Bargaining Over New Ideas: Rent Distribution and Stability of Innovative Firms[1]

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Abstract

We analyze a model of bargaining over new ideas. The model accounts for the problem of information leakage, i.e., the diffusion of information about the idea before and after the idea is implemented. We analyze the effects of information leakage on the distribution of rents within firms and the firms' stability to the introduction of innovation. In the model, the distribution of rents in a firm reflects the distribution of information about the idea. We show how the balance of power between the innovators and their collaborators depends on market conditions and firms' size. The model also provides a formal link between the organization of firms and their stability: the model predicts that, a larger firm will tend to be less stable to the introduction of innovation.

1 Introduction

Innovation starts with ideas. Before an idea is developed into a product, innovators often need to bargain over its future rents and to involve others in the new project. In the absence of perfect intellectual property rights, such a bargaining process is characterized by the presence of information leakage– that is, the diffusion of information both before and after an agreement has been reached. In this paper, we develop a general model of bargaining with information leakage over the expected rents of new ideas.

Understanding the effect of information leakage on bargaining is essential to the analysis of the formation of firms, as well as of their evolution and performance. Information leakage affects the distribution of rents when a new firm forms. Once a firm is formed, further innovation can affect it in two fundamental ways. First, innovation brings about changes to the firms' internal structure and distribution of rents. New players are brought in to the pictures, while the contracts of others in the firm are revaluated.[1]

A second issue relates to the effect of innovation on the firms' stability. A key focus of the literature about the high-tech industry has been the stability of firms involved in innovative activity.[2] Moreover, it has been suggested that large incumbent firms are disadvantaged when it comes to introducing innovation.[3] The model we develop in this paper allows us to analyze the effect of innovation on the distribution of rents in the firm and on its stability.

Consider the following scenarios that our analysis applies to:

(1) An innovator has a new idea, and in order to develop it into a product, he needs partners. The innovator knows that once he reveals his idea to someone, he is vulnerable to the risk of expropriation. In the absence of perfect intellectual property rights, how much of the value of the idea can he expect to appropriate in the formation of the new partnership? What is the effect of different property rights on the innovator's prospects?

(2) A firm considers implementing a new idea. For the implementation to be completed, a

[1] One manifestation of such changes is the so-called "founders' syndrome" in which original founders of firms find themselves marginalized as the firm follows new paths. See, for instance, McNamara (1999).

[2] The phenomenon of spin-out formation has received special attention in the literature. A big portion of the innovation in the high-tech industry occurs through the formation of spin-outs, often implying substantial losses for their maternal firms. This phenomenon motivated Christensen (1997) to coin the term "disruptive technology."

[3] This has been termed the "Curse of Incumbency." 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.

certain number of people in the firm will learn the details about the idea. Will the firm be able to stay intact and develop the technology, or will someone leave with the idea and try to develop it outside the firm's boundaries? What determines the stability of firms to the introduction of innovation?

(3) An employee in a firm has an idea for a new product. He has to decide whether to reveal his idea (and renegotiate his contract) within the firm or to leave the firm and form a spin-out. How is the structure of the original firm going to affect the decision of the innovative employee?

Our model allows us to address these and related questions. One or more agents initially know an idea for a business venture. This venture yields an expected return of one if only one firm implements it. We assume that if two firms implement the idea, competition dissipates some of the rents. The agents bargain over the rents either among themselves or with other agents who are initially uninformed about the idea.

We analyze a sequential-offer bargaining protocol based on the following assumptions. First, implementing the idea requires the collaboration of a certain number of agents. Second, any agent who is not informed about the idea and who receives an offer learns about the idea (*information leakage*). Third, only those who know the idea have a strictly positive probability of becoming proposers in the bargaining.

If the first group to form does not include all the informed agents, the game continues until a second group is formed. The game ends once either all the informed agents are part of a group or when two groups have formed.

Our main result, Proposition 1, characterizes the symmetric subgame perfect equilibria of the game. In the case in which the first firm to form is relatively protected (whether by the acquisition of a patent or by some other first-mover advantage), we find a unique equilibrium. The equilibrium has two main characteristics: (i) information diffusion occurs both on and off the equilibrium path, and (ii) the equilibrium establishes a relation between the size of the firm and its stability. In particular, there is a threshold for the initial group's size above which, in equilibrium, the group splits up and two firms form in equilibrium.

In the case in which the first firm to form is relatively unprotected, we again find a unique equilibrium. In equilibrium, the initial group of innovators always stays intact independently of its size. Also, in this equilibrium, information remains within the boundaries of the agents who are informed about the idea both on and off the equilibrium path.

We proceed by analyzing the implications of Proposition 1. We first examine the effects of information diffusion on the distribution of rents within firms, both for the case of a sole innovator (as in scenario (1)) and the case of a group of individuals implementing a new idea together (as in scenario (2)). In our model, the rents are distributed according to the ex-post bargaining position of agents that is due to their knowledge of information.

Appropriation rates of the sole innovator We find that there exist equilibrium effects that protect the appropriation rate of innovators even in the absence of perfect intellectual property rights on ideas. The intuition for this result lies in the anxiety of those around the bargaining table about the implications of rejecting today's offer. In particular, they might fear that they will not be included in any firm that will form in the future or that more firms will form and dissipate some of the rents.

In particular, consider the case in which the new product, once developed, is fully protected by a patent in the final product market. We find that there is a unique symmetric equilibrium in which the innovator always receives a surprisingly high share of the profits. In particular, if the collaboration of two agents is necessary to develop the product, as the bargaining frictions disappear, the share of a sole innovator goes to $1 - e^{-1}$, i.e. about 63% of the profits. If the number of people necessary to develop the product is arbitrarily large, the appropriation rate of the innovator is bounded below by e^{-1}, i.e. about 37% of the profits.

The innovator's success is due to a novel effect that is robust to the disappearance of bargaining frictions. We refer to this effect as the *Information Diffusion Advantage.* The intuition behind this effect comes from the structure of the equilibrium. Following a rejection of an offer, new proposers always make offers to new, uninformed agents. This is because by making an offer to an uninformed agent, a proposer is increasing the degree of competition this agent will face upon rejection and, as a result, ensuring a lower continuation value. The ability of proposers to credibly commit to make offers to uninformed agents implies that the innovator appropriates a sizable share of the profits in the first offer.

Now, consider the case in which the first firm to form is not protected. Any agent who is about to make an offer has to consider the effect of his offer on the product market structure; besides the potential defection of the agents he hires, a proposer has to evaluate the threat of future market competition. Thus, he faces an additional trade-off. In particular, he can either preempt the potential competition on the final product market by hiring all the agents that could potentially compete with him (i.e., all the informed agents), or he can form a firm in the least expensive way and face competition on the final product market.

We show that higher rents for the innovator can be sustained by a second effect that we term the *Threat of Competition Advantage*. We show that the innovator is sometimes able to threaten his partners with competition arising upon rejection of his offer. As competition dissipates rents, this tends to lower the continuation value of potential employees. Thus, this threat enables the innovator to appropriate all of the gap between monopoly rents and the total rents under market competition. This implies that the fiercer is the potential market competition, the stronger is the innovator's position.

On the other hand, the threat of competition is not always credible. In particular, when the degree of potential market competition is very high, upon rejection of an offer, agents always have incentives to avoid competition. We show that in this case *both* the information diffusion and market competition advantages cease to hold. This pushes the innovators' payoffs to the minimum.

The distribution of rents in the firm. Our analysis yields the rent distribution in the firm endogenously. Proposition 1 implies a connection between the market environment and the distribution of rents in firms. In particular, we show that the balance of power between innovators and their collaborators favors the former for intermediate levels of protection of new firms. On the other hand, when there is either full protection or no protection of new firms, the collaborators are able to extract more rents due to the presence of information leakage.

The distribution of rents in the firm that is due to innovation is important for several reasons. In Section 4.1.3, we present an example that shows how the presence of information leakage, through its effect on the distribution of rents, can affect the firms' performance.[4] Moreover, in Baccara and Razin (2006) we analyze the implications of the above results to the incentives within the firm towards the introduction of innovation.

The stability of an innovative firm. Our results link the stability of an innovative firm to its organization and to the degree of protection of new firms in the market. First, the number of people involved in the creation of new ideas in the firm is critical to answer the questions posed in scenario (2). Proposition 1 shows that as this number increases, so does the tendency of firms to split up. This tendency depends on variables such as the firm's size and organizational structure.

[4] This observation is consistent with the well-known comparison between Silicon Valley's success and Route 128 decline. Many legal scholars (see Saxenian (1996)) relate the different success of the regions to the relatively weak enforcement of IPR in California versus the stricter regine in Massachusetts.

Second, our analysis predicts that when the degree of market competition is relatively high, firms will tend to stay intact. When, on the other hand, the degree of potential competition in the final product market is low, we show that the firms are unstable and competition will arise. This result runs counter to the notion of bargaining efficiency, as competition entails rent dissipation. In this respect, our analysis highlights an important implication of information leakage as a reason for the breakdown of bargaining efficiency.

