Curb Your Innovation: Corporate Conservatism in the Presence of Imperfect Intellectual Property Rights[1]

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Abstract

In this paper we analyze the effects of information leakage on the incentives to innovate in firms. We analyze a situation in which an employee in a firm is inspired with a new idea for a product. In a framework in which Intellectual Property Rights on ideas are absent, we analyze the employee's decision of whether to disclose the idea within the firm or to form a spin-out. We next look at the shareholders of the original firm and analyze their incentives to promote creativity and innovations among employees. Our analysis highlights the effects of the distribution of shares within the firm and the firm's size on the incentives and behavior of firms towards innovation. In particular we highlight the following findings: (i) Often employees may not implement an idea neither within nor outside the firm. (ii) The ownership structure affects the incentives to promote innovation in firms. (iii) Firm shareholders may have incentives to curtail innovation even if these innovations are expected to be revealed within the firm. (iv) Firms may buy-off potential innovative agents, by providing them with compensation plans that dominate leaving the firm, or revealing new ideas within the firm. (v) Information leakage concerns affect both the hiring and the information provision decisions of the firm.

1 Introduction

The phenomenon of spin-out firms is well documented in both the popular press and the academic literature. Although spin-outs have been forming as early as firms existed, spin-out firms in the high-tech industry have received special attention. The labor mobility that is prompted by the formation of spin-outs has been recognized by some (see Saxenian (1994)) to be the engine behind information diffusion, incremental research and the growth of industries.

A big portion of the innovation in the high-tech industry occurs through the formation of spin-outs (see Christensen (1997)), often implying substantial losses for their maternal firms.[1] At the same time, innovation tends to stagnate in established firms.[2] This phenomenon has been termed 'The Curse of Incumbency'; existing market leaders are typically slower than entrants to see and adopt new technologies. As a result, technological change often enables challengers to enter a market and displace its leaders.

The 'gales of creative destruction' pose a problem to existing firms. Firms anticipate the potential defection of their most creative members. As this defection leads to the depletion of the intellectual capital developed within the firm and to the loss of substantial rents due to an increased market competition, the incentives of firms to promote innovation may be low. In this paper we develop a theoretical framework to analyze the promotion of cumulative research and innovation in firms.

To understand the phenomena mentioned above, it is necessary to understand the decision of innovators to introduce new ideas either within or outside their maternal firms. Consider an employee working for a firm who has an idea for a new product. In the absence of perfect intellectual property rights, as soon as the employee discloses his idea to someone (within or outside the firm), the information starts leaking and he looses control of his innovation. All the agents who become aware of the idea can start negotiating on the profits that are expected to be realized on the market once the idea is implemented. The renegotiation can involve both people people from within or outside the firm. To pin down the appropriation rates that innovators can expect under the different scenarios, it is necessary to take into account the fact that the outcome of the negotiation is affected by the number of people that become aware of the new idea and by the patterns of the information

[1] In fact this phenomenon motivated Christensen (1997) to coin the term "disruptive technology".

[2] For instance, Foster and Kaplan (2001) document that among the firms listed in the S&P 500 in 1957 only 2% are still listed and outperformed the index average in 1997, 13% are still listed but underperformed it, while 85% were off the list.

diffusion inside and outside the firm.

In a previous paper (Baccara and Razin (2003)), we introduce a simple bargaining protocol that accounts for the presence of information leakage. In this bargaining protocol, an agent who has a new idea tries to set up a team to develop the idea into a marketable product. We assume that the development process requires a team effort, so that ideas cannot be developed alone. At the beginning of the bargaining game, the innovator can make an offer to any subset of a pool of agents. All agents who receive the offer learn the idea, i.e. become "informed". If the offer is accepted by everybody, a team forms and the development takes place. If the offer is rejected by someone, a new negotiation ensues. As the set of informed agents is enlarged, the race to carry out the development is more intense. We model the intensity of the race by assuming that the probability any informed agent makes the next offer is inversely related to the number of informed agents. This model allows us to quantify the informational costs of the implementation of a new idea into the market.

In this paper, we base our model on the bargaining protocol we described above. We first focus on an agent who becomes inspired with a new idea while working in an established firm. In the model, this agent must choose between three courses of action. He may decide to disclose the new idea within the firm (*internal disclosure*). In this case, if the original firm develops the new product, the value of the firm will increase. Alternatively, the agent can decide to leave the original firm and form a *spin-out* that will compete to some degree with the old firm. Finally, the agent may decide to forego the disclosure of the new idea and keep his current compensation plan under the original firm.

Several factors affect the employee's decision. First, market structure considerations come into play. By staying in the firm, the surplus is maximized as the original firm will enjoy monopoly profits for both the old and the new products. In contrast, by forming a new firm, some rents may be lost due to competition between the old and the new firm.

Second, the organization and corporate governance structure of the original firm are important. By forming a new firm, the employee can design his new venture as he desires. In contrast, by staying in the original firm, the employee has to follow the organizational procedures of the original firm. The level of bureaucracy, hierarchical and ownership structure of the original firm may influence the outcome of any attempt of the employee to introduce a new idea within the firm. In our model, we use the number of people the innovator has to disclose the idea to within the firm as shorthand for these aspects of the firm's organization. As this number varies, the information leakage patterns that occur in the negotiation varies as well,

leading to different outcomes for the innovator.

We focus on two extreme cases of ownership structure. "Egalitarian" firms are modelled as firms in which ownership is equally distributed between all n shareholders of the firm. "Dictatorial" firms are modelled as firms in which one shareholder controls almost all the shares in the firm. We assume that a coalition holding more that fifty percent of the shares controls the firm.

First, we analyze the innovator's decision. We find that in egalitarian firms, employees will decide to form spin-outs when the firm is relatively large. Otherwise, when the number of shareholders is small, employees will decide to reveal the idea within the firm. On the other hand, in dictatorial firms, employees always decide to disclose their information internally. This result highlights the first effect of ownership structure or corporate governance on innovation in firms. The more people are involved in the process of approving new products in the firm, the more an employee stands to loose in terms of his control over the rents that the idea may produce.

Next, we focus on the original firm, In particular, we analyze the incentives within the firm to promote or discourage innovation by employees. We start by an observation related to our previous results. As implementing new ideas involve (informational) costs, it might be in the best interest of an inspired employee to remain silent and keep working under his current compensation scheme. In other words, firms might anticipate their employees' defection by offering generous compensation schemes to their employees. If these compensation schemes are equal to the ex-post expected value of an idea, the firm can guarantee that its employees will not defect (and will not introduce new ideas within the firm by starting a intra-firm renegotiation as well). On the other hand, this possibility may be costly for the firm, as the firm has to offer ex-ante a compensation scheme that is equivalent to the ex-post value of an idea for the employee.

Our results highlight a second relation between ownership structure and innovation in firms.[3] In particular, we show that the incentives for innovation depend

[3]From the start of the 'Silicon Valley' age there has been a great deal of discussion about the unique and innovative way in which many of these firms organized themselves. One of the symbols of firm culture and organization in Silicon Valley is what has been termed the "HP way" referring to the way in which the Heward Peckard company organized itself since inception. An important element of the 'HP way' was a democratization of the corporate governance and ownership:

"... To lessen this threat at HP all employees enjoyed the same terms and conditions of employment (i.e. a single status system operated). This included a share in the company's profits and eligibility for stock options. Profit sharing and shareholding in the company were widespread from its earliest days. These were first introduced as far back as 1945. When the company went

on the ownership structure in firms. While shareholders in both types of firms dislike employee defection, they differ substantially in their incentives for avoiding such outcomes or having employees bringing up new ideas within the firm. When innovators are expected to introduce their ideas within the firm, the shareholders in egalitarian firms always promote such innovations. Shares are initially divided equally within the firm and shareholders expect to be involved in the future implementation of the new idea and in the division of its rents. On the other hand, in a dictatorial firm, the owner faces a trade-off: an innovation would increase the rents the firm is producing but at the same time the new allocation of shares resulting from the renegotiation might entail lower expected value for him.

As a result, we get predictions on the different patterns of innovation in firms. Innovation can be introduced on the market either by spin-out firms or by established firms that keep on growing. Spin-outs tend to arise in equilibrium when the original firm is egalitarian and buying-off of the innovative employees is too costly. Internal disclosures are promoted and occur in small egalitarian firms. In dictatorial firms innovation always takes the form of an internal disclosure. Interestingly, we find that sometimes it is optimal for the owner of a dictatorial firm to discourage such disclosure nonetheless.

We next investigate the implication of information leakage on the firm's organizational decisions. First, we show how hiring decision are affected when the possibility of future innovations are considered. We show how firms often take inefficient decisions compared to a scenario in which there are perfect intellectual property rights.

Second, we focus on information provision within the firm.[4] The more information is provided to employees the more efficient they become in production. On the other hand, the more information in the hands of employees, the higher is the risk of these employees becoming inspired with new ideas. We show that these considerations can lead to the asymmetric treatment of otherwise identical employees. While some employees will be highly compensated and well informed about the firm's activities, others will be uninformed and paid wages that correspond to the workers' reservation utility.

Finally, we construct a dynamic example in which an endogenous life cycle for firms arises. In the equilibrium, firms initially grow and innovate through internal

public, in 1957, all staff, after six months tenure, became eligible for stock options. Bill and Dave firmly believed that a dynamic, decentralised technology firm that relied on innovation as the primary driver of its commercial success had to align the incentives of everyone in the company – from top management to production workers." in Forster (2002).

