation, i.e., when the worker can give a take-it or leave-it wage demand to the principal, and leaves the firm if these conditions are not met. Since the principal in practice may not know at which point in time the agent learns about x , this formulation may be more realistic and opens up for the interesting possibility that the agent through the wage demand can reveal information about x (if employed in a large firm). This can potentially make a large firm more able to keep the best workers than when the firm makes the offer. Our purpose here is to show that even if this conjecture is true, this case gives qualitatively the same results.

Let us begin by considering a small firm (symmetric information). Let us first suppose that $c > 0$. In that case, it is always efficient that the agent stays in the firm, and the optimal take-it or leave-it demand, denoted by w , clearly equals x . That leaves the firm's profit at zero. In the case with $c < 0$, the worker will take x if $x > c$ but leave the firm if $x < c$. Hence we can express the optimal take-it or leave-it demand as,

$$w = \begin{cases} 0 & \text{if } x < c \\ x & \text{if } x \geq c \end{cases} \quad (40)$$

We can note that we get an efficient level of separations also in this case, since the worker fully takes into account the social benefits and costs of a separation.

A large firm. To illustrate how the agent can convey information through his demand, and how this may affect who becomes entrepreneurs, we are interested in the equilibrium which conveys the maximal amount of information about the true x . This turns out to be a separating equilibrium where the agent fully reveals x through his demand.³⁹

³⁹This section has formal resemblance to the financier-entrepreneur costly state verification repayment

Let the agent's strategy be described by a (possibly random) function $w(x)$, which describes the wage he demands as a function of x , and let the firm's strategy be represented by an accept function $Q(w)$. The interpretation of the second function is that for any demand w , the firm accepts the demand with probability $Q(w)$ and rejects the demand (in which case the worker becomes an entrepreneur) with probability $1 - Q(w)$.

Let us suppose that there exists a separating equilibrium, where the agent fully reveals x through his demand w . By standard reasons, there cannot exist such an equilibrium where the firm's strategy is deterministic (i.e., only takes the values 0 or 1).⁴⁰ We therefore confine attention to the firm playing a mixed strategy.⁴¹ For a firm playing a mixed strategy, it must be indifferent between accepting the worker's demand or not, and consequently $w(x) = x$, i.e., the worker takes all the rents. For a given x and $Q(\cdot)$, the agent's utility from demanding w equals,

$$U(w, x) = Q(w)w + [1 - Q(w)][\eta x - c] \quad (41)$$

The first term reflects that the agent gets the continuation wage w if the firm accepts the demand. The second term reflects that the worker gets the entrepreneurial payoff $U(x)$ if the demand is rejected. Without loss of generality we can assume that $Q(\cdot)$ is continuous and differentiable. Writing $Q(w)$ as Q , and $\frac{dQ}{dw}$ as Q' , we then have that,

$$\frac{dU}{dw} = Q'[w - \eta x + c] + Q \quad (42)$$

For a separating equilibrium to exist, $w = x$ must be the optimal wage demand for all x ,

$$Q'[x - \eta x + c] + Q = 0 \quad (43)$$

game modeled in Hvide & Leite (2003). As discussed there, the maximally informative equilibrium has some attractive equilibrium selection properties in addition to being convenient. Issues of renegotiation are also discussed in that paper.

⁴⁰Suppose that the firm plays a pure strategy, and let \tilde{w} be the highest offer that the firm would accept with probability 1. Then all worker types would strictly prefer to offer \tilde{w} , which would contradict the assumption that there exists a fully separating equilibrium.

⁴¹One interpretation of such a mixed strategy is that there are many possible firm types, and that each of these play a pure strategy. In aggregate, however, they must play a mixed strategy described by $Q(\cdot)$.

This is a linear partial differential equation in x , with the solution,

$$Q(x) = K[(1 - \eta)x + c]^{-\frac{1}{1 - \eta}} \quad (44)$$

where K is an integration constant. Since it is strictly optimal for the firm to accept a zero demand, we can impose the corner condition $Q(0) = 1$ to arrive at,

$$Q(x) = c^{\frac{1}{1 - \eta}} [(1 - \eta)x + c]^{-\frac{1}{1 - \eta}} \quad (45)$$

As can easily be verified, this function is decreasing and convex in x .⁴² We therefore have that,

Proposition 4 *When the agent makes the take-it or leave-it demand, the firm makes zero profits, and the probability of the worker becoming an entrepreneur increases in x .*

Proof. This follows directly from $Q(x)$ decreasing in x . ■

As can be shown, this equilibrium has the same qualitative comparative statics properties to that in the main case (Remark 3).

14 References

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⁴²That $Q(\cdot)$ is convex intuitively means that the principal is particularly sensitive to the agent lying when making small offers w , which is economically plausible.

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