One way in which firms split up in practice is by the formation of spin-outs by employees, as highlighted in scenario (3). To analyze such a phenomenon, we address the case in which one employee of a firm has a new idea. Our results suggest that an innovative employee is more likely to form a spin-out the higher the number of agents involved in the intra-firm decision making process– i.e., when the original firm is large or bureaucratic. When, on the other hand, the firm is small and/or the decision-making power is concentrated, innovation is more likely to be disclosed within the firm.

This paper is organized as follows. After a literature review, we present the main model in Section 2. In Section 3, we present the results. In Section 4, we analyze the implications of our results to the distribution of rents and the stability of the innovative firm. Finally, in Section 5, we discuss some normative implications, extensions of the model and modeling assumptions. We conclude in Section 6.

1.1 Related literature

The literature on the informational concerns of innovators is both young and sparse. The first papers to approach the informational concerns of inventors in the absence of intellectual property rights are Arrow (1962), Nitzan and Pakes (1983) and, more recently, Anton and Yao (1994 and 1995).[5]

Anton and Yao (1994, 1995) are the first to model explicitly the bargaining mechanism by which innovators implement their ideas in the presence of information leakage. Anton and Yao (1994) shows how an innovator can appropriate a substantial share of the rents of his ideas by threatening to generate more competition on the product market. Anton and Yao (1995) applies a similar logic to a model in which the innovator works for a firm and has the option to implement the idea by himself in a spin-out.

[5] See also d'Aspremont, Bhattacharya and Gerard-Varet (2000) for a different approach to information diffusion by voluntary disclosure.

In both these papers, the firm is modeled as a unitary agent that reacts to the actions of the innovator. This implies that there is a fundamental asymmetry between innovators and firms because firms do not face the problem of information leakage as innovators do. In contrast, our aim is to develop a general framework to model information leakage among individuals. These could be collaborators or decision-makers within the firm as well as any potential partner outside the firm. This generality allows us to yield predictions about the connection between the organization of the firm and the implementation of innovation.

Our model also relates to the notion that a firm's employees could be tempted to appropriate the firm's source of the rent. Rajan and Zingales (2001) analyze the optimal design of a hierarchy to prevent employees from doing so. The difference to our analysis is reflected in the modeling assumptions: in their model, employees bargain on their wage after deciding whether to stay in the firm or to defect. In our model, the defection decision can occur at any moment between the bargaining and the completion of the development process, so it affects the outcome of the bargaining.[6]

Several papers offer competitive treatments of information diffusion. In particular, Chari and Hopenhayn (1991) and Jovanovic and McDonald (1994) study the dynamics of the diffusion of new technologies. More recently, Boldrin and Levin 2003 (see also 2004) construct a competitive model of innovation and growth in which innovative products can be either consumed or duplicated and sold on a competitive market.

We think that a better understanding of the strategic issues underlying information diffusion can shed more light on the macro implications of such a phenomenon. In particular, this paper develops a methodology that can potentially be applied to understanding a wide set of issues related to innovation and IPR. As a first step in this direction, in Baccara and Razin (2006), we apply the methodology developed in this paper to the problem of incremental research and incentives to innovate in established firms.

[6] For other papers that relate the possibility of employees' defection to the distribution of wages within the firm, see Stole and Zweibel (1994), Wolinsky (2000) and Zabojnik (2002). In particular, Zabojnik (2002) explores how hierarchical firms pay employees efficiency wages in accordance with the potential threat of their leaving the firm with relevant information.

2 The Model

In this section, we introduce our model of bargaining with information leakage. Three assumptions underlie our bargaining protocol.[7] First, we assume that no agent can develop an idea into a product on his own. Second, we assume that the act of recruiting entails sharing information about the idea. The final 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.[8]

In the model, which is based on a multi-agent alternating-offer bargaining protocol, upon each rejection, the next proposer is chosen randomly by Nature.[9] The novelty in this model is that the set of those who can make offers is endogenous and expands as the game progresses; in each period of the game, an agent is chosen among all the agents that know about the idea to make the next offer.

We now present the model in detail. Let us consider a finite set of $n > 2$ agents, denoted by N, among which there is a set of innovators $K^0 = \{1, 2, .., k^0\}$ that have an idea for a business venture. All the agents in $N \backslash K^0$ are initially unaware of the business idea. If developed, this idea can be implemented into one or more marketable products. The process of developing the idea requires the work of $m + 1 < n$ agents, where $m \geq 1$. We initially assume that $m = 1$ and relax this assumption in Section 4.

We assume that knowledge of the idea is necessary for any group of agents to develop it. Thus, if all the informed agents are in one firm, this firm enjoys a monopoly in the product market. Any knowledgeable agent who is not part of an existing firm can always try to form her own firm and develop the same or a similar product. This new firm will compete to some degree with the first firm on the final product market.

For simplicity, we assume that the market can accommodate only two firms. Obviously, there will be an advantage to being the first firm that develops the product. This advantage depends on the technology produced, the market demand characteristics and intellectual property rights' enforcement. We normalize the present value of all the profits earned by the first firm if the second firm never enters the market to be equal to 1. Let π_2 be the present value of all the profits

[7] The assumptions of this model are discussed further in Section 5.

[8] Uninformed agents are unaware of the existence of the idea or of its potential profitability. They become aware of it only when approached by an informed agent.

[9] See, for instance, Baron and Ferejohn (1989).

earned by the second firm in competition. Then, notice that the present value of all the profits earned by the first firm increases with the delay with which the second firm enters the market. We let $\pi_1 \leq 1$ be the present value of all the profits of the first firm if a second firm forms *after one period*. We assume $\pi_1 \geq \pi_2$ and $\pi_1 + \pi_2 \leq 1$.[10]

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

Suppose that 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 idea– is $K' \supseteq K^0$. 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, α, to a subset of agents $C' \subset N \backslash \{i\}$, including at least m agents. 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 two resulting cases are possible.

If $C' \supseteq K' \backslash \{i\}$– i.e. all the other informed agents are included in the offer– 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 $N \backslash (C' \cup \{i\})$ receive zero. We refer to an offer such that $C' \supseteq K' \backslash \{i\}$ as a "*grand coalition*" offer. If $C' \not\supseteq K' \backslash \{i\}$, not all the informed agents become part of the first firm. The informed agents that are not part of the first firm can continue to negotiate until they form a second firm. We, therefore, enter a second type of negotiation subgame in which one firm has already been formed and for which the set of informed agents left in the game is $K' \backslash (C' \cup \{i\})$. 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 $C' \not\supseteq K' \backslash \{i\}$ as a "*sub-coalition*" offer.

Let us now introduce the second type of negotiation subgame. Such subgames ensue after some

[10] These profits should be interpreted as incorporating any downstream effects due to imitation. Also, observe that $1 - \pi_1$ is a measure of the cost of competition for an incumbent firm. Since the first firm to form chooses the most profitable project, $\pi_1 \geq \pi_2$ and competition implies $\pi_1 + \pi_2 \leq 1$. See Section 5.2 for a discussion of the case in which $\pi_1 + \pi_2 > 1$.

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 l is chosen from K'' to propose a division of the surplus to a set of agents $C'' \subset N \backslash (C' \cup \{i\} \cup \{l\})$, including at least m agents. Let β be the proposed division. If everybody accepts the offer, the game ends, agent l 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 $N \backslash (C' \cup C'' \cup \{i\} \cup \{l\})$ receive zero. If someone in C'' rejects offer β, then 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 offers that are binding as soon as at least one agent accepts it ("*unconditional offer*").[11]

The game begins with a negotiation subgame for which the set of informed agents is K^0. We assume that, due to impatience, there are frictions in the bargaining 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 is reached, we assume payoffs are zero. All the agents have reservation values normalized to zero and are risk-neutral.

To analyze this model, we look at *Symmetric Subgame Perfect Equilibria (SSPE)*.[12] Among the SSPE, we look at those in which agents do not use weakly dominated actions when responding to offers.[13]

For any player $i \in N$, a strategy s_i is defined for all histories at which agent i takes an action. For any history h, in which nature chooses the next proposer, let $k(h)$ denote the number of informed agents at that history, and let $K(h)$ denote the set of these agents. In the analysis of the model, we compute the continuation values of the players at such histories. We denote the continuation value of an informed agent i at a given history h as $v^i(h)$. A property of the SSPE is that for any such history h, all the informed agents have the same continuation value– i.e., $v^i(h) = v^j(h) = v(h)$ for all $i, j \in K(h)$.

[11] In Section 5, we discuss this assumption in detail.

[12] For the formal definition of SSPE we refer to the Appendix. In Section 5, we discuss the implications of restricting attention to SSPE.

[13] 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.

3 Main Results

In this section, we derive the main result of the model. In Proposition 1, we characterize the set of equilibria. For simplicity, here we describe the conditions for n arbitrarily large, while in the Appendix, we present the result and the proof for any n.