[4]This problem is related to work by Zabojnik (2002) and Rajan and Zingales (2001).

disclosures of ideas. As the firm becomes larger, innovations are introduced through the formation of spin-outs. This implies the decline of the original firm and the origin of a new life cycle for the next one.

The paper is organized as follows: after the literature review, we introduce the model in Section 2. In Section 3, we analyze the innovator's problem (taking the compensation scheme of the firm as given) and in Section 4 we analyze the firm's incentives to promote innovation. In Section 5 we extend the model in different directions, and we present an example of a dynamic version of it. Section 6 concludes the paper with suggestions for further research. The formal description of the model (and in particular of the bargaining protocol) and all proofs are in the Appendix.

1.1 Related literature

The economic literature on technological diffusion can be roughly divided into two branches. First, papers like Jovanovic and McDonald (1994), Chari and Hopenhayn (1991), and Boldrin and Levine (2002 and 2004) study the macroeconomic implications of information diffusion. These papers assume an exogenous mechanism through which new technologies are made available to firms or individuals.[5] On the other hand, several papers analyze informational concerns from an individual innovator's point of view. This line of research has been carried out, among the others, by Pakes and Nitzan (1983), Anton and Yao (1994), Rajan and Zingales (2001) and, more recently, by Bhattacharya and Guriev (2004) and Modica (2004). However, because of their different focus, none of these papers is equipped to capture the phenomenon of information diffusion, innovation, and industry equilibrium effects.

This paper is a first step to bridge these two strands of the literature. We think that a better understanding of the strategic issues underlying cumulative research and information diffusion can shed more light on the macro-implications of such phenomenon. In particular, here we use the methodology developed in Baccara and Razin (2003) to study the problem of cumulative research in firms. We think that the same methodology can be used to understand a very wide set of issues related to innovation and intellectual property.

The problem of incremental research has been analyzed from a normative perspective by Scotchmer (1991 and 2005), and the phenomena of workers' mobility

[5] See also Schivardi and Schneider (2001) for an interesting model on the episodes of 'disruptive changes' that analyzes the adoption of new technologies of incumbent firms after entrants innovate.

and spin-out formation have been analyzed by Anton and Yao (1995), Klepper (2001), Franco and Filson (2002) and Lewis and Yao (2003). The paper with the focus closest to ours is Anton and Yao (1995). Anton and Yao use a setting that is different from ours in the sense that in their case ex-ante negotiation on new ideas is possible. However, but innovators have to face an adverse selection problem that may lead them to leave the firm and form their own start-ups. Moreover, in their setting the problem of information leakage ceases to affect the negotiating sides after the idea has been disclosed to the firm (i.e., firms do not face the problem of information expropriation as innovators do).

This paper is also related to the vast literature on corporate governance.[6] Notice that in our model we completely abstract from the issue (that is at the core of the corporate governance literature) of the separation between ownership and control (in particular, the conflict between the manager and outside shareholders, and the one between large and minority shareholders). In this paper, we make the assumption that decisions within the firm are made by shareholders by majority rule, and it is necessary to negotiate directly with a shareholder to have her vote. Even if we think this assumption fits quite well the reality of high-tech start-ups and small partnerships, notice that it is made mainly for simplicity. One could reinterpret our definition of "dictatorial" firms as firms where decisions can be made involving a few people (a decentralized and efficient firm) and our definition of an "egalitarian" as a firm in which decision can only be made with the approval of many people (a hierarchical and rather bureaucratic firm).[7] Our results find a link, that is novel in the corporate governance literature, between the decision-making structure of a firm and the likelihood of success in staying ahead in the innovation race.

Our analysis formalizes (in Section 5.3) the notion that large established firms are often stagnant and prone to dissolution by small innovative spin-outs ('The Curse of Incumbency'). Explanations for this puzzle are often based on unawareness or bounded rationality of established firms when making decisions regarding new technologies. In particular, Christensen (1997) suggests that established firms tend to focus too much attention to their current customer base, not realizing that the existing customers are not the best predictors of tomorrow's market.[8] In contrast, we offer a rational decision making model in which the size of the firm is

[6] For a survey, see Shleifer and Vishny (1997).

[7] See for instance Stein (2002).

[8] Large firms tend to miss opportunities to innovate as they are focused on a specific product and its consumers. They overlook technological innovation that may seem irrelevant, but in the long run tends to become "disruptive".

directly linked to the vulnerability of the firm to defection from within.

2 The Model

Assume that there is a firm producing a patented product. The production of the firm requires labor as an input. Let us assume for simplicity that in order to produce, the firm needs to hire exactly one employee. There is an infinite supply of potential employees, and their reservation wage is zero. Let w be the wage (endogenously) set by the firm to compensate the employee.

After working in the firm for one period, the employee is inspired with a new idea. As we describe in Section 2.1, the new idea can be implemented either within the firm or outside the firm, with an independent spin-out. The new product competes to some degree with the old product, and the profits of the firms on the market are the following: (i) one firm producing only the old product enjoys a rent of $\pi < 1$ per period, (ii) one firm producing both the old and the new products receives a rent of 1, (iii) if two firms produce one the old and the other the new product, they receive π_1 and π_2 respectively.[9] We assume that if there is more than one firm on the new product market, Bertrand competition dissipates all the profits.[10] This assumption captures cases in which new technologies are not protected by intellectual property rights.[11]

In our analysis, we are interested in modelling explicitly the corporate governance in the original firm. In what follows we take a simplifying view of corporate governance in which the firm is governed by the majority of shareholders. In particular, from the point of view of an inspired employee, let $n_0 \geq 1$ be the minimal number of people that need to approve a new product line in order for it to be implemented.[12] The number n_0 depends on how the shares are distributed across the

[9]Notice that the patent on the old product guarantees that there cannot be two firms producting the old product.

[10]Notice that in general, when there is Bertratnd competition on the new product, the old firm can still earn some small $\pi_1' < \pi_1$ from the old product. For simplicity, we assume $\pi_1' = 0$.

[11]Our results in this paper hold for more general market structure assumptions. In particular, all the results in Sections 3 and 4 can be replicated for the case of the new product receiving a patent at the end of the development stage. These two alternative market structure assumptions capture the polar cases of the results in Baccara and Razin (2003). In particular, the case of patent protecion corresponds to the "Partial Protection" regime in Baccara and Razin (2003), while in this paper we focus on the "No Protection" regime. See that paper for a more general analysis that accounts for all the possible configurations of market competition.

[12]Note that the approach we take here restricts the number m_0 to be directly tied to the distribution of the shares. More generally, this number may depend on other factors like the level

shareholders and on the number of shareholders. For instance, if there are n shareholders (where n is odd) and the shares are equally distributed, then $n_0 = \frac{n+1}{2}$. If one shareholder controls almost all the shares, then $n_0 = 1$ for any n. In general, n_0 is weakly increasing in the size of the firm. When we analyze the decision taken in the firm about compensation, hiring and information provision (Section 4), we assume that the decisions are taken to maximize the utility of the ruling coalition within the firm.

For simplicity, we focus on two extreme distributions of shares within firms. 'Egalitarian' firms have n shareholders each with an equal stake in the firm. 'Dictatorial' firms are firms in which there is one shareholder holding almost all the shares in the firm.

Once an employee decides whether to disclose his idea to someone, either within the firm or outside, a bargaining game ensues. We next introduce our model of bargaining over new ideas.

2.1 Bargaining on new ideas

We assume that there are no perfect intellectual property rights on ideas. This implies that the bargaining over any new idea is affected by the risk of information leakage. In this paper we model bargaining with information leakage using the protocol developed in Baccara and Razin (2003). Three assumptions underlie this protocol. First, we assume that no agent can develop a new idea into a product on his own. In particular we assume that $m+1$ individuals are needed to develop the product and that nothing is gained by having more than $m+1$ agents working on it (we take m as a measure of the labor intensity of the development of the new product). Second, we assume that the act of recruiting entails sharing information about the idea. Finally, our third assumption relates to the asymmetry between informed and uninformed agents. As the only element differentiating otherwise homogeneous agents is the knowledge of the idea, we capture this asymmetry by assuming that offers can be made only by informed agents.[13]

The bargaining protocol is as follows.[14] The employee who is inspired with a new idea can make an offer to any number of other agents (either the shareholders of

of bureaucracy and decentralization in the firm. As long as this number is increasing with the size of the firm, our qualitative results will hold.

[13]This assumption is motivated by the uninformed agents being unaware of the existence of the idea or of its potential profitability. They become aware of it only when approached by an informed agent for the first time.

[14]We provide a formal description of the bargaining protocol in the Appendix.

the original firm or any other agent out of the infinite pool of potential employees), or can stay silent. If he stays silent, the game ends, the innovator gets w and the original firm splits the profit $\pi - w$ according with the original share allocation.

We refer to an offer which includes the n_0 agents required to introduce the new product within the firm as an *internal disclosure*, and to any other offer as a *spin-out*. Notice that, according to this definition, an agent can form a spin-out also by making an offer to some agents that are part of the original firm, as long as they are not the controlling majority. In this case, if the offer is accepted, a group of agents will leave the original firm to form a spin-out.

Any offer on the new idea implies information leakage, that is, all the agents receiving the offer become informed about the new idea themselves. All those who are part of an offer respond simultaneously. If an offer is accepted unanimously, the new product is introduced by the new team and the profits are realized on the market.[15] If an offer is rejected by anyone, a competition ensues among all the agents who are informed about the new idea up to that point. We model this competition by assuming that upon any rejection Nature chooses the next proposer in the bargaining on the new idea with the same probability among all the agents who are informed.