Proposition 1 *(i) When $\pi_1 > \frac{1-\delta^2\pi_2}{1+\delta}$, there is a unique SSPE. In this equilibrium, there is a $\bar{k}$ such that in any subgame with $k > \bar{k}$ informed agents, the proposers always make offers to an uninformed agent. (ii) When $\pi_1 < 1-\delta$, there is a unique SSPE. In this equilibrium, proposers always make grand coalition offers that include only informed agents. (iii) When $\pi_1 \in (1-\delta, \frac{1-\delta^2\pi_2}{1+\delta})$, there are multiple equilibria. In particular, there exist both a SSPE in which offers are made to only uninformed agents and a SSPE in which offers are made to a grand coalition.*

To understand this result, it is instructive to look at the extreme configurations of the model's parameters. Consider first the case in which $\pi_1 = 1$– i.e., when the new product is fully protected against competition. Let us denote by v_k the continuation value of an informed agent at a history in which there are k informed players and nature is about to choose the next proposer. To build the unique equilibrium sequence $\{v_k\}_{k=k^0}^n$ of the continuation values of each informed player, start with n informed agents. When everybody is informed, symmetry guarantees that the continuation value of every player is $v_n = \frac{\delta}{n}$, i.e., $1/n$-th fraction of the discounted pie δ.

When $n-1$ agents are informed, consider the options of a proposer. He can either form a firm only with one or more informed agents, or he can include an uninformed agent in his offer. If the offer includes the uninformed agent, every agent has to be paid $v_n = \frac{\delta}{n}$. Suppose that he offers only to informed agents. Upon rejection, each of them is chosen as next proposer with probability $\frac{1}{n-1}$. In that event, each can guarantee himself at least $1 - \frac{\delta}{n}$ by making an offer to the only uninformed agent. Thus, the amount $\frac{\delta}{n-1}\left(1-\frac{\delta}{n}\right)$ represents a *lower bound* of the continuation value of an informed agent. However, as $\frac{\delta}{n-1}\left(1-\frac{\delta}{n}\right) > \frac{\delta}{n}$, it is always optimal to offer to the only uninformed agent. This implies that $v_{n-1} = \frac{\delta}{n-1}\left(1-\frac{\delta}{n}\right)$.

Working backwards by induction on the number of informed agents, assume that $k < n$ agents are informed, and the continuation value sequence is defined by $v_l = \frac{\delta}{l}(1-v_{l+1})$ for all $l \in \{k+1, .., n-1\}$. Again, by making an offer to an informed agent, a proposer has to pay him at least $\frac{\delta}{k}(1-v_{k+1})$, and it can be shown that $\frac{\delta}{k}(1-v_{k+1}) > v_{k+1}$. This implies that it is always optimal to make an offer to an uninformed rather than an informed agent (i.e., *information diffuses* off the equilibrium path) and that $v_k = \frac{\delta}{k}(1-v_{k+1})$ for all $k \in \{2, .., n-1\}$. Moreover, since the sequence $\{v_j\}_{j=k+1}^{n}$ displays the property $lv_{k+l} > (l+1)\, v_{k+l+1}$ for any $l \geq 1$, it is not optimal to make an offer to more than one agent.

By the analysis above, when $\pi_1 = 1$, informed agents always make offers to uninformed agents in any subgame (i.e., $\bar{k} = 1$). When $\pi_1 < 1$, a trade-off will emerge between grand coalition offers and offers to uninformed agents. As the number of informed agents increases, the cost of grand coalition offers does too. Thus, agents will tend to make sub-coalition offers and, in that case, the cost of a sub-coalition offer is minimized if it is made to uninformed agents. Therefore, $\bar{k}$ represents the cut-off above which grand coalition offers become too expensive and agents start to make offers to uninformed agents.

Note that we can interpret the equilibrium described above in the following way. An agent who is in the position to make an offer is able to credibly threaten the recipients of the offer; if they reject the offer, future offers will be made to different agents and, as a result, they cannot be assured to be included in the firm in the future. The proof sketched above shows why, when π_1 is large enough, such threats are credible. However, when π_1 is low, these threats are no longer credible as agents tend to make grand coalition offers: indeed, the cost of making a grand-coalition offer never exceeds δ, while a sub-coalition offer guarantees *at most* π_1. Therefore, if $\pi_1 < 1 - \delta$, no agent would ever make a sub-coalition offer, no matter how many informed agents there are on the market, and grand coalition offers are always made in every SP equilibrium. Note also that point (ii) of Proposition 1 guarantees that when $\pi_1 < 1 - \delta$, the equilibrium grand coalition offers are never extended to any uninformed agent. This equilibrium feature of case (ii) has important implications that we explore and discusse in the next section.

Finally, for intermediate values of π_1, different equilibria can be sustained by sustaining different credible threats. To give the intuition for this result, consider an equilibrium in which two firms arise in equilibrium. One can sustain competition using the following strategies. As long as proposers make sub-coalition offers, the continuation game involves future sub-coalition offers. This entails a large share of the profits to the proposers. But proposers may be tempted to go for a grand-coalition offer. Such behavior is discouraged by the threat that if such offers are made, continuation games will involve further grand coalition offers that tend to increase the continuation value of those who are part of the initial offer.

4 Implications

In this section, we focus on two effects of information leakage on firms. First, we analyze the implication of Proposition 1 on the distribution of rents in firms. In our model, the distribution of rents in the firm is determined by the ex-post bargaining positions in the firm due to the knowledge of information. On the one hand, innovators bring the new information to light and enjoy a first-mover advantage. On the other hand, new agents who are recruited in order to implement the new idea enjoy some bargaining power vis-à-vis others due to their newly acquired knowledge of the information.

Second, we analyze the stability of firms with respect to the introduction of an innovation. The choice of informed agents between remaining within the confines of the firm or opting out implies that the firm's organization might influence its ability to stay intact. We examine this question from two perspectives: first, we examine whether a group of informed agents will decide to implement the idea together; next, we examine the incentives of an inspired employee to either disclose his idea within the firm or implement the idea outside the firm.

4.1 Distribution of Rents in Firms

We now consider the implications of Proposition 1 for the distribution of rents within the firm. It is instructive to start our analysis with a sole innovator, as it will allow us to examine the balance of power between innovators and their recruits. To this end, we focus on the case of $k^0 = 1$ and $m > 1$. Below, we show that the innovator's ability to appropriate rents depends on two equilibrium effects: (a) *the information diffusion advantage* relates to the ability of the innovator to threaten his collaborators that if they do not abide by his offer, then they will not be guaranteed to be part of any future firm formed, as more and more people will be informed of the idea; and (b) *the market competition advantage* relates to the ability of the innovator to threaten his collaborators that if they do not abide by his offer, rents will be dissipated due to the emergence of two firms competing in the market.

4.1.1 The Information Diffusion Advantage

To illustrate the information diffusion advantage, we consider the case in which $\pi_1 = 1$. This case occurs, for instance, when the first firm to form is protected either by intellectual property rights or by other first-mover advantages (e.g., on the demand side). In this case, Proposition 1 can be generalized to the case of $m > 1$ as follows.

Proposition 2 *When $\pi_1 = 1$, there is a unique SSPE. In this equilibrium, in any subgame, the proposers always make offers to m uninformed agents.*

In the above equilibrium, the innovator's appropriation rate is $1 - mv_{m+1}$. Since the sequence $\{v_k\}_{k=2}^n$ is a function of m, n and of the discount factor δ, let us denote the appropriation rate $v(m, \delta, n) \equiv 1 - mv_{m+1}$. We use the notation $v(m, \delta, \infty) \equiv \lim_{n\to\infty} v(m, \delta, n)$, $v(\infty, \delta, \infty) \equiv \lim_{m\to\infty} v(m, \delta, \infty)$, etc.

Corollary 3 *When $\pi_1 = 1$, the initial innovator always appropriates more than a share $\frac{1}{m+1}$ of the profit. When n becomes arbitrarly large, the innovator's share is bounded above by $1 - e^{-\delta}$ and bounded below by $e^{-\delta}$. The upper bound is achieved when $m = 1$, and the lower bound when m becomes arbitrarily large.*

Corollary 3 implies that in the absence of both first-mover advantage and legal protection, the innovator enjoys an advantage that is driven by equilibrium incentives. Even for large m, and as the bargaining frictions disappear, the presence of the *information diffusion advantage* keeps the appropriation rate of the innovator bounded away from zero.

The source of the innovator's ability to appropriate rents is his ability to take advantage of his collaborators' anxiety about what will happen upon rejection. This anxiety is a result of the presence of information diffusion. Indeed, upon the rejection of the innovator's offer, each recipient knows that with probability $\frac{m}{m+1}$ he is not going to become the next proposer; in that case, the next proposer is going to make an offer to uninformed agents, leaving that agent with a payoff of zero. This effect tends to lower the bargaining position of the agents the innovator involves in his first offer. Indeed, let us compare the above result to a model in which $m = 1$ and $n = 2$. In this case, there is no scope for information to diffuse. Indeed, it is easy to see that in the only SPE, proposers always offer $\frac{\delta}{2}$, and agents always accept the offer. As the players get more patient (δ tends to 1), the first-mover advantage of the first proposer vanishes, and his payoff goes to $\frac{1}{2}$.

4.1.2 The Market Competition Advantage

Consider, now, the case in which there is little protection on the final product market– that is, $\pi_1 < 1$. In this section, we show how the threat of market competition affects the innovator's payoff.

We start the discussion with an observation: if exactly two agents are informed, the continuation value of each of them is *at most* $\frac{\delta}{2}$. This implies that the innovator can always secure $1-\frac{\delta}{2}$ by offering $\frac{\delta}{2}$ to one agent.[14] Thus, $\underline{v}(\delta) \equiv 1-\frac{\delta}{2}$ represents a lower bound of the appropriation rate of a single innovator.