Every proposer in the bargaining (even if he was not in the original firm) can decide whether to try and bring the idea back to the shareholders of the original firm, or form a spin-out firm outside the original firm.[16] After an agreement has been reached to introduce the new idea on the market, there could be informed agents left outside the agreement. In this case, the game goes on until a second firm has formed to market the new idea. This implies that the possible outcomes of the bargaining can be the following: (i) an internal disclosure with a monopoly on the new product, (ii) a spin-out with a monopoly on the new product, (iii) an internal disclosure with another firm marketing the new product (iv) a spin-out with another firm marketing the new product.

[15] Note that as we use unanimity as the rule that governs the formation of a firm, the offers are conditional upon the acceptance of all the agents involved. This implies that agents cannot make an offer that is binding as soon as at least one agent accepts it (unconditional offer). We find these kinds of offers unfit for our applied situation because we want to capture the competition that arises among the informed agents once they all know the information. In order to do so, we give the possibility of counter-offers to all the informed agents. See Baccara and Razin (2003) for an extensive discussion of this assumption.

[16] Notice that the definition of spin-out we use in this paper refers to the idea being generated in the original firm and implemented outside, rather than the new firm necessarily being run by a former employee of the original firm. However, since there will be no delays in the bargaining, when a spin-out forms in equilibrium, the former employee is always the one who originates it.

We assume that there are frictions in bargaining due to impatience. These frictions are represented by a common discount factor $\delta \in (0,1)$. Every time we enter a negotiation subgame, payoffs in that subgame are discounted by δ.[17] If no agreement on the implementation of the new idea is reached, the original firm carries on its production and all the shareholders get their share of the profit π, while all the other agents have a reservation value normalized to zero. We assume all the agents are risk-neutral.

2.2 Timing

To summarize the description of the model made so far, here we present the timing of the game.

(1) The original firm (with n shareholders) hires an employee and promises him a payment w

(2) The employee works for the firm and has an idea for a new product

(3) The employee decides whether to disclose his idea to someone and start bargaining on it, or to stay silent.

(4a) If he stays silent the game ends. The firm gets a profit of π, the employee is paid w and $\pi - w$ is divided according to the distribution of shares in the firm.

(4b) If the employee starts a bargaining on his idea, the bargaining game described in Section 2.1 ensues. The outcome of the bargaining can be one of the following.

(5a) If the outcome of the bargaining is an internal disclosure with monopoly on the new product, the old firm realizes a profit of one on the market, which is divided according to the accepted offer.

(5b) If the outcome of the bargaining is a spin-out with a monopoly on the new product, the old firm realizes π_1, which is divided according to the initial distribution of the shares, and the spin-out realizes π_2, which is divided according to the accepted offer.

(5c) If the outcome of the bargaining is an internal disclosure with a second firm marketing the new product, the profits are driven down to zero, so all agents get zero.

(5d) If the outcome of the bargaining is a spin-out with a second firm marketing the new products, the profits are driven down to zero, so all agents get zero.

[17] Notice that, although our results in Sections 3 and 4 hold for any $\delta \in (0,1)$, for simplicity of exposition in those Sections we present them for $\delta \approx 1$.

As in Baccara and Razin (2003), we focus on Symmetric Subgame Perfect Equilibria in the analysis of this game.[18] In particular, we restrict our attention to the equilibria which do not require agents to use weakly dominated strategies.

2.3 Fundamental Lemma

The following Lemma is helpful for the analysis to come. In Baccara and Razin (2003) we prove the following result:[19]

LEMMA **1** *A monopoly on the new idea always arises in equilibrium. Moreover, any offer always includes all the agents who are informed about the new idea at that time.*

A consequence of Lemma 1 is that innovators have to pay each agent they include in an offer that includes s agents, a share $\frac{\delta}{s+1}$ of the profit of the future firm. Since every agent who receives an offer becomes informed of the new idea, in equilibrium they are included in every subsequent offer that will be made. This guarantees that every agent included in the offer receives an equal part of the pie and, as δ tends to 1, this share is equal to the innovator's one.[20]

3 The Innovator's Dilemma

In this Section we focus on the problem of the innovative employee of the original firm. Recall that such an employee is expected to receive a wage w from the firm, but he also has a new idea and has to decide whether to disclose his idea within the firm, leave the firm and form a spin-out, or not implement the idea at all.

In the following two results we highlight the impact of the original firm's size and structure on the optimal decision of the employee.

PROPOSITION **1** *If the original firm is egalitarian, then there is a $\overline{w}$ such that (i) if $w > \overline{w}$, then the innovator does not disclose his idea at all, (ii) if $w < \overline{w}$ then*

[18] We define Symmetric Subgame Perfect Equilibria formally in the Appendix.

[19] In particular, see Propositions 7 and 10 of Baccara and Razin (2003).

[20] Lemma 1 is a consequence of the assumption that two firms producing the new products have zero profits. Things would be different under alternative assumptions of less aggressive competition between the two firms. For instance, one could assume that the first firm to introduce the new idea on the market enjoys a monopoly on it. In that case, Propositions 6 and 9 in Baccara and Razin (2003) would apply: in equilibrium the innovator enjoys an additional effect we named "the information diffusion advantage", and his payoff turns out to be higher.

the innovator will leave the firm and form a spin-out if the size of the original firm is high enough, otherwise he reveals the idea within the firm.

Proposition 1 shows that in the case of an egalitarian firm, when a new idea arises, the size of the firm influences the optimal choice of the innovator. As the size becomes larger, the renegotiation the innovator faces if he discloses the idea within the firm becomes less and less profitable for him. In particular, the renegotiation within the firm leads a payoff of $\frac{1}{n+1}$ for the innovator, while a spin-out, in which just the minimal number of agents required to develop the product get the offer, leads to a payoff of $\frac{\pi_2}{m+1}$. This implies that a spin-out is more likely to emerge as n becomes larger.

Note that for this result to be true, our assumptions about corporate governance does not need to be taken literally. In particular, n_0 can be interpreted more generally as some measure of the "bureaucracy" in the firm. What is important for the result to be true is that the number of people who would be involved in the decision to develop the new idea within the firm is increasing in the size of the firm.

PROPOSITION **2** *If the original firm is dictatorial, then there is $\overline{w}$ such that if $w < \overline{w}$, the innovator discloses the idea within the firm and if $w > \overline{w}$, then the innovator does not disclose his idea anywhere. Therefore, spin-out firms never arise in equilibrium.*

The previous Proposition shows that if the distribution of shares of the original firm is very concentrated, the renegotiation within the original firm becomes less costly for the innovator. This implies that, in the case of a dictatorial firm, spin-outs will never occur, and if a new idea is implemented at all, it is implemented within the original firm. Notice that the agent who originally held all the shares of the firm is left with just the $\frac{1}{m+1}$-th fraction of the shares at the end of the negotiation. This illustrates the fact that internal disclosures tend to equalize ownership in dictatorial firms.

We now proceed to check the implications of Propositions 1 and 2 on the decisions of the original firm about employee compensation, allowing spin-out formation, hiring decisions and information provision within the firm.

4 The Firm's Problem

The previous section has illustrated the problem that firms and in particular shareholders face when confronted with the possibility of employees becoming creative.

These employees will sometimes decide to leave, start their own firm and later compete with the original firm. Even if they decide to stay within the original firm, the introduction of the innovation and the subsequent negotiation will reshuffle the shares within the firm in a way that may hurt the original shareholders.

We highlight several channels through which firms can curtail the effects generated by innovative employees. In this section we analyze the ability of firms to buy-off potential innovators by assuring that their initial compensation package dominates any expected post-innovation rents. We show that a consequence of the presence of information leakage is that any buying-off of an employee must be done before that employee is inspired about the new idea.

4.1 Buying-off Potential Innovators

In what follows we solve the firm's problem, that is we analyze the choice of the optimal w given the behavior expected from the employee once he becomes innovative. Let us recall that w, the salary of an employee, is set by the controlling coalition of shareholders, that the initial outside option of this employee is normalized to zero and there is no issue of information leakage in the hiring of employees to the original firm.

Before proceeding to the results let us provide the intuition for how a firm might buy-off an employee. Suppose that when an agent is inspired with a new idea, the best course of action (excluding the possibility of remaining silent) will lead to a payoff of v. Alternatively, by remaining silent the employee can always guarantee himself w. To buy-off the employee, the firm needs to pay the employee at least v. Therefore, if the firm decides to buy the employee off, it will set the current compensation of the employee at $w = v$. This will guarantee that when the employee has an idea nothing will change in the firm and the new idea will not be implemented.

Let us make two remarks. First, note that w has to be set *before* the inspiration occurs. Indeed, the firm cannot rely on the agent to come back and renegotiate his compensation ex-post. This is because the presence of information leakage will modify the bargaining power of the employee within the firm as soon as the renegotiation starts. In particular, at that stage the employee might decide to try his luck outside the firm without starting a renegotiation of his contract that would lead to a leakage of his idea within the firm.

Second, the distribution of shares within the original firm is important in the analysis for two reasons. First, as discussed in Section 3, the distribution of shares affects the choice of the employee of whether to introduce the idea in the original

firm or outside this firm. Second, the distribution of shares determines the incentives of the "ruling" coalition to buy-off the agent or not. In particular, we find that in an egalitarian firm, if shareholders expect that the employee is going to introduce the idea within the firm, it is in their interest to allow this to happen and there is no buying-off of the employee. On the other hand, if the firm is dictatorial, the owner of the firm may want to discourage this. The following two Propositions summarize these observations.

PROPOSITION **3** *In an egalitarian firm, if an internal disclosure is expected, there is no buying-off. If a spin-out is expected, buying-off will take place if* $\frac{\pi_2}{m+1}$ *is relatively small, otherwise a spin-out forms in equilibrium.*

Proposition 3 highlights that in an egalitarian firm an internal disclosure is always encouraged. The value of the firm is equally shared, before and after disclosure. If the firm decides to discourage disclosure, it has to pay the innovator enough to keep him indifferent between staying silent and disclosing his idea internally. This implies that shareholders always prefer the value of the firm to increase, even if they will have to share it with one more partner. Alternatively, when a spin-out is expected, the cost of buying-off the employee depends on his payoff in a spin-out, i.e. $\frac{\pi_2}{m+1}$. If this cost is high enough, buying-off does not occur in equilibrium, and a spin-out arises in equilibrium.

PROPOSITION **4** *In a dictatorial firm, in which internal disclosure is always expected, buying-off occurs when the idea is relatively labor intensive (that is,* m *is high).*

From Proposition 2 we know that forming a spin-out is never optimal for an innovator working in a dictatorial firm, as an internal disclosure always dominates leaving the firm . Proposition 4 shows that the owner of a dictatorial firm can still prefer to buy-off the innovative employee. The reason for this is the reshuffling of the ownership of the firm upon disclosure. Before the disclosure, one shareholder owned almost the entire value of the firm. After the disclosure, the value of the firm increases, but the bargaining over the new idea entails a more equitable ownership structure between all those involved in the development of the new idea. As the idea requires more people to be developed, the bargaining will involve more agents and the share of each of them is going to be smaller. This implies that the owner has more incentive to deter the disclosure of the new idea by buying-off the innovator.

It is interesting to stress the difference between the cases in which buying-off occurs in egalitarian and in dictatorial firms. In an egalitarian firm buying-off occurs only to prevent a spin-out. When an internal disclosure is expected, the efficient outcome is always realized as the innovation stays in the firm and it is implemented. In the case of a dictatorial firm, in which spin-outs are never expected, buying-off can still occur, causing the firm to stop introducing innovation.

4.2 Examples

In the following two examples we explore the implications of our results on two important cases of market structure: (i) **Strong competition between old and new product**. The competition between two firms producing one the old and the other the new products is strong enough to nullify all the rents, i.e. $\pi_1 = \pi_2 = 0$. (ii) **Vertical innovation**. The new product is an improvement of the old one under every dimension, resulting in the market for the old product to disappear in case the new one is introduced by a competing firm, i.e. $\pi_1 = 0$ and $\pi_2 = 1$.

Strong competition between old and new product. If $\pi_1 = \pi_2 = 0$ a spin-out is never expected. From Proposition 3 we know that an egalitarian firm would always introduce the innovation, while a dictatorial firm will buy-off the innovator only if $\pi > \frac{2}{m+1}$.

In this case, egalitarian firms lead to more innovations than dictatorial firms. The reason for this is that the strong market competitions makes employees shy away from forming spin-outs. As egalitarian ownership structures always promote internal disclosure, these firms will always innovate. On the other hand, dictatorial firms would sometimes have incentives to discourage such disclosures out of fear of a reshuffling of shares within the firm.

Vertical innovation. If $\pi_1 = 0$ and $\pi_2 = 1$, we have that without buying-off in an egalitarian firm a spin-out will always emerge. Then, an egalitarian firm will buy-off the innovator if and only if $\pi > \frac{1}{m+1}$. On the other hand, in a dictatorial firm, the buying-off will occur if and only if $\pi > \frac{2}{m+1}$.[21]

Observe that in the vertical innovation case the new product will be introduced on the market more often with a dictatorial firm than in an egalitarian firm. This market structure promotes spin-outs to occur when firms are egalitarian. As a

[21] Note that this is an extreme case in which the innovator in a dictatorial firm is indifferent between forming a spin-out and an internal disclosure.

consequence, these firms will take measures to discourage employees from leaving the firm by buying them off. Dictatorial firms also have incentives to buy-off employees in this case, for reasons similar to the previous example.

Although both types of firms have incentives to buy-off employees, their incentives differ markedly. The consequence of a spin-out for an egalitarian firm is zero profits, while the consequence of an internal disclosure to the original owner of a dictatorial firm is a rent of $\frac{1}{m+1} > 0$. Therefore, we will tend to see more innovations happening when firms are dictatorial.

5 Extensions

In this Section, we examine the implication of our findings on the organization and lifecycle of a firm. We first analyze a firm's hiring decisions and provide results showing that firms chooses to produce inefficiently (i.e. with few employees), in order to limit the effects of future innovation. Then, we analyze information provision within a firm. We assume that the more information is provided to employees, the more productive they are in the firm. On the other hand, if innovation is cumulative, the more information employees have about what the firm produces, the more they will be able to use this information to come up with their own ideas. We show that often this trade-off will be solved asymmetrically within the firm. In particular, there will be two types of employees. Some employees will be bought-off and will receive all the relevant information about the firm. Other employees will be given the minimum level of compensation and will be provided with limited information about the firm's production.

5.1 The Hiring Decision

We now focus on the decision of the firm of whether to hire new employees or not. Hiring new employees may be efficient in terms of increasing production but in our framework the costs of hiring are related to the possibility of the employees becoming innovative.

Suppose that currently the firm has to decide whether to hire one agent or not. The decision of hiring an agent has several implications. First, the worker increases the rents of the original firm by increasing production of the original product. We model this by assuming that rents from the original product are $\underline{\pi}$ whereas if the new employee is hired rents are $\pi > \underline{\pi}$. Second, the employee may become inspired (as in the previous sections, we assume that the probability of this event is one).

If the firm decides to hire the agent, then the firm has to decide what compensation plan to provide him with. This decision was analyzed in the previous section. Let us recall that the initial distribution of shares within the original firm affects the outcome of that decision. Therefore, the distribution of shares will also influence the hiring decisions of firms. The following proposition characterizes the hiring decisions of different types of firms.

PROPOSITION **5** *(i) In both types of firms, hiring becomes more attractive as the new idea is more labor intensive, i.e. m is larger, and the higher is the marginal productivity of the employee (ii) In an "egalitarian" firm, hiring decisions depend negatively on the employee's outside option, π_2 (iii) In a "dictatorial" firm, hiring decisions depend positively on the outside option of the firm, π_1 (whereas they do not depend on π_2).*

In both types of firms, an increase in m implies a decrease in the cost of hiring. This is evident, as any innovator must divide the rents that he generates among at least m individuals. Note, however, the difference in the key variables that determine the firms' hiring decisions in the two types of firms. As we saw in the previous sections, a dictatorial firm expects its employee to introduce the new idea in-house. Therefore, the cost of hiring an employee is related to the price of buying-off this employee. Remember that an employee's share from introducing the idea within the firm is proportional to the surplus that is available in the firm minus the outside option of the owner, π_1. The larger is π_1 the less costly it is to buy-off the employee and therefore the more profitable it is to hire him.

On the other hand, an egalitarian firm will have a trade-off in its hiring decision when it expects its employee to leave the firm with the new idea. In this case, buying-off the employee implies guaranteeing an amount that will compensate him for his outside option that depends on π_2.

5.2 Information Provision

In this section we investigate the optimal information provision within a firm. In the presence of a potentially innovative employee, a firm may face a trade-off. On the one hand, the more information is communicated to employees the more efficient the production process is. On the other hand, the more information in the hands of employees, the more they learn about the technology and the more likely they are to be inspired with new ideas.

We illustrate how information leakage concerns may result in an asymmetric treatment of otherwise symmetric employees. We will show that often the optimal

structure of the firm will involve some agents being fully informed and highly compensated while others receiving minimum compensation and being relatively uninformed.

We now introduce a model of information provision.[22] Let $\pi(x_1, x_2)$ for $x_1, x_2 \in [0,1]$ be the profit of the firm given that two agents receive the information levels x_1 and x_2 respectively (x_i may represent the level of information about the market, the production processes, the technology, and so on). We assume that production is increasing in the level of information of employees. i.e. $\pi(x_1, x_2)$ is increasing in both arguments. Let $\alpha(x_i)$ be the probability of agent i having a new idea given that his information is x_i. We assume that α is increasing, convex and that $\alpha'(0) = 0$. The events in which the two employees become inspired are stochastically independent from each other. An idea may potentially bring about the rent of one if implemented within the original firm and the rent of π_2 (leaving the original firm with a rent of π_1) when implemented outside the original firm.[23]

The game proceeds as follows. The owner of the firm decides the levels of information of the two employees, (x_1, x_2), and the compensation of each of the employees, (w_1, w_2). New ideas are realized according to the probabilities $\alpha(x_1)$ and $\alpha(x_2)$ and the inspired employee/s decide whether to disclose the idea internally, leave the firm and start a new firm or keep the status quo. The following proposition characterizes the firm's optimal information provision decision.

PROPOSITION **6** *In both types of firms, the optimal information provision schemes are of one of the following forms: (i) Both agents are fully informed and bought-off. (ii) One agent is fully informed and bought-off while the other receives minimum compensation and is informed to some level. (iii) Both agents receive minimum compensation and are informed to some level.*

An interesting implication of Proposition 6 is that often the solution to the firm's problem will involve an asymmetric treatment of otherwise symmetric employees. The intuition for this result is based on two simple features of the model.