To see how the threat of market competition affects the innovator's appropriation rate, we first consider the equilibria when π_1 is relatively large.

Proposition 4 *There exists a $\bar{\pi} < 1$ such that if $\pi_1 > \bar{\pi}$, there is a unique SSPE. In this equilibrium, in any subgame, the proposers always make offers to m uninformed agents and the innovator's appropriation rate is decreasing in both π_1 and π_2.*

Let us now look more carefully at the appropriation rate of the innovator in this equilibrium. Note that the generic element of the sequence $\{v_k\}_{k=2}^{n}$ for large n is

$$\begin{aligned} v_k &= \pi_1[\sum_{i=1}^{\infty}\frac{(-1)^{i-1}\delta^i(k-1)!}{(k-1+i)!}+\sum_{i=1}^{\infty}\frac{\delta^i}{k}] \\ &+\pi_2\sum_{i=1}^{\infty}(k+i)\sum_{j=1}^{\infty}\delta^j\frac{(k+i)!}{(k+i+j)!}(-1)^{j-1})) \end{aligned}$$

The innovator's appropriation rate is given by

$$v(\delta,\infty)=1-v_2>1-\frac{\delta}{2}=\underline{v}(\delta)$$

The innovator's ability to guarantee a share larger than $1-\frac{\delta}{2}$ is now due to two distinct effects. The first effect, the information diffusion advantage, was introduced in the previous section. This effect allows the innovator to appropriate more than half of the surplus of the continuation game, i.e. $\pi_1+\delta\pi_2$.

However, the innovator's share of the profits is even higher. The innovator is able to appropriate also the entire gap between monopoly profits and the surplus under competition, i.e., $1-(\pi_1+\delta\pi_2)$. This is because the innovator can credibly threaten a potential employee that if he rejects his offer, competition will arise on the final product market.[15]

Note that the continuation value of the potential employee is increasing in both π_1 and π_2. When competition arises in any subgame, the total pie divided among agents is $\pi_1+\delta\pi_2$. Therefore, as the value of the pie increases, the agents' continuation values increase as well. As a result, the

[14] Note that this is a result of the assumption that only one agent is needed in the production function. When the production function involves more and more agents, the minimum payoff an agent can secure tends to be $1-\delta$.

[15] This effect is reminiscent of a similar effect in Anton and Yao (1994).

innovator's appropriation rate decreases in both π_1 and π_2. As π_1 and π_2 decrease, the threat of competition in the subgame that ensues in case of a rejection becomes more powerful. This enables the innovator to pay his employees less and, therefore, increase his own share of the profit.

The link between fiercer potential competition on the market and higher bargaining power of the innovators is very intuitive. Anton and Yao (1994) consider a similar effect and show that fiercer competition on the market cannot hurt the innovator and often strengthens his position.

However, point (ii) of Proposition 1 implies that for high degrees of potential market competition, the threat of competition *ceases to be credible*. As a result, the innovator's position is compromised, and he is unable to appropriate the gap between the monopoly and competition rents.

Corollary 5 *If $\pi_1 < 1 - \delta$, the appropriation rate of a single innovator is $1 - \frac{\delta}{2}$.*

Corollary 5 follows directly from point (ii) of Proposition 1. One could think that even when grand coalition offers are made in equilibrium, proposers may still extend the offers to uninformed agents to lower the continuation value of every agent included in their offer. However, when grand coalition offers are made along the equilibrium path, the continuation value of the agents included in the offer are relatively high (that is, equal to $\frac{\delta}{1+k}$ when k agents are informed). This prevents the proposers from extending the offer to more individuals than necessary. This implies that information diffusion advantage and market competition advantage cease to hold at the same time, leaving the innovator's appropriation level at the lowest possible level– that is, equal to $1 - \frac{\delta}{2}$.

Finally, Proposition 1 implies that for values of π_1 in the interval $[1-\delta, \frac{1-\delta^2\pi_2}{1+\delta}]$, one can sustain equilibria in which the innovator appropriates the minimum appropriation rate, $1 - \frac{\delta}{2}$, as well as equilibria in which he is able to appropriate more than that.

In the middle range, a competitive market outcome is sustainable only if the number of informed agents is high enough. However, Proposition 1 shows that there are equilibria in which a single innovator can still benefit from it. In fact, in the equilibrium we present in the Appendix, the innovator's payoff is higher than $1 - \frac{\delta}{2}$ even if a competitive market outcome can be sustained only for a high enough number of informed agents. The innovator's success is again due to the information diffusion and the threat of competition advantages.

4.1.3 The Distribution of Rents in the Firm

The analysis carried out above highlights a clear relationship between the market conditions and the distribution of rents within a new firm. In particular, the distribution of rents will tends to be relatively more egalitarian in the extreme configuration of the parameter space– i.e., when the potential competition on the product market is either fierce (neither information diffusion advantage nor threat of market competition is present) or when it is non-existent (only information diffusion advantage is present). For intermediate values of market competition, the balance of power in the firm discriminates between the innovators and their collaborators because for these parameters information diffusion advantage is present and threat of market competition is at its peak.

The distribution of rents and effort extraction. Our model pins down the endogenous distribution of rents that arises in the absence of property rights. The distribution of rents in the firm has important implications for the firms' performance.

Here, we present a simple example to illustrate the effect of information leakage on the firm's performance of when an investment is required from both employer and employee to produce the product. The point of this example is that weak protection of intellectual property rights and the presence of information leakage alter the incentives to exert effort and may indeed improve the efficiency of production in a firm.[16]

Consider a situation in which a non-contractable effort from two agents is required to carry out the development of a product. Assume that the production function is $V\left(e^E, e^W\right) = \left(e^E e^W\right)^{\frac{1}{2}}$, where $e^E, e^W \in \Re_+$ are the efforts of the employer and employee, respectively. The cost of effort is the same for both agents involved in the production, and it is defined by $c\left(e\right) = \frac{e^2}{2}$, where $e = e^E, e^W$. The first best effort levels $\left(e^{E*}, e^{W*}\right)$ maximize $V\left(e^E, e^W\right) - \frac{(e^E)^2}{2} - \frac{(e^W)^2}{2}$ and they are $e^{E*} = e^{W*} = 1/2$.

Without the presence of information leakage– that is, when intellectual property rights are perfectly enforced– the employer chooses the share, $x \in [0, 1]$ of the employee. By solving the employer's problem, it is easy to see that he offers the employee the share $x^* = 1/4$.

[16] Aghion and Tirole (1994) and Lester and Talley (2001) suggest that different allocations of property rights could help to improve the inefficiency that results when uncontractable effort goes into the production function. However, these papers take an optimal contract approach and compare exogenously given property rights allocations. Here, we argue that when intellectual property rights are weak, the presence of information leakage itself can endogenously deliver a more equal division of the value and sometime improve the efficiency of production.

Consider now the case in which there is information leakage and a patent is granted at the end of the development process– that is, $\pi_1 = 1$– and focus on an example in which $n = 3$. Let us consider a strategy profile in which proposers always offer an uninformed agent the minimum between his continuation value (i.e., v_k) and 1/4. [17]

Proposition 6 *There exist $\overline{\delta}$ such that if $\delta \geq \overline{\delta}$ there is an equilibrium in which the firm's production is more efficient in the presence of information leakage than in the no-leakage case.*

In this example, the presence of information leakage improves efficiency by guaranteeing a more equal distribution of the proceeds of an idea. In general, when more equal shares imply higher production, a weak property regime will lead to better performances of the firm.

4.2 Innovation and Firm Stability

In this Section we discuss the implications of Proposition 1 on the stability of a firm with respect to the implementation of innovation. In particular, first we consider the case in which a firm is considering implementing a new product. Since the implementation implies the diffusion of the information throughout the firm, we address the issue of the stability of the firm as a group to the implementation of the innovation. Second, we focus on a single innovative employee within a firm and we study how the firm organization affects his incentive to implement his idea within or outside the firm.

4.2.1 Stability of an Innovative Firm

We now consider the situation in which innovation arises in a firm composed by k individuals and we analyze the stability of this group to the introduction of new ideas.

Proposition 1 implies that two parameters affect the stability of innovative firms. First, the number of the agents in the firm who know and can possibly implement the idea is important (the parameter k). When π_1 is relatively large, if more than $\bar{k}$ in the firm are informed about the idea, the result will be that some will leave the firm and competition will ensue. The model, therefore, formalizes the connection between the organization or size of the firm and its stability.

[17] Moreover, employees always accept if and only if offered at least their continuation value. If everybody is informed, offerers always choose one employee by selecting him randomly between the other two agents with the same probability.

This result is in line with the stylized facts about high-tech industries, which suggest that large established firms often innovate less than younger and smaller competitors.

Second, market conditions also affect the stability of firms. The fiercer is the competition when two firms compete for the same product, the more the firm is able to stay intact. In particular, when $\pi_1 < 1 - \delta$, the firm always stays intact, irrespective of its size. This implies that firms will tend to be more stable in situations with weak protection of new firms.