[22] Note that this can also be interpreted as a model of task allocation within the firm. Under this interpretation we analyze the compensation levels that are associated with different tasks in the firm.

[23] Note that for simplicity we assume that the rents of the idea do not depend on the level of information of the employee. Our results will hold more generally, provided that there is a lower bound to the rent a new idea generates. Also, we assume that the two ideas are not competing against each other, i.e. the profit generated by any idea is independent on the second being implemented or not. Notice also that for simplicity we assume that the profit of the original firm π_1 is the same in case of one or two ideas being implemented outside the firm.

First, when the firm decides to buy-off an additional employee, there is a discrete jump in the compensation it has to pay to this employee even before he is inspired. This is because buying-off involves compensation that is equal to the ex-post value of the new idea

Second, if a firm buys-off an employee, it guarantees that this agent will not leave the firm (or introduce the idea within the firm). If information provision is more related to the probability that the employee is inspired than to the rents such an agent will secure if he is inspired, then the firm might as well provide him with the full information.[24]

5.3 Lifecycle of a Firm

In this Section we analyze the implications of our results to a firm's lifecycle. In particular, we introduce a dynamic model that starts at time $t = 0$ with an innovator having an idea for a new product. The bargaining for the formation of a firm that will develop this product is affected by information leakage. Once the firm is formed, the development of the product takes place, a patent is acquired and more employees are hired. At every period, one employee is inspired with a new idea, and faces the same set of choices we considered in the model introduced in Section 2, namely remaining silent, disclosing the idea internally, or forming a spin-out firm. We normalize the initial profit of the firm to be one, and we assume that every idea introduced within the firm increases the profit of the firm by a coefficient of $\gamma > 1$. This implies that a firm marketing all products up the t-th generation has a profit of γ^t. On the other hand, when the t-th new idea is introduced into the market by a spin-out firm, and it competes against the previous product, the original firm gets $\gamma^t \pi_1$ and the spin-out gets $\gamma^t \pi_2$, with $\pi_1 + \pi_2 < 1$. Also, we assume that all ideas require a similar to be developed. This similarity is reflected in our model by the fact that ideas require the same number of people (i.e., $m + 1$) to be developed.[25] We assume that ideas are cumulative, that is, it is necessary to have worked on the t-th idea to have the $t + 1$-th idea. Future profits

[24] More generally, if the information provision affects also the rents an agent might secure ex-post, the firm may not provide him with all the information, but will be more inclined to provide him with more information than if he were not "bought-off".

[25] This assumption could be easily replaced with ideas requiring an increasing number of people to be developed as they become more and more advanced without changing the main points of the analysis.

are discounted by a factor $\delta' \in [0,1]$.[26] Finally, we assume that after a period without innovation, the profits of a firm disappear (for instance because imitators start producing similar products after two periods).

The following result highlights the implications of our previous analysis on the lifecycle of a firm.

PROPOSITION **7** *There is an equilibrium such that for some $\bar{t} \geq 0$, if a firm existed for less than or for exactly $\bar{t}$ periods, new ideas are always disclosed internally and introduced on the market within the firm. After $\bar{t}$ periods, the next innovation is introduced forming a spin-out, and a new firm starts its growth. If $\gamma\delta' < 1$, there exist parameters for which $\bar{t} \geq 1$.*

The engine behind the firm's lifecycle in Proposition 7 is the fact that an innovating firm grows in size. As employees introduce new ideas within the firm, their bargaining power vis-a-vis the firm increases. As a result, these employees will be involved in the future decisions of the firm. In our model this increase in power is captured by the fact that innovative employees become partners of the firm themselves. At some point, when the number of shareholders is large enough, new innovative employees tend to form spin-outs.

We want to stress the fact that even if the increase in growth occurs for other reasons (e.g., bureaucracy), the above results on the lifecycle of firms are similar: as long as the firm is small in size we expect internal disclosure and growth. As the size of firms increases, there is a higher tendency to form a spin-out.

Finally, in this model we have abstracted away from the possibility of firms to buy-off their employees. Adding this possibility to the model will keep the qualitative results intact but will enrich the set of manifestations of the 'Curse of Incumbency'. In particular, in such a model, a possible detriment of an established firm will be the lack of innovation due to the buying-off of its employees.

6 Conclusion and Further Research

In this paper we examine the effects of information leakage on the decisions firms make to encourage or discourage creativity in their workplace. We offer an applicable model of bargaining in the presence of information leakage. We analyze the

[26] This discount factor is different from the discount factor δ according to which the payoffs are discounted in the bargaining on new ideas.

decisions of innovative employees to reveal their ideas within the firms, form spin-out ventures or to remain silent about their ideas. We show that the ownership structure of the original firm is an important factor in this decision.

We believe that our methodology is applicable to a wide range of issues that pertain to the evolution of firms and industries. In Baccara and Razin (2004) we examine the measures firms use to secure their information in the context of an industry cluster.

As a motivation, it is interesting to compare the two distinct cultures that had developed in two regional industrial zones in the United States, namely Silicon Valley in California and Route 128 in Massachusetts. This comparison is interesting as these two regions are similar in many respects: the two industrial regions are active in similar markets (i.e., the high-tech industry), both regions were energized after WWII by government investment and by a relationship with local universities (MIT and Stanford). Finally, both industries are in the US, and share similar legal environments.[27]

In contrast to these similarities, the two regions had developed into two very different models of industrial organization. While Silicon Valley adopted a network-based culture characterized by high labor mobility, Route 128 was organized into an individual firm-based system in which large integrated firms had a long life-span. In Silicon Valley labor mobility was very high and a long resume' was interpreted as a good sign of experience and knowledge. In contrast, in Route 128, loyalty to the firm was highly valued, labor mobility very low and spontaneous regrouping of workers rare.

Evidence suggests that the rate of innovation was overwhelmingly higher in Silicon Valley in comparison to Route 128. Saxenian (1994) links the differences in labor mobility and culture between the two regions to a difference in the rate of innovation and adaptation to changes.[28] Implicit in these observations is the idea

[27] Hyde (2002), however, claims that the enforcement of trade secret law and no-compete agreements in Silicon Valley is weak in comparison to Route 128. On the other hand, Saxenian (1995) argues for a cultural difference between the two regions in terms of legal standards.

[28] In her own words: "In a network-based industrial system like Silicon Valley, the region (..) is organized to adapt continuously to fast-changing markets and technologies. The system's decentralization encourages the pursuit of multiple technical opportunities through spontaneous regroupings of skill, technology and capital. Its production networks promote a process of collective technological learning that reduces the distinctions between large and small firms (..) The independent firm-based industrial system [Route 128] flourished in an environment of market stability and slow-changing technologies (..). In the case of semiconductors and again with computers, Silicon Valley's network-based system supported a decentralized process of experimentation and learning that fostered successful adaptation, while Route 128's firm-based system was

that innovation is generated and reinvigorated through the mobility of people and ideas.[29] Under this view, two elements are essential to create innovation. First, ideas are cumulative in the sense that one idea generates another.[30] Second, in order to exploit the cumulative potential of ideas one needs to match knowledge with people coming from different experiences. These observations suggest that different industries may be characterized by different cultures that relate to secrecy and information diffusion. It is our goal to use our framework to gain a better understanding of the strategic mechanics of these cultures.

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constrained by the isolation of its producers from external sources of know-how and information."

[29] This view of innovation has also been assumed in modelling the effect of cities on growth, see Glaeser et al (1992).

[30] See Gallini (1992), Scotchmer (1991) and Green and Schotchmer (1995) for normative analysis on cumulative research. See also Lewis and Yao (2003) for a related model of information diffusion and worker mobility.

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Appendix

The Model

We now present the bargaining protocol in detail. Let us consider a finite set of agents N, with $|N| = n > 2$, among which there are n_0 shareholders of an original firm. Among the n_0 agents in the firm, there is an innovator, say agent 1, that has an idea for a business venture. All the agents in $N \setminus \{1\}$ are initially unaware of the business idea. If developed, this idea can be implemented into one marketable product. The process of developing the idea requires the work of m agents. Let n_0 be the minimal number of agents one needs to negotiate with in order to introduce a new product within the firm. Let also Σ be the set of the possible majority coalitions within the original firm. Let S a generic element in Σ.

The structure of the game builds recursively on two types of negotiation subgames. What distinguishes the two types of subgames is whether one firm producing the new product has already formed or it has not.

Suppose we are at some history along the game at which a firm has not yet formed and the set of the informed agents, i.e. the agents who know the new idea, is $K' \supseteq \{1\}$. We are now ready to introduce the first negotiation subgame. We assume that nature chooses with equal probability among the informed agents in K' the next agent to make an offer. The chosen agent, say agent $i \in K'$, can propose a division of the surplus to a set of agents $C' \subset N \setminus \{i\}$. The division of the surplus, α, is a vector $\alpha \in \Delta^{card(C)}$, where $\Delta^{card(C')}$ is the simplex in $R^{card(C)}$ An offer is fully represented by the pair (C', α). The agents in C' have to decide simultaneously whether to reject or to accept the offer. The crucial assumption in this model is that all of the agents who receive an offer become informed, and the set of the informed agents becomes $C' \cup K'$. If at least one agent in C' rejects the offer, they enter a negotiation subgame in which no firm has formed. If all accept, then the first firm is formed, and four resulting cases are possible.

(1) If $C' \supseteq K' \setminus \{i\}$ and $C' \supseteq S$,with $S \in \Sigma$, i.e. all the other informed agents are included in the offer and the offer is an internal disclosure, then the game ends; the firm implements the idea and enjoys a monopoly status. Any agent $j \in C'$ receives α_j, agent i receives $(1 - \sum_{j \in C'} \alpha_j)$, and agents in $N \setminus (C' \cup \{i\})$ receive zero. We refer to an offer such that $C' \supseteq K' \setminus \{i\}$ as a "grand coalition" offer.

(2) If $C' \not\supseteq K' \setminus \{i\}$ and $C' \supseteq S$ with $S \in \Sigma$, not all the informed agents become part of the first firm, which is still an internal disclosure. The informed agents that are not part of the first firm can keep on negotiating and form a second firm. We therefore enter a second type of negotiation subgame in which one firm has formed and for which

the set of informed agents left in the game is $K' \setminus (C' \cup \{i\})$. In any terminal node following this history agent i receives $(1 - \sum_{j \in C'} \alpha_j)\pi'_1$ and any agent $j \in C'$ receives $\alpha_j \pi'_1$. We refer to an offer such that $C' \not\supseteq K' \setminus \{i\}$ as a "cost minimizing" offer.

(3) If $C' \supseteq K' \setminus \{i\}$ and $C' \not\supseteq S$,for any $S \in \Sigma$,then the offer is a grand-coalition "spin-out". If it is accepted, every agent $j \in C'$ receives $\alpha_j \pi'_2$, agent i receives $(1 - \sum_{j \in C'} \alpha_j)\pi'_2$, and agents in the original firm split π'_1 according with their original shares. All the others receive zero.

(4) If $C' \not\supseteq K' \setminus \{i\}$ and $C' \not\supseteq S$,for any $S \in \Sigma$,then the offer is a "cost-minimizing spin-out". If it is accepted, every agent $j \in C'$ receives $\alpha_j \pi''_2$, agent i receives $(1 - \sum_{j \in C'} \alpha_j)\pi''_2$, and agents in the original firm split π''_1 according with their original shares. The informed agents that are not part of the first firm can keep on negotiating and form a second firm. We therefore enter a second type of negotiation subgame in which one firm has formed and for which the set of informed agents left in the game is $K' \setminus (C' \cup \{i\})$.

Let us now introduce the second type of negotiation subgame. Such subgames ensue after some agent i has already formed a firm making a successful offer to the set of agents C'. Let K'' be the set of informed agents left in the game. With equal probability, an agent h is chosen from K'' to propose a division of the surplus to a set of agents $C'' \subset N \setminus (C' \cup \{i\} \cup \{h\})$. Let $\beta \in \Delta^{card(C')}$ be the proposed division. If everybody accepts the offer, the game ends. After case (2), agent h receives $(1 - \sum_{j \in C''} \beta_j)\pi'_2$, and any agent $j \in C''$ receives $\beta_j \pi'_2$. All the agents in $N \setminus (C' \cup C'' \cup \{i\} \cup \{h\})$ receive zero. After case (4), agent h receives $(1 - \sum_{j \in C''} \beta_j)\pi''_3$, and any agent $j \in C''$ receives $\beta_j \pi''_3$. All the agents in $N \setminus (C' \cup C'' \cup \{i\} \cup \{h\})$ receive zero. If someone in C'' rejects offer β, then the we enter a negotiation subgame in which one firm has formed and for which the set of informed agents is $K'' \cup C''$.

Note that we use unanimity as the rule that governs the formation of a firm, so that the offers are conditional upon the acceptance of all the agents involved. This implies that agents cannot make an offer that is binding on his side as soon as at least one agent accepts it ("unconditional offer").

We assume that there are frictions in bargaining due to impatience. These frictions are represented by a common discount factor $\delta \in (0, 1)$. Every time we enter a negotiation subgame, payoffs in that subgame are discounted by δ. If no agreement on the implementation of the new idea is reached, the original firm keeps on its production and all the shareholders get their share of the profit π., while all the other agents have reservation value normalized to zero. We assume all the agents are risk-neutral.

Before we specify the notion of equilibrium we adopt, let us introduce the set of possible histories of this game, H. The set H can be decomposed into the subsets H_O, H_R, H_N and H_T. The set H_O includes all the histories at which an agent is called to

make an offer, and we denote by h_i a generic history in H_O at which agent i is called to make an offer. The set H_R includes all the histories at which agents are simultaneously called to reply to an offer, the set H_N includes all the histories at which nature chooses the next proposer, and the set H_T include all the terminal histories. Every history in H_O is followed by a history in H_R, and every history in H_R is followed either by a history in H_T or by a history in H_N. Every history in H_N is followed by a history in H_O. Let $K(h)$ be the set of informed agents in the game at history $h \in H$, and let $k(h) \equiv card(K(h))$.

For any player $i \in N$, a strategy s_i is defined for all histories in H at which agent i takes an action, specifically for all histories in H_O at which he is called to make an offer and all histories in H_R at which he is called to reply.

To analyze this model, we look at Symmetric Subgame Perfect Equilibria (SSPE). Among the SSPE, we look at those in which agents do not use weakly dominated actions when responding to offers.[31]

To define Symmetric Subgame Perfect Equilibria, we first have to require strategies to be anonymous. Let σ_i be a mixed strategy of player $i \in N$. We say that σ_i is anonymous if at any history $h_i \in H_O$, $\sigma_i(h_i)$ can be described by a triple $\left(n^I, n^U, \gamma\right)$, where n^I and n^U are the number of informed and uninformed agents getting the offer, respectively, and γ is the vector of shares offered to each agent.[32] The agents included in the offer are randomly chosen from among the two groups.[33] The vector γ has dimension $n^I + n^U$. The first n^I elements, the shares offered to the informed agents, are all equal to γ^I and the remaining n^U elements, the shares offered to the uninformed agents, are all equal to γ^U.[34]

[31] This assumption is important only in Subsection 3.1 and Section 4, where situations in which proposers are forced to make offers to more than one agent become relavant. We want to rule out equilibria that are sustained by the mere fact that agents are not pivotal. For example, one can sustain equilibria in which offers to more than one agent are never accepted by any agent. These strategies could be chosen in equilibrium as, by our unanimity assumption, no agent is pivotal in the acceptance or rejection of such offer. By assuming away weakly dominated actions, we guarantee that an agent who desires the offer to be accepted, votes in its favor.

[32] This implies that $n^I \in \{0, 1, ..k(h_i) - 1\}$, $n^U \in \{0, 1, .., n - k(h_i)\}$, and γ is such that $\gamma \geq 0$ and $\sum_i \gamma_i \leq 1$.

[33] Then, since at history h_i there are $card(K(h_i) \setminus \{i\})$ informed agents and $card(N \setminus K(h_i))$ uninformed agents, each informed agent gets the offer with probability $\frac{n^I}{card(K(h_i)\setminus\{i\})}$, and each uninformed agent gets the offer with probability $\frac{n^U}{card(N\setminus K(h_i))}$.

[34] More generally, we could allow for any mixture of these strategies. The results would remain the same under this alternative formulation.

Definition 1 *A Subgame Perfect equilibrium is Symmetric if σ_i is anonymous for any $i \in N$ and at any $h_i, h_j \in H_O$ following the same history $h \in N$, $\sigma_i(h_i)$ and $\sigma_j(h_j)$ can be described by the same triple $\left(n^I, n^U, \gamma\right)$. Moreover, at any $h' \in H_R$, $\sigma_i(h')$ and $\sigma_j(h')$ are the same for any i and j who are playing at h'.*

In the analysis of the model, we compute the continuation values of the players at histories $h \in H_N$, i.e., when nature is about to choose the next proposer and the payoffs are about to be discounted. We denote the continuation value of agent i at a given history h as $v^i(h)$.

A property of the SSPE is that for any $h \in H_N$, all the informed agents have the same continuation value, or $v^i(h) = v^j(h) = v(h)$ for all $i, j \in K(h)$.

Proofs

Proposition 1 *If the original firm is egalitarian, then there is $\overline{w}$ such that (i) if $w > \overline{w}$, then the innovator does not disclose his idea at all, (ii) if $w < \overline{w}$ then the innovator will leave the firm and form a spin-out if the size of the original firm is high enough, otherwise he reveals the idea within the firm.*

Proof: Let us first show that if the innovator decides to reveal his idea within the firm his payoff is $\frac{1}{n+1}$. To show this, it is necessary to see that within the firm the innovator will reveal his idea to all n shareholders, even if he needs to get the approval only from n_0 of them. Observe that if he stays in the firm and discloses the idea to s shareholders, by Lemma 1, he gets $\frac{s}{n}\frac{1}{s+1}$, which is increasing in s. This implies that the optimal s is $s = n$, and the final share of the innovator is $\frac{1}{n+1}$.

If the innovator stays silent his payoff is w. If he leaves the firm, by Lemma 1, he gets $\frac{\pi_2}{m+1}$.