4.2.2 Innovative Employees and Spin-out formation

Proposition 1 can be used to analyze the formation of spin-outs. Consider an employee in a firm who is inspired by a new idea. This employee will compare the consequences of revealing the idea inside the firm to those of leaving the firm and forming a spin-out. The consequences of internal disclosure are given by our analysis of a subgame in which k people are informed, where k depends on the organization of the firm and represents the number of people in the firm that will be exposed to the idea upon disclosure (for instance, k could represent the number of managers the employee has to talk to before obtaining an approval for the implementation of the new idea). Our analysis provides the continuation values of the k agents in the firm and, as a consequence, the cost of disclosing the idea internally.

The consequences of forming a spin-out are given by the analysis of the game in which $k^0 = 1$. Note that the payoff from a spin-out depends only on the technology of the idea (captured by the parameter m), whereas the payoffs from internal disclosure depend, in addition, on the organization of the firm (captured by the parameter k). Thus, our model provides a connection between the organization of the firm and the tendency of employees to disclose innovations internally or form spin-outs. Our model predicts that more spin-out formation is expected when the original firm is relatively large or bureaucratic.

In addition, the model offers predictions about the effect of market conditions on the propensity of employees to leave the firm. It is important to distinguish between two markets, who are relevant for these prediction. The first is the market for the new product. The result of Proposition 1 implies that if k is large enough, and the first firm to implement the new idea is relatively protected (i.e., π_1 is large enough), disclosing the idea within the firm could lead to an outcome in which the group of agents informed about the idea will tend to split generating competition on the new product market. In such cases, employees will anticipate such changes by leaving the firm. The second market of interest is the relation between the original firm's product and the new products.

The more the profits from a new product are dissipated by competition with the old product, the less prone the employee will be to leave the firm.

5 Discussion

5.1 Welfare Implications

5.1.1 Intellectual Property Rights Protection

Our analysis suggests that incentives to innovate do not disappear even in the complete absence of legal protection.[18] Innovators are protected by their ability to take advantage of their collaborators' anxiety about being included in the first firm to form and about the possibility that competition will ensue.

The legal literature has suggested that innovation still takes place in the presence of weak enforcement of IPR. In particular, in contrast with common wisdom, Hyde (2000) points out that the Silicon Valley phenomenon cannot be understood without considering the weak IPR enforcement guaranteed by the State of California.[19] Hyde's claims are based on the assumption that when IPR are weak, information diffusion occurs. Therefore, he does not take into account the incentives of firms to protect themselves against information leakage. In contrast, our model accounts for the innovators' incentives to protect their information.

Consider the high-tech industry in Silicon Valley, which is characterized by a very rapid growth of markets, by a constantly increasing number of applications of high-tech ideas, and by a geographical concentration that facilitates communication. These facts suggest that π_1, π_2, and the number of agents initially aware of new ideas are all high. Our results show that, in these cases, competition will arise. This implies that information diffusion may occur, innovators will still appropriate relatively high shares of the returns on their ideas, and ideas are likely to be fully exploited and disclosed to stimulate future incremental research.

[18] See Boldrin and Levine (2003) for a similar conclusion drawn from a setting in which goods can be duplicated and sold on perfectly competitive markets.

[19] California prohibits no-compete clauses (unless one of a number of exceptions are met). The application extent of patents and copyrights in the software industry is also an issue that does not seem to have found a precise legal answer yet (see Besen and Raskind (1991).

5.1.2 Narrow Patents

Consider the monopoly market outcome that arises for high degrees of potential market competition (i.e., for very low levels of π_1). Several points suggest that a narrow patent will be more socially desirable in this case. First, a monopolistic outcome from the point of view of consumers is indistinguishable from the introduction of a patent. Second, the monopoly outcome is based on information remaining confined within the boundaries of the firm, implying that this outcome precludes any potential information disclosure from the firm. This is not socially desirable as information disclosure may stimulate incremental research and future discoveries.[20] Finally, from the point of view of the innovator's incentives, we have shown that when monopoly is the market outcome, the appropriation rate is the lowest possible. This is because the innovators have to bear high costs to recruit all the informed agents, that in this equilibrium have high continuation values. Thus, compared to the case of no intellectual property rights, the introduction of a *narrow patent* should improve social welfare. This is because narrow patents capture the situations in which the second firm markets a product very similar to the first one (i.e. low π_1), but do not apply to lower degrees of market competition, where the social costs of patent introduction may be higher.[21]

5.2 Modeling Assumptions

Information Leakage. An important feature of our model is the presence of information leakage, which is captured by the assumptions that developing an idea requires collaboration and that collaboration entails information sharing. The first of these assumptions is motivated by a production function increase in labor. Involving more people in the development stage may increase productivity and quicken the development process. The second assumption is motivated by the innovators' incentives to inform their co-workers. Information is an input into the development process; the more information is shared with co-workers, the more efficient the development stage

[20] It has been observed (see Scotchmer (1991) and Scotchmer (1999)) that when one firm is the exclusive user of a new technology (either because of secrecy or because of a patent), cumulative research may end up being discouraged. This argument usually relies on the assumptions that either frictions or specialization prevent the first patent-holder from fully exploiting all the applications of his patent.

[21] If the degree of potential market competition is low, we can have a competitive market outcome. First, this is desirable for consumers. Second, it allows for information disclosure, as agents do not have incentives to keep information secret. This may stimulate incremental reseach. Finally, for high π_1, the appropriation rates of innovators are high, and their incentives to innovate are relatively protected.

may be.

Therefore, the innovator faces a trade-off. On the one hand, he would like to collaborate with a number of other agents and inform them. On the other hand, he has an incentive to hold information back, as he fears information leakage and employee defection. Innovators will often solve this trade-off by collaborating with some agents and sharing information to some extent.

In this paper, we abstract from the above trade-off by assuming that innovators *must* hire a given number of agents and must share *all* of the information with them. The assumption of information sharing should not be interpreted to mean that all the information is exchanged immediately at the time of an offer. We prefer the point of view that contracts on undeveloped ideas do not become immediately binding. However, there is a moment in which they do. This moment occurs when the idea becomes well defined and when someone defecting from the original team can still successfully compete with the other informed agents in the development process. An agent can defect at any time between the moment at which he learns the information and the moment at which the contract becomes binding.

Bargaining Protocol. The bargaining protocol we use in this paper is a natural benchmark of the applied situation that we address. The symmetry of the probabilities with which nature chooses the next proposer captures the symmetry among the informed agents. Once an agent is made aware of the information, nothing differentiates him from the inventor. This implies that every informed agent should have the same probability of being the next proposer. Similar results to those reported in this paper arise in other specifications of the model. The analysis of an alternative specification in which informed agents make *simultaneous offers* suggests the same results, albeit a more cumbersome analysis.[22]

In our model, when an agent receives an offer, he is endowed with veto power on the success of the offer itself (i.e., the offers are *conditional* upon the acceptance of all the agents included in them). This assumption is motivated by our desire to provide those who are offered with the opportunity to make a counteroffer, if they so desire. Relaxing this assumption would lead to trivial, unrealistic equilibria in which innovators enjoy the non-pivotality of those to whom they make an offer. Our assumption is consistent with similar models in the literature on intra-firm bargaining. Both Stole and Zweibel (1996) and Wolinsky (2000) assume renegotiation of all contracts once an agent has defected from the firm.

[22] The analysis of a bargaining protocol with simultaneous offers is available upon request. In particular, we show the existence of the information diffusion effect in the simultaneous offer model.

Market competition. In the presentation of the model, we restrict our attention to the case in which $\pi_1 + \pi_2 \leq 1-$ i.e., the presence of a second firm can only generate competition and dissipate some of these rents. Relaxing this assumption and allowing for the case $\pi_1 + \pi_2 > 1$ requires us to assume some frictions to prevent the first firm from developing both applications.[23] However, the analysis of the $\pi_1 + \pi_2 > 1$ case yields similar results.[24]

Equilibrium concept. Focusing on SSPE simplifies our analysis by making the computation of the equilibrium continuation values sequence tractable. Enlarging the set of equilibria to all the Subgame Perfect equilibria is likely to generate a high level of indeterminacy in the predictions of the model. For instance, when $\pi_1 = 1$, enlarging the set of equilibria to all the SPE leads to a folk theorem in which any distribution of rents can be supported in equilibrium.

The focus on SSPE allows us to highlight the strategic aspects that are specific to our bargaining model in contrast to other models of multi-agent bargaining. Our analysis introduces a novel equilibrium effect that is driven by the endogeneity of the set of potential proposers. We show that the implication of this effect is an asymmetry in the equilibrium payoffs that holds even as bargaining frictions disappear.

Partial information leakage. Throughout the analysis, we assume that the act of hiring/developing necessarily involves full sharing of the information about the idea. Obviously, this is a strong assumption. Organizations find ways to secure information against insiders, as well as against outside intruders. Information is often classified, and different agents gain access to different pieces of information. These measures will tend to decrease the amount of information that the innovator must share with potential employees. But as long as these measures are costly, some information will always leak. One way to model such an extension is to assume an agent who receives an offer learns the idea with probability $\alpha \in [0, 1]$. Again, we expect our qualitative results to hold. When $\pi_1 = 1$ and $m = 1$, the SSPE is still unique, and the payoff for the innovator is higher than the payoff for the partner. For high n, the payoff to the innovator is $\frac{1}{\alpha\delta}(1 - e^{-\alpha\delta})$, which is higher than the payoff to the innovator when there is full information sharing. More-

[23] e.g. timing problems, necessity to specialize, increasing management costs, etc.