If $w < \max\{\frac{1}{n+1}, \frac{\pi_2}{m+1}\} \equiv \overline{w}$ then the innovator leaves if and only if

$$\frac{\pi_2}{m+1} > \frac{1}{n+1}$$

and discloses the idea within the firm otherwise. If $w > \overline{w}$ then the employee stays silent■

Proposition 2 *If the original firm is dictatorial, then there is $\overline{w}$ such that if $w < \overline{w}$, the innovator discloses the idea within the firm and if $w > \overline{w}$, then the innovator does not disclose his idea anywhere. Therefore, spin-out firms never arise in equilibrium.*

Proof: Suppose that the inspired employee is introducing the idea within the firm. The owner can always guarantee himself π_1. Therefore, in the ensuing negotiation he gets $\max\left\{\pi_1, \frac{1}{m+1}\right\}$.[35] Suppose that $\pi_1 > \frac{1}{m+1}$. Then, the innovator has to compare $\frac{1-\pi_1}{m}$ to $\frac{\pi_2}{m}$. Remember that $\pi_1 + \pi_2 \leq 1$. Then, if $w < \overline{w} = \frac{1-\pi_1}{m}$, the innovator discloses the idea within the firm as $\frac{1-\pi_1}{m} > \frac{\pi_2}{m}$. Suppose that $\pi_1 < \frac{1}{m+1}$. Then, if $w < \overline{w} = \frac{1}{m+1}$, the innovator has to compare $\frac{1}{m+1}$ to $\frac{\pi_2}{m+1}$, and obviously he discloses the idea within the firm■

Proposition 3 *In an egalitarian firm, whenever an internal disclosure is expected, there is no buying-off. If a spin-out is expected, buying-off will take place if $\frac{\pi_2}{m+1}$ is relatively small, otherwise a spin-out forms in equilibrium.*

[35] The continuation game is similar to a Rubinstein bargaining game with a binding outside option for the owner.

Proof: (i) From Proposition 1 we know that, if the employee decides to disclose his idea internally his payoff is $\frac{1}{n+1}$, if he forms a spin-out he gets $\frac{\pi_2}{m+1}$, while if he stays silent he gets w. From the point of view of the shareholders, we have two possible cases.

(ia) If $\frac{1}{n+1} > \frac{\pi_2}{m+1}$, we know that if $w < \frac{1}{n+1}$, then the employee will disclose the idea internally. From the point of view of the shareholders, we have the if they decide not to buy the employee off, they will get $\frac{1}{n+1}$, while of they decide to silence him, they have to set $w = \frac{1}{n+1}$, and they get $\frac{\pi - w}{n} = \frac{\pi - \frac{1}{n+1}}{n}$. The shareholders will silence the employee if and only if $\frac{\pi - \frac{1}{n+1}}{n} > \frac{1}{n+1}$, or $\pi - \frac{1}{n+1} > \frac{n}{n+1}$, or $\pi > 1$, which is impossible.

(ib) If $\frac{1}{n+1} < \frac{\pi_2}{m+1}$, we know that if $w < \frac{\pi_2}{m+1}$, then the employee will leave and form a spin-out. If the shareholders set $w = \frac{\pi_2}{m+1}$, they prevent this to happen, and they get $\frac{\pi - w}{n} = \frac{\pi - \frac{\pi_2}{m+1}}{n}$, otherwise they get $\frac{\pi_1}{n}$. Then, the buying off of the employee occurs if and only if $\frac{\pi - \frac{\pi_2}{m+1}}{n} > \frac{\pi_1}{n}$, or $\pi - \frac{\pi_2}{m+1} > \pi_1$.

Proposition 4 *In a dictatorial firm, in which internal disclosure is always expected, buying-off will occur when the idea is relatively labor intensive.*

Proof: From Proposition 2 we know that the owner of a "dictatorial" firm, in case of an internal disclosure gets $\max\left\{\pi_1, \frac{1}{m+1}\right\}$, and the innovator never forms a spin-out.

(iia) Suppose that $\pi_1 > \frac{1}{m+1}$. Then, if he sets $\overline{w} = \frac{1-\pi_1}{m}$, the owner of the firm gets $\pi - \overline{w} = \pi - \frac{1-\pi_1}{m}$. If he sets $w = 0$, there will be a renegotiation where he will get π_1. Then, the buying off occurs if and only if $\pi - \frac{1-\pi_1}{m} > \pi_1$, or $\pi m - 1 > m\pi_1 - \pi$. Notice that if $\pi < \pi_1$ there is never buying off, while if $\pi > \pi_1$, then for m high enough the owner will buy off the innovator.

(iib) Suppose that $\pi_1 < \frac{1}{m+1}$. Then, if $\overline{w} = \frac{1}{m+1}$, the owner of the firm gets $\pi - \overline{w} = \pi - \frac{1}{m+1}$, while if he sets $\overline{w} = 0$ he gets $\frac{1}{m+1}$. Then, there is buying off if and only if $\pi > \frac{2}{m+1}$ ■

Proposition 5 *(i) In both types of firms, hiring becomes more attractive as the new idea is more labor intensive, i.e. m is large, and the higher is the marginal productivity of the employee (ii) In an "egalitarian" firm, hiring decisions depend negatively on the employee's outside option, π_2 (iii) In a "dictatorial" firm, hiring decisions depend positively on the outside option of the firm, π_1 (whereas they do not depend on π_2).*

Proof: (i) is obvious. (ii) If an egalitarian firm decides not to hire an employee then every shareholder gets $\frac{\pi}{n}(1+\delta)$.

If the firm hires, then from Proposition 3, we have two cases.

(iia) Suppose first that $\frac{1}{n+1} < \frac{\pi_2}{m}$. Then, the employee is expected to leave the firm. The firm decides to buying him off if and only if $\frac{\pi - \frac{\pi_2}{m}}{n} > \frac{\pi_1}{n}$, or $\pi - \frac{\pi_2}{m} > \pi_1$. Then, we have that hiring will take place if and only if $\max\{\frac{\pi}{n} + \delta\frac{\pi_1}{n}, \frac{\pi}{n} + \delta\frac{\pi - \frac{\pi_2}{m}}{n}\} > \frac{\underline{\pi}}{n} + \delta\frac{\underline{\pi}}{n}$, or $\max\{\pi_1, \pi - \frac{\pi_2}{m}\} > \frac{\underline{\pi}(1+\delta)-\pi}{\delta}$.

(iib) Suppose now that $\frac{1}{n+1} > \frac{\pi_2}{m}$. Then, the employee is expected to disclose the idea internally and, from Proposition 3, we know that there is no buying-off. From hiring the employees, the shareholders get $\frac{\pi}{n} + \delta\frac{1}{n+1}$, so they will hire him if and only if $\frac{\underline{\pi}}{n} + \delta\frac{\underline{\pi}}{n} < \frac{\pi}{n} + \delta\frac{1}{n+1}$, or $\delta(\frac{\underline{\pi}}{n} - \frac{1}{n+1}) < \frac{(\pi - \underline{\pi})}{n}$, which is always satisfied.

(iii) If the owner of a dictatorial firm doesn't hire, he gets $\underline{\pi}(1+\delta)$. If he hires, we know from Proposition 2 that there cannot be a spin-out. Then, if $\pi_1 > \frac{1}{m+1}$, he buys the employee off if and only if $\pi - \frac{1-\pi_1}{m} > \pi_1$ (the payoffs in the second period in the two cases). Comparing the payoff from hiring to the payoff from not hiring, we get that the owner should hire if and only if

$$\max\left\{\pi + \delta\left(\pi - \frac{1-\pi_1}{m}\right), \pi + \delta\pi_1\right\} > \underline{\pi}(1+\delta)$$

or, equivalently,

$$\max\left\{\pi - \frac{1-\pi_1}{m}, \pi_1\right\} > \frac{\underline{\pi}(1+\delta) - \pi}{\delta}$$

The case $\pi_1 < \frac{1}{m+1}$ is very similar to the case we just analyzed. This concludes the proof■

Proposition 6: *In both types of firms, the optimal information provision schemes are of one of the following forms: (i) Both agents are fully informed and bought off. (ii) One agent is fully informed and bought off while the other receives minimum compensation and is informed to some level.* (iii) *Both agents receive minimum compensation and are informed to some level.*

Proof: First we examine the case of an "egalitarian" firm. Suppose, that only one employee is inspired with a new idea. If he discloses the idea internally, we know by Proposition 3 that there is no buying-off, so the optimal information provision scheme is as in (iii). If he leaves the firm, buying him off will cost $\frac{\pi_2}{m+1}$. If two employees are inspired, to buy each of them off, the firm must guarantee that employee $\frac{\pi_2}{m+1}$.

There are three possible courses of action for the shareholders of the original firm:

(a) Buy only one employee, say 1, off. In this case, the original firm's shareholders

problem is

$$\max_{(x_1,x_2)\in[0,1]^2} \frac{\pi(x_1,x_2)-\delta\frac{\pi_2}{m+1}}{n}+\delta(1-\alpha(x_2))\frac{\pi(x_1,x_2)}{n}+\delta\alpha(x_2)\frac{\pi_1}{n} \tag{1}$$

(b) Buy both employees off. In this case, the original firm's shareholders problem is

$$\max_{(x_1,x_2)\in[0,1]^2} \frac{\pi(x_1,x_2)(1+\delta)-2\delta\frac{\pi_2}{m+1}}{n} \tag{2}$$

(c) Buy no agent off. In this case, the original firm's shareholders problem is

$$\max_{(x_1,x_2)\in[0,1]^2} \frac{\pi(x_1,x_2)}{n}[1+\delta(1-\alpha(x_1))(1-\alpha(x_2))]+\delta[1-(1-\alpha(x_1))(1-\alpha(x_2))]\frac{\pi_1}{n} \tag{3}$$

It is apparent that if one buys an employee off, it is always optimal to give them the entire information. This is evident as the objective functions of problems (1), (2) and (3) are always increasing in the level of information provided to the agent who is bought off. Then, letting (x_1^*, x_2^*) be the optimal solution of (1), and (x_1^{**}, x_2^{**}) be the optimal solution of (3), we can rewrite the objective functions at the optimum solution respectively as:

$$\frac{\pi(1,x_2^*)-\delta\frac{\pi_2}{m+1}}{n}+\delta(1-\alpha(x_2^*))\frac{\pi(1,x_2^*)}{n}+\delta\alpha(x_2^*)\frac{\pi_1}{n}$$

$$\frac{\pi(1,1)(1+\delta)-2\delta\frac{\pi_2}{m+1}}{n}$$

and

$$\frac{\pi(x_1^{**},x_2^{**})}{n}[1+\delta(1-\alpha(x_1^{**}))(1-\alpha(x_2^{**}))]+\delta[1-(1-\alpha(x_1^{**}))(1-\alpha(x_2^{**}))]\frac{\pi_1}{n}$$

Note that the buying off an additional employee involves a trade-off between a discrete jump in the compensation paid to the employee, $\frac{\pi_2}{m+1}$, and a benefit that is related to a decrease in the probability of defection and in the productivity in production. Notice that if m is very large, the firm will buy off both agents as buying off is relatively inexpensive. If m is intermediate the firm will buy off one employee. If m is small the firm will not buy off any employee.

We now examine the case of a "dictatorial" firm. Suppose, that only one employee is inspired with a new idea. If $w < \overline{w}$, from Proposition 2, we know that he will choose

to disclose the idea internally, and the owner of the firm will get $\phi \equiv \max\left\{\pi_1, \frac{1}{m+1}\right\}$. Suppose the owner buys the employee off, i.e. $w = \overline{w}$ (from Proposition 4, $\overline{w}$ is either $\frac{1}{m+1}$ or $\frac{1-\pi_1}{m}$ to the firm, depending whether π_1 is smaller or greater than $\frac{1}{m+1}$). If two employees are inspired, to buy each of them off, the firm must guarantee that employee $\overline{w}$.

The following are the three possible courses of action for the owner of the firm:

(a) Buy only one employee, say 1, off. In this case, the original firm's owner problem is

$$\max_{(x_1,x_2)\in[0,1]^2} \pi\left(x_1,x_2\right) - \delta\overline{w} + \delta\left(1-\alpha\left(x_2\right)\right)\pi\left(x_1,x_2\right) + \delta\alpha\left(x_2\right)\phi \tag{4}$$

(b) Buy both employees off. In this case, the original firm's owner problem is

$$\max_{(x_1,x_2)\in[0,1]^2} \pi\left(x_1,x_2\right)\left(1+\delta\right) - 2\delta\overline{w} \tag{5}$$

(c) Buy no agent off. In this case, the original firm's owner problem is

$$\max_{(x_1,x_2)\in[0,1]^2} \pi\left(x_1,x_2\right)\left[1+\delta(1-\alpha(x_1)(1-\alpha(x_2))\right] + \left[1-(1-\alpha(x_1)(1-\alpha(x_2))\right]\phi \tag{6}$$

Observe that, as in the egalitarian firm case, if the owner buys an employee off, it is optimal to give them the entire information(again, the objective functions of (4), (5), (6) are always increasing in the level of information provided to the agent who is bought off.

Then, letting $\left(x_1^*, x_2^*\right)$ be the optimal solution of (4), and $\left(x_1^{**}, x_2^{**}\right)$ be the optimal solution of (6), we can rewrite the objective functions at the optimum solution respectively as:

$$\frac{\pi\left(1,x_2^*\right)}{n} - \delta\overline{w} + \delta(1-\alpha(x_2^*))\pi\left(1,x_2^*\right) + \delta\alpha(x_2^*)\phi$$

$$\pi\left(1,1\right) - 2\delta\overline{w} + \delta\pi\left(1,1\right)$$

and

$$\pi\left(x_1^{**},x_2^{**}\right)\left[1+\delta(1-\alpha(x_2^{**}))(1-\alpha(x_2^{**}))\right] + \left(1-(1-\alpha(x_1^{**}))(1-\alpha(x_2^{**}))\right)\phi$$

Again, buying off an additional employee involves a trade-off between a discrete jump in compensation paid to the employee, $\overline{w}$ (notice that $\overline{w}$ is always inversely related to m) and a benefit that is related to a decrease in the probability of defection and in

productivity of production. If m is very large, the firm will buy off both agents as buying off is relatively cheap. If m is intermediate the firm will buy off one employee. If m is small the firm will not buy off any employee■

Proposition 7: *There is an equilibrium such that for some $\bar{t} \geq 0$, if a firm existed for less than or for exactly $\bar{t}$ periods, new ideas are always disclosed internally and introduced on the market within the firm. After $\bar{t}$ periods, the next innovation is introduced forming a spin-out, and a new firm starts its growth. If* $\gamma\delta' < 1$, there exist parameters for which $\bar{t} \geq 1$.

Proof: In the proposed equilibrium, at time $t = 0$ the innovator makes an offer to m agents, offering $\frac{1}{m+1}$ to each of them. An egalitarian firm is then formed, and the number of people in this firm is $n = m + 1$. The wage that is paid to employee in any period, is equal to zero. At period in which the age of the firm is $t < \bar{t}$, the inspired agent faces the following choice: if he discloses the idea internally, the firm grows by one person, and the employee gets his share of the profits as long as the firm will keep on making profits. If he leaves to form a spin-out, it will face competition from the old firm in the first period, but then it will start a new life cycle. Therefore, the equilibrium stratgies are stationary with respect to the state variable, which is the age of the firm.

First step: If

$$\frac{\gamma}{m+2}+\frac{\delta'\gamma^2\pi_1}{m+2}\leq\frac{\gamma\pi_2}{m+1}+\frac{\delta'\gamma^2}{m+2}+\frac{\left(\delta'\right)^2\gamma^3\pi_1}{m+2} \tag{7}$$

Then let $\bar{t} \equiv 0$ and the above proposed strategies form an equilibrium.

Second step: If condition (7) is not satisfied, we have to find a $\bar{t} \geq 1$ such that if the firm has been existing for less or exactly $\bar{t}$ periods the idea is introduced internally, while if the firm has existed for $\bar{t}+1$ periods a spin-out forms. In any first period of the existence of a firm, the employees discloses the idea internally if and only if

$$\frac{1}{m+2}+\frac{\delta'\gamma}{m+3}+..+\frac{\left(\delta'\right)^{\bar{t}-1}\gamma^{\bar{t}-t}}{m+\bar{t}+1}+\frac{\left(\delta'\right)^{\bar{t}}\gamma^{\bar{t}-t+1}\pi_1}{m+\bar{t}+1}\geq\frac{\pi_2}{m+1}+\frac{\delta'\gamma}{m+2}+..+\frac{\left(\delta'\right)^{\bar{t}+1}\gamma^{\bar{t}+1}\pi_1}{m+\bar{t}+1}$$

More in general, at any period $t \leq \bar{t}$ of the existence of a firm, we have that the innovator discloses the idea internally if and only if

$$\begin{aligned} & \frac{1}{m+t+1}+\frac{\delta'\gamma}{m+t+2}+..+\frac{\left(\delta'\right)^{\bar{t}-t-1}\gamma^{\bar{t}}}{m+\bar{t}+1}+\frac{\left(\delta'\right)^{\bar{t}-t}\gamma^{\bar{t}-t+1}\pi_1}{m+\bar{t}+1} \\ \geq & \frac{\pi_2}{m+1}+\frac{\delta'\gamma}{m+2}+..+\frac{\left(\delta'\right)^{\bar{t}}\gamma^{\bar{t}+1}}{m+\bar{t}+1}+\frac{\left(\delta'\right)^{\bar{t}+1}\gamma^{\bar{t}+1}\pi_1}{m+\bar{t}+1} \end{aligned} \tag{8}$$

Notice that for any $\bar{t}$ the LHS of condition (8) decreases in t while the RHS does not depend on t. So, the date at which it is the hardest to sustain internal disclosure is at $\bar{t}$. At that date, we have

$$\begin{aligned} & \frac{1}{m+\bar{t}+1}+\frac{\delta'\gamma\pi_1}{m+\bar{t}+1} \\ \geq \quad & \frac{\pi_2}{m+1}+\frac{\delta'\gamma}{m+2}+..+\frac{\left(\delta'\right)^{\bar{t}+1}\gamma^{\bar{t}+1}\pi_1}{m+\bar{t}+1} \end{aligned} \tag{9}$$

If (9) is satisfied, then (8) is satisfied for any $t \leq \bar{t}$.

To sustain this equilibrium it must be the case that at $\bar{t}+1$ the innovator prefers to form a spin-out, that is

$$\begin{aligned} & \frac{1}{m+\bar{t}+2}+\frac{\delta'\gamma\pi_1}{m+\bar{t}+2} \\ < \quad & \frac{\pi_2}{m+1}+\frac{\delta'\gamma}{m+2}+..+\frac{\left(\delta'\right)^{\bar{t}+1}\gamma^{\bar{t}+1}\pi_1}{m+\bar{t}+1} \end{aligned} \tag{10}$$

Thus, the equilibrium age of the firm, $\bar{t}$, must be the smallest integer such that conditions (9) and (10) are both satisfied. Such a solution must exist as by (7) that (9) is satisfied for $\bar{t}=1$, and the LHS decreases and the RHS increases in $\bar{t}$■