[24] In particular, if $\pi_1 + \pi_2 > 1$, it can be easily checked that when all the n agents are informed, a grand coalition offer costs *at least* $(n-1)\frac{\delta}{n}$. Then, whenever $\pi_1 > 1 - \delta$, for a high enough number of informed agents competition arises. Notice that the case $\pi_1 \leq 1 - \delta$ is not consistent with the assumption $\pi_1 \geq \pi_2$ in the case in which $\pi_1 + \pi_2 > 1$. This implies that, for high enough k, we always have a competitive market outcome. However, for lower k, we could still have monopolistic market outcomes.

over, the innovator's appropriation rate is decreasing in α and reaches full appropriation when α approaches zero.

6 Conclusion

In this paper we present a model of bargaining over new ideas. The model pins down the distribution of rents within the firm, reflecting the knowledge of agents about the idea. In addition, the model determines the stability of a firm with respect to the introduction of an idea; depending on the firm's organization, new ideas can split the firm up into several groups competing with one another.

From the point of view of an owner of a firm, the following two effects of innovation on his firm determine his attitudes towards innovation. The introduction of a new ides within the firm implies a reshuffling of the rents' distribution. Often, innovation will bring new players into the picture and the initial owner will have to forgo part of the pie to accommodate the new collaborators. If, as a result of innovation, the firm splits up, rents are dissipated through the creation of competition. An owner might fear the instability of his firm and, as a result, try to discourage such innovation from arising.

The model analyzed in this paper provides a building block to understand the evolution of firms in industries with high rates of innovation. In Baccara and Razin (2006), we take a step toward studying the firm's attitudes towards innovation and their relation to the way firms are organized.

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Appendix A

Definition of SSPE

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 includes 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 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 (n^I, n^U, γ), 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.[25] The agents included in the offer are randomly chosen from among the two groups.[26] 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.[27]

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 (n^I, n^U, γ). 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'.*

[25] 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 $\sum_i \gamma_i \leq 1$.

[26] 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 $\frac{n^U}{card(N\setminus K(h_i))}$.

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

Proof of Proposition 1: (i) Focus on a subgame where all n agents are informed. Then, any proposer can make an offer to one agent and guarantee himself $\pi_1 - \frac{\delta}{n}$ (by symmetry, $\frac{\delta}{n}$ is the maximum possible continuation value of another player), or he can make a grand coalition offer. If he makes a grand coalition offer, as $\pi_1 + \delta\pi_2 < 1$, the least he has to pay each player is $\frac{\delta}{n}(\pi_1 + \delta\pi_2)$, so that the minimum cost of the offer is $(n-1)\frac{\delta}{n}(\pi_1 + \delta\pi_2)$. Notice that, under our assumption, if n is high enough, we have

$$1 - \frac{\delta(n-1)}{n}(\pi_1 + \delta\pi_2) \leq \pi_1 - \frac{\delta}{n}$$

This implies that making a sub-coalition offer dominates making a grand-coalition offer. Consider a subgame in which $n-1$ agents are informed. If a proposer makes a sub-coalition offer, the one that maximizes his payoff is making an offer to the only uninformed, which yields at least $\pi_1 - \frac{\delta}{n}$. If he makes a grand coalition offer, he gets at most $1 - \frac{\delta(n-2)}{n}(\pi_1 + \delta\pi_2)$. Again, under our assumptions for n high enough the first option dominates the first. Thus, setting $\overline{k} = n-1$ concludes the proof■

(ii) Suppose that n agents are informed. Then, we have that making a sub-coalition offer costs at least $\delta\frac{\pi_1+\delta\pi_2}{n}$, and a grand coalition offer costs at most $(n-1)\frac{\delta}{n}$. This implies that a grand coalition arises if $\pi_1 - \delta\frac{\pi_1+\delta\pi_2}{n} < 1-(n-1)\frac{\delta}{n}$, which is equivalent to $\pi_1\left(1-\frac{\delta}{n}\right) < 1-(n-1)\frac{\delta}{n} + \frac{\delta^2\pi_2}{n} = \frac{n-\delta(n-1)+\delta^2\pi_2}{n}$, or $\pi_1 < \frac{n-(n-1)\delta+\delta^2\pi_2}{n-\delta}$, which is satisfied by assumption. Then, we have $v_n = \frac{\delta}{n}$. Let us move to a subgame where $n-1$ agents are informed. Any chosen proposer can offer to all the other players and pay $(n-1)\frac{\delta}{n}$, he can decide to make an offer only to the other $n-2$ informed players, paying each at most $\frac{\delta}{n-1}$ (in this case he pays at most $(n-2)\frac{\delta}{n-1} < (n-1)\frac{\delta}{n}$); or he can decide to offer only to the only uninformed player and get $\pi_1 - \frac{\delta}{n}$. Observe that $\pi_1 - \frac{\delta}{n} < 1-(n-2)\frac{\delta}{n-1}$ if $\pi_1 < 1-(n-2)\frac{\delta}{n-1} + \frac{\delta}{n}$. However, we have

$$\pi_1 < \frac{n-(n-1)\delta+\delta^2\pi_2}{n-\delta} < 1 - \frac{n-2}{n}\delta < 1-(n-2)\frac{\delta}{n-1} + \frac{\delta}{n}$$

This guarantees that $v_{n-1} = \frac{\delta}{n-1}$. Assume now as an inductive hypothesis that $v_{k+1} = \frac{\delta}{k+1}$ and in all the subgames with $k+1$ or more agents informed, only informed agents receive offers. Then, focus on a subgame starting with k agents informed. Every proposer has the choice of making a sub-coalition offer, exactly a grand coalition offer or a more extended grand coalition offer. In the last case, he has to pay $(h-1)\frac{\delta}{h}$ with $h \geq k+1$, while with an offer made only to informed agents, he pays at most $(k-1)\frac{\delta}{k} < (h-1)\frac{\delta}{h}$ for $h \geq k+1$. Making a sub-coalition offer yields $\pi_1 - \frac{\delta}{k+1}$. We have that $\pi_1 - \frac{\delta}{k+1} < 1-(k-1)\frac{\delta}{k}$ if $\pi_1 < 1-(k-1)\frac{\delta}{k} + \frac{\delta}{k+1}$, but we have

$$\pi_1 < \frac{n-(n-1)\delta+\delta^2\pi_2}{n-\delta} < 1 - \frac{n-2}{n}\delta < 1 - (k-1)\frac{\delta}{k} + \frac{\delta}{k+1}$$

This concludes the proof of (ii).

(iii) Let us build a SSPE in which at any history $h \in H_O$ such that $k(h) > \bar{k}$, all the informed agents at a history h offer a grand coalition if chosen by nature as next proposers (subgame of type 1). If one of the players chooses to offer the grand coalition, let all the players offer an uninformed player in the subsequent subgame. To support a subgame in which all the players make an offer to an uninformed player (subgame of type 2), let all the players make grand coalition offers in the subsequent subgame. Then, we have

$$\begin{aligned} v_k^1 &= \frac{\delta}{k}\left(1-(k-1)v_k^2\right) + \frac{\delta(k-1)}{k}v_k^2 \\ v_k^2 &= \frac{\delta}{k}\left(\pi_1 - v_{k+1}^1\right) + \frac{\delta(k-1)}{k}\pi_2 v_{k-1}^* \end{aligned}$$

Notice that $\lim_k v_k^1 = \lim_k v_k^2 = 0$. To check if a subgame of type 1 is a SSPE, we show that

$$1 - (k-1)v_k^2 > \pi_1 \tag{1}$$

Notice that $\lim_k \left[1-(k-1)v_k^2\right] = 1 - \delta\pi_1 - \delta^2\pi_2 > \pi_1$, so for high k (1) is satisfied. Also, we need to check that it is not optimal to offer to more than the grand coalition, but we can sustain this by imposing a type 1 subgame upon rejection. Therefore we must have

$$1 - (k-1)v_k^2 > 1 - (k+m-1)v_{k+m}^1$$

or

$$(k-1)v_k^2 < (k+m-1)v_{k+m}^1$$

This is satisfied as $\lim_k (k-1)v_k^2 = \delta\pi_1 + \delta^2\pi_2$ and $\lim_{k\to\infty}(k+m-1)v_{k+m}^1 = \delta$. Moreover, we know that $\delta\pi_1 + \delta^2\pi_2 > \delta$ as $\pi_1 < \frac{1-\delta^2\pi_2}{1+\delta} < 1 - \delta\pi_2$.

Now, to check the sustainability of the subgames of type 2, we need to check that

$$\pi_1 - v_{k+1}^1 > 1 - (k-1)v_k^1 \tag{2}$$

But we have $\lim_k \left[1-(k-1)v_k^1\right] = \lim_{k\to\infty}\left\{1-(k-1)\left[\frac{\delta}{k}\left(1-(k-1)v_k^2\right) + \frac{\delta(k-1)}{k}v_k^2\right]\right\}$
$= 1 - \delta < \pi_1$, so that (2) is satisfied as well.■

Proof of Proposition 2 The sequence $\{v_k\}_{k=2}^n$ of the continuation values of the informed players at the beginning of a renegotiation subgame with k informed player is defined by $v_n = \frac{\delta}{n}$, $v_k = \frac{\delta}{k}\left(1-(n-k)\frac{\delta}{n}\right)$ for $n-m \leq k < n$ and $v_k = \frac{\delta}{k}\left(1-mv_{k+m}^m\right)$ for $k < n-m$.

We show that this is the only SSPE by backward induction on the number of informed agents k. Let all the n agents be informed. Then, symmetry guarantees that $v_n = \frac{\delta}{n}$.

Let now the number of informed people be $n-1$. Any proposer can involve the only uninformed agent in his offer or decide to offer only to informed agents. If the offers includes the uninformed, each player included in the offer has a reservation value of $\frac{\delta}{n}$.

We claim that if the offer does not involve the uninformed agent, each player has to be paid at least $\frac{\delta}{n-1}\left(1-m\frac{\delta}{n}\right)+\frac{\delta(m-1)}{n-1}\frac{\delta}{n}$. To prove this claim, observe that, upon rejection, an informed agent, say i, will be the next proposer with probability $\frac{1}{n-1}$ and in that case he could decide to make an offer involving the uninformed, and get $\left(1-m\frac{\delta}{n}\right)$. If he is not chosen as next proposer (an event that occurs with probability $\frac{n-2}{n-1}$), only two cases are possible: the next proposer is going to include the uninformed in the offer, or the next proposer is not going to include the uninformed in the offer. In the first case, symmetry guarantees that player i is going to be included in the offer with probability not inferior to $\frac{m-1}{n-2}$ (the probability will be greater if the offer involves more than m people) and he gets $\frac{\delta}{n}$, while in the second case, symmetry guarantees that player i is going to be included in the offer with probability not inferior to $\frac{m}{n-2}$ and that the least he gets is $\frac{\delta\left(1-\frac{\delta}{n}\right)}{n-1}$ as the entire pie to share among all the agents is δ, while a maximum of $\frac{\delta}{n}$ can be appropriated by the uninformed. Then, we have that the expected value in the first and second cases are respectively, $\frac{m-1}{n-2}\frac{\delta}{n}$ and $\frac{m}{n-2}\frac{\delta\left(1-\frac{\delta}{n}\right)}{n-1}$. It is easy to see that $\frac{m-1}{n-2}\frac{\delta}{n} < \frac{m}{n-2}\frac{\delta\left(1-\frac{\delta}{n}\right)}{n-1}$. This implies our claim. In fact, if the offer does not involve the uninformed agent, each player has to be paid at least

$$
\begin{aligned}
\frac{\delta}{n-1}\left(1-m\frac{\delta}{n}\right)+\frac{n-2}{n-1}\frac{\delta\,(m-1)}{n-2}\frac{\delta}{n} &= \frac{\delta}{n-1}\left(1-m\frac{\delta}{n}\right)+\frac{\delta\,(m-1)}{n-1}\frac{\delta}{n} \\
&= \frac{\delta}{n-1}\left(1-\frac{\delta}{n}\right) \\
&> \frac{\delta}{n}
\end{aligned}
$$

which guarantees that including the uninformed in the offer dominates not doing it. This implies that

$$
v_{n-1}=\frac{\delta}{n-1}\left(1-\frac{\delta}{n}\right)
$$

Notice that $v_{n-1} < 2v_n$.

Let us now fix $k+1 > n-m$ and assume as an inductive hypothesis that for all $n-2 \geq h \geq k+1$, we have that in all the subgames starting with h agents informed, all the available $n-h$ uninformed agents are offered, and the remaining $m-n+h$ agents necessary to form the firm are chosen with equal probability among the informed ones. Also, $v_h > v_{h+1}$ and $sv_{h+1+s} < (s+1)\,v_{h+2+s}$. Let us now focus on a subgame starting with k informed agents. Observe that any proposer, say i, can exhaust the uninformed agents and pay $\frac{\delta}{n}$ each, or decide to substitute some uninformed agents with informed ones. If he chooses the second option and offers to, say $s > 0$, uninformed agents, he has to pay each agent v_{k+s}. However, by our inductive hypothesis, $v_{k+h} > \frac{\delta}{n}$. This implies that offering to all uninformed dominates this option. Suppose, then, that $s = 0$, meaning that proposer i offers only to informed agents. Observe that, in this case, the reservation value of each agent who gets the offer, say agent j, is at least $\frac{\delta}{k}\left(1-m\frac{\delta}{n}\right)+\frac{\delta(k-1)}{k}\frac{m}{k-1}\frac{\delta}{k}$. In fact, notice that symmetry guarantees that if agent i does not offer to any uninformed agent, the other agents do not do so either. This implies that $\frac{1}{k}$ is the probability of being chosen as the next proposer; $1-m\frac{\delta}{n}$ is the payoff he can guarantee himself in that event; $\frac{k-1}{k}$ is the probability of not being chosen as the next proposer; $\frac{m}{k-1}$ is the probability that agent j is included in the offer of someone else, and $\frac{\delta}{k}$ is the minimum value agent j will be offered. However, notice that

$$\begin{aligned}
\frac{\delta}{k}\left(1-m\frac{\delta}{n}\right)+\frac{\delta\,(k-1)}{k}\frac{m}{k-1}\frac{\delta}{k} &= \frac{\delta}{k}\left(1-m\frac{\delta}{n}\right)+\delta\frac{m}{k}\frac{\delta}{k} \\
&= \frac{\delta}{k}\left(1-m\frac{\delta}{n}+\delta\frac{m}{k}\right) \\
&> \frac{\delta}{n}
\end{aligned}$$

This implies that, again, offering to all available uninformed agents dominates offering to only informed agents. For $k \geq n-m$, we have

$$\begin{aligned}
v_k &= \frac{\delta}{k}\left(1-m\frac{\delta}{n}\right)+\frac{\delta\,(k-1)}{k}\frac{m-n+k}{k-1}\frac{\delta}{n} \\
&= \frac{\delta}{k}\left(1-(n-k)\,\frac{\delta}{n}\right)
\end{aligned}$$

Notice also that $v_k > v_{k+1}$ as

$$\begin{aligned}
v_k &= \frac{\delta}{k}\left[1-(n-k)\,\frac{\delta}{n}\right] \\
&> \frac{\delta}{k+1}\left[1-(n-k-1)\,\frac{\delta}{n}\right] \\
&= v_{k+1}
\end{aligned}$$

and

$$\frac{v_{k+1}}{v_k} = \frac{k}{k+1}\frac{\left[1-(n-k-1)\frac{\delta}{n}\right]}{\left[1-(n-k)\frac{\delta}{n}\right]}$$
$$> \frac{k}{k+1}$$

which conclude the inductive proof for $k \geq n-m$.

To complete the construction of the equilibrium sequence, take as the first step of the new induction the subgame in which $k = n-m$, for which we already know that

$$v_{n-m} = \frac{\delta}{n-m}(1-m\frac{\delta}{n}) = \frac{\delta}{n-m}(\frac{n-\delta m}{n})$$

We have already showed that $v_{n-m} > v_{n-m+1}$ and that $\frac{v_{n-m+1}}{v_{n-m}} > \frac{n-m}{n-m+1}$. Let us now fix $k < n-m$ and assume as an inductive hypothesis that for $h \geq k+1$, we have $v_h > v_{h+1}$ and $\frac{v_{h+1}}{v_h} > \frac{h}{h+1}$, so that offers are always made to exactly m uninformed agents. Focus now on a subgame starting with k agents informed. If a proposer offers only to uninformed agents, he has to pay each of them v_{k+m}. If he offers to $s < m$ uninformed agents, he has to pay each agent v_{k+s}, but we know by our inductive hypothesis that $v_{k+s} > v_{k+m}$, so it is optimal to offer to all uninformed agents instead. Finally, suppose the proposer offers only to m informed agents. In this case, each of them has to be paid at least $\frac{\delta}{k}(1-mv_{k+m})$. However, notice that

$$\frac{\delta}{k}(1-mv_{k+m}) > v_{k+m}$$

as by inductive hypothesis $v_{k+m} \leq \frac{\delta}{k+m}$. It is, then, always optimal to extend the offer only to uninformed agents. For $k \leq n-m$, we have

$$v_k = \frac{\delta}{k}(1-mv_{k+m})$$

Moreover, notice that for all such k, we have $v_k < \frac{\delta}{k}$ and $v_k^m > \frac{\delta}{k}\left(\frac{k+m(1-\delta)}{k+m}\right)$. We have

$$\frac{v_{k-1}}{v_k} = \frac{\frac{\delta}{k-1}(1-mv_{k-1+m})}{\frac{\delta}{k}(1-mv_{k+m})}$$
$$= \frac{k}{k-1}\frac{(1-mv_{k-1+m})}{(1-mv_{k+m})}$$
$$> \frac{k}{k-1}\frac{(1-mv_{k-1+m})}{\left(1-m\frac{m}{m+1}v_{k-1+m}\right)}$$

as $\frac{v_{k+m}}{v_{k+m-1}} > \frac{k+m-1}{k+m} > \frac{m}{m+1}$. Now, observe that

$$\frac{\partial \frac{(1-mx)}{\left(1-m\frac{m}{m+1}x\right)}}{\partial x} = -m\frac{m+1}{\left(-m-1+m^2x\right)^2} < 0$$

and

$$\frac{\partial \left[\frac{k-1+m(1-\delta)}{k-1+m(1-\frac{m}{m+1}\delta)}\right]}{\partial \delta} = \frac{-m\left(k-1+m\right)\left(m+1\right)}{\left(-\left(k-1\right)m-\left(k-1\right)-m^2-m+m^2\delta\right)^2} < 0$$

Therefore, we have

$$\begin{aligned}
\frac{v_{k-1}}{v_k} &> \frac{k}{k-1}\frac{\left(1-mv_{k-1+m}\right)}{\left(1-m\frac{m}{m+1}v_{k-1+m}\right)} \\
&> \frac{k}{k-1}\frac{\left(1-m\frac{\delta}{k-1+m}\right)}{\left(1-m\frac{m}{m+1}\frac{\delta}{k-1+m}\right)} \\
&> \frac{k}{k-1}\frac{k-1+m(1-\delta)}{k-1+m(1-\frac{m}{m+1}\delta)} \\
&> \frac{k}{k-1}\frac{k-1}{k-1+\frac{m}{m+1}} \\
&= \frac{k}{k-1+(\frac{m}{m+1})} > 1
\end{aligned}$$

Finally, we have $\frac{v_k}{v_{k-1}} > \frac{k-1}{k}$ as

$$\begin{aligned}
\frac{v_k}{v_{k-1}} &= \frac{\frac{\delta}{k}\left(1-mv_{k+m}\right)}{\frac{\delta}{k-1}\left(1-mv_{k-1+m}\right)} \\
&= \frac{k-1}{k}\frac{\left(1-mv_{k+m}\right)}{\left(1-mv_{k-1+m}\right)} \\
&> \frac{k-1}{k}
\end{aligned}$$

Proof of Corollary 3: Focus on the case in which n is large. For any number of players n and any optimal firm size $m+1$, Proposition 1 guarantees that there exists a unique SSPE such that the sequence of continuation values is $\{v_k\}_{k=1}^n$ Such a sequence is such that v_{m+1} is defined as

$$
\begin{aligned}
v_{m+1} &= \frac{\delta}{m+1}(1-mv_{2m+1}^{m}) \\
&= \frac{\delta}{m+1}(1-m(\frac{\delta}{2m+1}(1-m(\frac{\delta}{3m+1}(1-m\,(....)))))) \\
&\approx \sum_{i=1}^{\max\{j|jm+1\leq n\}} \frac{\delta^{i}(m)^{i-1}\,(-1)^{i-1}}{\prod_{s=1}^{i}(sm+1)}
\end{aligned}
$$

This can be approximated for large n by

$$
v_{m+1} \backsimeq \sum_{i=1}^{\infty} \frac{\delta^{i}(m)^{i-1}\,(-1)^{i-1}}{\prod_{s=1}^{i}(sm+1)}
$$

The innovator's appropriation rate is $v(m,\delta,\infty) \equiv 1 - mv_{m+1}(\infty)$, which for large m is approximated by

$$
\begin{aligned}
v(\infty,\delta,\infty) &\equiv \lim_{m\to\infty} v(m,\delta,\infty) = 1 - \lim_{m\to\infty} m \sum_{i=1}^{\infty} \frac{\delta^{i} m^{i-1}\,(-1)^{i-1}}{\prod_{s=1}^{i}(sm+1)} = e^{-\delta} \\
&\geq e^{-1} > 0
\end{aligned}
$$

As δ tends to 1, we have $\lim_{\delta\to 1} v(\infty,\delta,\infty) = e^{-1} \simeq 0.368$■

Proof of Proposition 4:We need to show that there is $\widetilde{\pi}(\pi_2,\delta,n) < 1$ such that if $\pi_1 > \widetilde{\pi}(\pi_2,\delta,n)$, then always offering one uninformed agent is an equilibrium. In this strategy profile, the continuation value sequence is $\{v_k\}_{k=2}^{n}$ defined by $v_n = \frac{\delta}{n}(\pi_1 + \delta\pi_2)$ and $v_k = \frac{\delta}{k}(\pi_1 - v_{k+1}) + \frac{\delta(k-1)}{k}\pi_2 v_{k-1}^{\star}$, where we denote by $\{v_k^{*}\}_{k=2}^{n}$ the (unique) SSPE sequence we studied in the $\pi_1 = 1$, $\pi_2 = 0$ case (observe that after the formation of the first firm, if k informed agents are left on the market, each agent has a continuation value of $\delta\pi_2 v_k^{*}$). To show that this is an equilibrium, we need to prove that the sequence $\{v_k\}_{k=2}^{n}$ is decreasing, that $mv_{k+m} < (m+1)\,v_{k+m+1}$ for all k and m such that $1 \leq m \leq n-k-1$, and that offering to one uninformed agent always dominates making a grand-coalition offer. Let us first show that the sequence $\{v_k\}_{k=2}^{n}$ is decreasing and that $mv_{k+m} < (m+1)\,v_{k+m+1}$ for all k, m. To see that $\{v_k\}_{k=2}^{n}$ is decreasing, notice that we have $v_k = \frac{\delta}{k}(\pi_1 - v_{k+1}) + \frac{\delta(k-1)}{k}\pi_2 v_{k-2}^{*}$ and $v_n = \frac{\delta}{n}(\pi_1 - v_n) + \frac{\delta(n-1)}{n}(\frac{1}{n-1}v_n + \frac{n-2}{n-1}\pi_2 v_{n-2}^{*})$ where $v_{n-2}^{*} = \frac{\delta}{n-2}$. Therefore, $v_n = \frac{\delta}{n}(\pi_1 + \delta\pi_2)$ and for any $k \leq n$ we have

$$
\begin{aligned}
\lim_{\pi_1\to 1} v_k &= \lim_{\pi_1\to 1} \frac{\delta}{k}(\pi_1 - v_{k+1}) + \frac{\delta\,(k-1)}{k}\pi_2 v_{k-2}^{*} = \\
&= v_k^{*} > v_{k+1}^{*} = \lim_{\pi_1\to 1} v_{k+1}
\end{aligned}
$$

In the same way, it is easy to see that

$$\lim_{\pi_1 \to 1} [(m+1) v_{k+m+1}] > \lim_{\pi_1 \to 1} [v_{k+1} m v_{k+m}]$$

for all $1 \leq m \leq n-k-1$. So, there exists $\pi' (\pi_2, \delta, n) < 1$ such that for all $\pi_1 \geq \pi' (\pi_2, \delta, n)$ the sequence $\{v_k\}_{k=2}^n$ is decreasing and satisfies $m v_{k+m} < (m+1) v_{k+m+1}$.

To show that offering to one uninformed agent always dominates making a grand-coalition offer we need

$$\pi_1 - \frac{\delta (\pi_1 - v_{k+2}) + \delta k \pi_2 v_k^*}{k+1} > 1 - (k-1) \frac{\delta (\pi_1 - v_{k+1}) + \delta (k-1) \pi_2 v_{k-1}^*}{k} \tag{3}$$

for all k. Notice that

$$\begin{aligned} \lim_{\pi_1 \to 1} \left[\pi_1 - \tfrac{\delta(\pi_1 - v_{k+2}) + \delta k \pi_2 v_k^*}{k+1} \right] & \quad 1 - v_{k+1}^* \\ & > 1 - (k-1) v_k^* = \\ & \lim_{\pi_1 \to 1} \left[1 - (k-1) \tfrac{\delta(\pi_1 - v_{k+1}) + \delta(k-1)\pi_2 v_{k-1}^*}{k} \right] \end{aligned}$$

for all k. So, by continuity with respect to π_1, there is $\pi'' (\pi_2, \delta, n) < 1$, such that for all $\pi_1 \geq \pi'' (\pi_2, \delta, n)$, (3) is satisfied for all k. Define the bound $\widetilde{\pi} (\pi_2, \delta, n) \equiv \max [\pi' (\pi_2, \delta, n), \pi'' (\pi_2, \delta, n)]$.

Notice that the generic element of the sequence $\{v_k\}_{k=2}^n$ for n going to infinity is

$$\begin{aligned} v_k &= \frac{\delta}{k} (\pi_1 - v_{k+1}) + \frac{\delta (k-1)}{k} \pi_2 v_{k-1}^\star \\ &= \frac{\delta}{k} \left[\pi_1 - \left(\frac{\delta}{k+1} (\pi_1 - ...) + \frac{\delta k}{k+1} \pi_2 v_k^\star \right) \right] + \frac{\delta (k-1)}{k} \pi_2 v_{k-1}^\star \\ &= \sum_{i=1}^{\infty} \left[\frac{\pi_1 (-1)^{i-1} \delta^i (k-1)!}{(k-1+i)!} \right. \\ & \quad \left. + \frac{\delta^i}{k} (1 + (k+i) \pi_2 \sum_{j=1}^{\infty} \delta^j \frac{(k+i)!}{(k+i+j)!} (-1)^{j-1})) \right] \end{aligned}$$

which is increasing in both π_1 and π_2. This implies that the appropriation rate of the innovator, $v(\delta) = 1 - v_2$, is decreasing in π_1■